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Invisible Contamination: Geographic, Economic, and Policy Barriers to Controlling Soil Pollution from Oil and Gas Production in the United States

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Abstract. Soil pollution has received significantly less regulatory attention than air and water pollution, despite its critical role in ecosystem functioning and human livelihoods. This paper examines the political, geographic, and economic reasons for the persistent lack of effective controls on soil contamination from oil and gas production in the United States. While the Clean Air Act and Clean Water Act provide robust national frameworks for protecting air and water quality, there is no equivalent legislation for soil protection. The analysis identifies three intersecting causes for this neglect: (1) the low visibility and monitoring difficulty of soil contamination; (2) the remoteness and aridity of most U.S. oil-producing regions, which limit public scrutiny and slow natural remediation; and (3) the dependence of regional and state economies on oil and gas revenues, which creates strong political disincentives for strict environmental enforcement. Drawing on examples from major production states such as Texas, New Mexico, and North Dakota, the study argues that economic reliance and geographic isolation reinforce a permissive regulatory culture. The paper concludes that emerging remote-sensing and monitoring technologies could increase transparency, enhance public awareness, and catalyse policy reforms aimed at sustainable soil protection in oil-producing regions.

Keywords: *Oil and gas pollution, soil pollution, United States of America, policy barriers, environmental policy, energy policy, geography, political economy*

1. Introduction

When compared with air and water, soil is much less the subject of environmental protection policy. For example, in the USA, the Clean Air Act was put in place in 1970 and the Clean Water Act in 1972. [1][2] These laws, updated and reauthorized several times, remain in force and have expanded protections for air and water resources. However, there is still no US law that would specifically protect soils. Similarly, the European Union (EU) has legislation (directives) directly addressing air quality and water quality but none directly protecting soil. [3][4]

Several reasons have been suggested as causes for this relative inattention on soil in environmental policy. These can be categorized into three broad issue areas:

1. *Visibility and awareness*—Human beings are permanently in intimate and direct contact with air and water. Consequently, substances that do not normally belong in air and water are usually easy to perceive and identify. If such substances are harmful to human health, their negative impacts are direct and easily understood. Air and water pollution generally motivate significant public outcry and demand for policy response. [5]

2. *Measurement and monitoring*—Air and water, being fluids, easily mix and carry pollutants over long distances. As a result, even if a pollutant is emitted at a single point (i.e. a smokestack or effluent pipe outlet), it will be present over a sizeable area—easily over a hundred and often thousands of square kilometres. Networks of air and water quality monitoring systems can be set up, consisting of fairly spaced-apart stations, which can constantly measure levels of pollutants. Such networks would not work in the case of soil because pollutants do not easily disperse through this medium.
3. *Socioeconomic issues*— Human activities tend to produce air and water pollution incidentally—that is they do not tend to directly extract resources from these media and, in so doing, change their chemical composition. However, from the advent of agriculture, approximately 12,000 years ago, to the present, people have relied on the extraction of resources from the soil (primarily nutrients) and on the alteration of terrestrial biomes for their survival. Activities impacting the structure and quality of soil can be thought of as basic to the evolution of human societies and enabling the most fundamental economic activities. [6]

The inattention to soil quality protection (relative to air and water quality) has meant that, globally, soil quality is continuously being threatened by degradation processes such as erosion, compaction, salinization, nutrient depletion, and contamination. The adverse effects of soil degradation on agricultural systems and food production have been a long-standing and global concern. [7] More recently, however, there has been increasing recognition of the broader impacts of soil pollution on soil biota, ecosystem services, carbon sequestration, and global climate change. [8][9]

2. Significance of soil pollution from oil and gas production

While, globally, agricultural activities remain the number one source of soil pollutants, oil and gas production is also an important source. When we look specifically at hydrocarbon-producing regions, such as the Niger Delta, western Texas, Alberta (Canada), and Siberia, oil and gas production becomes the most important source of soil pollution. For example, up to 70% of soil samples near production facilities show unacceptable levels of contamination from hydrocarbons and heavy metals. [10][11][12]

The contamination impact on soils is actually worse than this because of additional pollutants, such as drilling muds, minerals, salts, etc. which, unlike hydrocarbons and heavy metals, are not considered toxic but can nevertheless have serious adverse effects on soil ecologies. Each part of the process of producing oil and gas is a source of various potential soil contaminants (see Table 1).

Table 1. Sources of soil pollution from oil and gas production.

Stage	Main Soil Pollutants	Mechanism of Contamination
Exploration & Drilling	Drilling muds, barite, bentonite, hydrocarbons, heavy metals (e.g., Pb, Cr, Cd)	Spillage or improper disposal of drilling fluids and cuttings contaminate soils.
Production & Processing	Crude oil, produced water (saline, contains hydrocarbons and metals), corrosion inhibitors	Leakage from wellheads, storage tanks, and pipelines; infiltration of produced water.
Transportation & Storage	Petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs)	Pipeline leaks, accidental spills, tank failures.
Refining & Waste Management	Heavy metals, acids, alkalis, spent catalysts, sludges	Improper waste handling or illegal dumping around refineries.
Decommissioning/ Abandoned Wells	Residual hydrocarbons, saline water	Legacy pollution from uncapped wells and leaking infrastructure.

The significant increase in the utilization of hydraulic fracturing for oil and gas extraction has resulted in additional new potential soil contaminants such as produced (briny) water, surfactants, and biocides. Though the U.S.A. has been the global epicentre of use of this drilling technique, its use has been expanding in Canada, Argentina, and China (See Figures 1 and 2). Other countries, such as Russia, Colombia, and South Africa are beginning to test or are considering testing hydraulic fracturing at a limited scale, at least initially. [13][14]

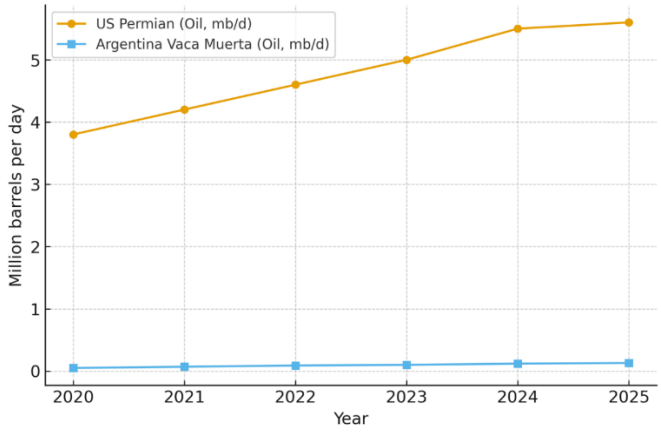

Figure 1. Hydraulic fracturing growth in oil production (2020-2025)

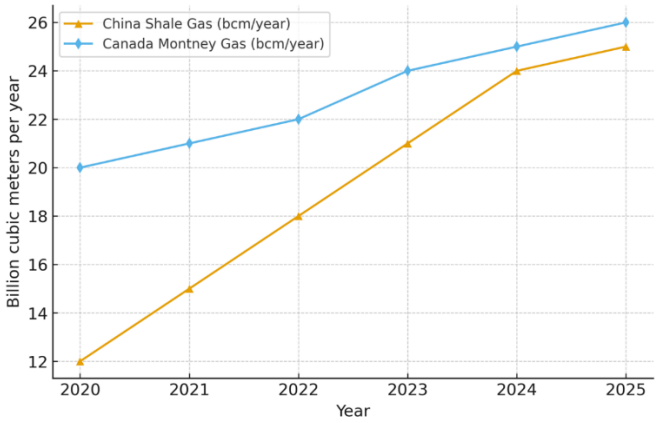

Figure 2. Hydraulic fracturing growth in gas production (2020-2025)

In the U.S.A., a substantial majority of oil (85.6%) and almost all natural gas (97.7%) are produced on land. [15] Consequently, the volume of hydrocarbon (oil and gas) spilled on land is significantly more than in the ocean. Although exact, comprehensive, national totals for all land and ocean spills in the U.S. for a single year like 2024 are difficult to ascertain due to varied reporting systems and data availability, even partial data highlight this difference. For example, data from just three top producing states (Colorado, New Mexico, and Wyoming) in 2024 reported at least 7 million gallons of crude oil and other hazardous liquids and billions of cubic feet of methane escaped from drilling-related incidents alone. [16] During approximately the same period, researchers monitoring satellite imagery estimated that 20 offshore facilities accounted for nearly 300,000 gallons of oil released. [17] Despite this, ocean spills receive more public attention in the U.S. than land spills primarily due to their high visibility, immediate and visible harm to charismatic marine wildlife (like seabirds and otters coated in oil), and significant economic impact on coastal communities that depend on tourism and fishing. Because of the disparity in public attention, government action, including legislation, has successfully reduced marine oil spills by at least 50%, while regulation for land spills remains minimal and largely ineffective. [18]

3. Reasons for lack of effective controls on soil pollution from oil production in the U.S.A.

Natural gas exploration and production primarily contributes to air pollution and only in a very small way to soil pollution. Therefore, as we explore the reasons for lack of effective controls on soil pollution from hydrocarbon production in the U.S.A., we will focus on oil exploration and production.

Just three states account for 77.8% of land-based oil production in the U.S.A.: Texas, with 49.6%, New Mexico, with 17.7%, and North Dakota, with 10.4%. The climatic conditions of these states are classified as arid/semiarid, and oil extraction is concentrated in sparsely populated areas. Furthermore, if we look at the overall geographic distribution of oil production in the U.S.A., we see that an even greater proportion is located in arid/semiarid states (Figure 2).

In the case of Alaska, the largest U.S. state, there are several climate zones. However, all of the state's oil and gas production is concentrated in the north, around Prudhoe Bay. The climate of this region of the state is very dry, with precipitation averaging 330 mm/year. It is classified as Polar Desert.

If we add the contributions of Colorado, Alaska, Oklahoma, Wyoming, Utah, and Kansas, we conclude that 10,726 of the 11,433 thousand barrels per day of onshore U.S.A. oil production (93.8%) comes from sparsely populated arid/semiarid regions.

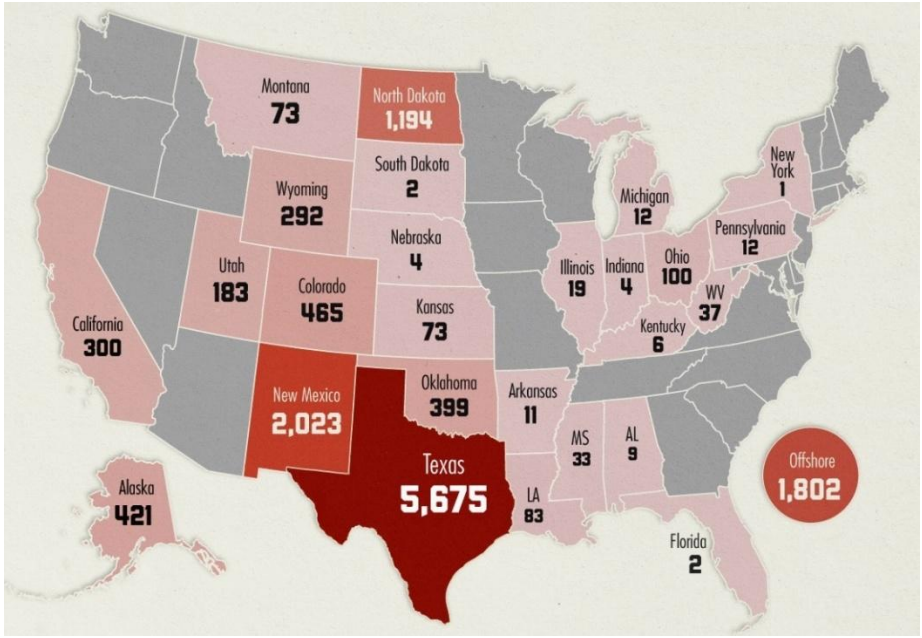

Figure 2. U.S.A. petroleum production by state in thousands of barrels per day (2024)

Climatic conditions and population density or the proximity of oil production to densely populated areas are important conditions that impact public and political attitudes towards controlling soil pollution from oil production. Another very important factor is the contribution of oil production to the economies of the states and regions in which the industry is concentrated. Although it is very difficult to compare this contribution across states (because, for example, they derive revenue from the oil and gas industry in a variety of ways such as income taxes, royalties, severance fees, etc., and, in many instances, local governments derive their own, separate income), the data summarized in Table 2 shows that it can be very substantial. The table shows the direct revenue derived from the oil and gas industry by each of the top seven oil-producing states. This does not include the indirect economic benefits of the industry, such as from increased employment, increased sales taxes from other goods, increased property values, etc. This is compared with total state revenue. The inescapable conclusion is that for almost all major oil-producing states the revenue generated by the oil and gas industry is very large and contributes significantly to the states' economies.

Table 2. Oil&Gas Revenue and General Revenue ($ billion) for 2024 fiscal year (July 2024-June 2025)

State	Oil & gas	Total	Oil & gas as % of total
Texas	23.7	87.3	27.1%
New Mexico	10.5	13.7	76.6%
North Dakota	3.8	5.9	64.4%
Colorado	1.0	18.5	5.4%
Alaska	3.1	16.3	19.0%
Oklahoma	4.4	13.0	33.8%
Wyoming	2.5	2.7	92.6%

4.1 Impact of remote location on effective soil pollution controls from oil production.

As we discussed above, soil contamination tends to be localized and less visible than air or water pollution, making it less politically salient. Geographic isolation significantly reduces public scrutiny and media visibility, weakening political incentives to develop or enforce strict soil-pollution controls in the United States' oil-producing regions. As shown above, almost all of the nation's crude oil (at least 94.8%) is extracted from remote areas, which are characterized by low population density and economic dependence on fossil fuel production. The remoteness of these areas limits the presence of journalists, environmental non-governmental organizations (NGOs), and citizen observers who might otherwise expose contamination incidents or pressure regulators to act. [20][21] Consequently, pollution events such as produced-water spills, oil leaks, or illegal wastewater dumping often go underreported and unresolved for extended periods. [18][22]

Regulatory authority over most exploration and production wastes rests primarily with states. However, stat authorities are constrained at the federal level by statutory exclusions (notably the long-standing exclusion of the Resource Conservation and Recovery Act—RCRA— for many oil-and-gas exploration and production wastes), which limits the Environmental Protection Agency's direct hazardous-waste tools for soil protection. Enforcement capacity and oversight are further hampered by institutional and resource constraints: federal and state agencies have repeatedly been found to face data, staffing, and inspection challenges in overseeing vast, dispersed oil-and-gas operations, allowing leaks, dumping, and produced-water spills (intentional and unintentional) to continue for longer periods in remote settings. [21][22][23]

4.2 Impact of climatic conditions on effective soil pollution controls from oil production.

The low precipitation that characterizes arid and semi-arid regions, where the vast majority of U.S.A. oil production takes place, determines the alternative economic uses to which this land could be put. Specifically, the lower the level of annual precipitation, the lower the likelihood that land would be in agricultural production. In fact, with the exception of the eastern parts of Texas, Oklahoma, and Kansas, the main economic use of land is cattle ranching. As a result, the land surrounding oil and gas wells, storage facilities and pipelines is not visited frequently by people and leaks, spills, and other contamination events can easily go undetected for long periods. [21][23][24]

In arid landscapes, soil degradation from oil operations—including brine spills, produced-water releases, and hydrocarbon residues—may cause ecological damage that is more severe and long-lasting than in areas that receive significantly higher levels of precipitation. This is because the main natural mechanisms for soil recovery from contamination, biodegradation and plant uptake, are slowed down by lower rates of microorganism and plant and fungal reproduction and growth. [22]

Where there is any institutional urgency and concern over the issue of soil contamination is when this would impact agricultural productivity. When a significant majority of the land on which oil and gas development is placed is not under cultivation, such concerns are minimal, if extant at all.

Furthermore, it should be noted that much of the land in question is not privately owned but in the public domain. The federal and state agencies that have oversight are consistently under-resourced and lack the staff and resources that are necessary for effective oversight of all types of activities on public lands, including use by the oil and gas industry. [25]

4.3 Impact of the dependence of regional economies on revenues from the oil and gas industry

The dependence of the economies of U.S. oil-producing regions on revenue from the oil and gas industry significantly blunts political pressure for strict soil-pollution controls. In regions such as the Permian Basin in Texas and New Mexico, the Bakken Formation in North Dakota, and parts of Alaska and Oklahoma, local and state governments rely heavily on oil and gas revenues to fund public services, infrastructure, and education. This fiscal dependence creates strong political incentives to maintain favourable conditions for industry investment, often at the expense of environmental oversight. The result is a regulatory environment where soil-pollution controls are weakly enforced, underfunded, or receive very little attention by policymakers despite evidence of widespread contamination risks.

Oil-producing states collect billions in severance taxes, lease royalties, and related revenues, accounting for substantial portions of their budgets (Table 2). Such fiscal reliance shapes political behaviour, as policymakers face pressure from both industry and constituents employed in extraction-related sectors. Local economies in these areas are tightly intertwined with oil and gas operations, meaning that stricter soil-pollution regulations—such as tighter controls on produced-water spills, oil leaks, or waste pit closures—are often framed as potential threats to jobs and tax bases. [26] This dynamic has produced what political ecologists term a "resource dependence trap," where environmental regulation becomes subordinate to short-term economic stability. [27]

The political narrative in oil-producing regions frequently casts environmental regulation as external interference—often from the federal government or urban-based advocacy groups—rather than as a locally driven necessity. This framing, amplified by industry lobbying and rural economic anxieties, weakens grassroots political movements for stronger soil-pollution controls. [28] As a result, community members may prioritize economic continuity over long-term ecological health, even in the face of documented soil degradation from oil and gas extraction, storage, and transportation activities.

5. Conclusion

In the U.S.A., soil pollution from hydrocarbon (oil and natural gas) extractive activities is a major concern nation-wide, second only to pollution from agricultural activities. In arid and semi-arid oil-producing regions, this source of pollution emerges as the major concern, as much smaller proportions of these areas are under cultivation. However, as discussed above, effectively addressing the problems caused by contamination of soils by the oil and gas industry is difficult as it faces several distinct challenges. These emerge because the issue is lodged in the intersection of energy policy, environmental policy, geography, and political economy.

For more than a century, U.S. governments have granted substantial benefits to the oil industry. Some of the earliest were the Intangible Drilling Costs (IDC) deduction initiated in 1916 and the oil depreciation allowance in 1926. These were designed to encourage oil exploration and development by lowering immediate tax liabilities. Government benefits continue to the present and include numerous and varied benefits given by states as well as the most recent fiscal and tax law, known as the "One Big Beautiful Bill Act", enacted on July 4, 2025. This law reinstated the full deduction for intangible drilling costs, mandated oil and gas lease sales on federal onshore and offshore lands, and reduced royalty rates for resource extraction from these lands. It also delayed the implementation of a methane emissions fee until 2035. There is little reason to believe that U.S. federal and state energy policies will shift in a consistent way to enhance environmental accountability of the oil and gas industry or to effectively decrease the environmental footprint of the industry.

As we discuss in this paper, U.S. environmental policy is focused on protecting air and water resources but not specifically on protecting land resources. Soil ecosystems are protected indirectly through air and water quality protection laws and through certain provisions of toxic substance control

and waste management statutes. However, control of pollutants produced by the oil and gas industry is limited by specific exemptions written into the Resource Conservation and Recovery Act (the major waste management federal statute). U.S. environmental policy reserves important planning and enforcement responsibilities for the states. This causes a fragmentation of responsibilities that is often exploited by polluting industries to avoid the costs associated with decreasing polluting emissions.

The geographical dimensions that serve as barriers to more effective protections for soil from pollutants produced by the oil and gas industry appear to be the most amenable to amelioration. The low public visibility, limitations to monitoring, and misperceptions about the severity of the ecological impacts of this pollution can be corrected by technological developments. Remote sensing, monitoring, and measuring technologies, which can be mounted on satellites and drones, can provide accurate detection, measurement, and monitoring of soil (as well as air and water) pollution from oil and gas operations. [29][30][31] These technologies dramatically lower the cost and increase the frequency, duration, and geographic scope of environmental monitoring. They can be implemented and supported by non-governmental as well as governmental organizations. Consequently, they can raise public visibility, address misperceptions, and reduce or remove limitations to pollution monitoring. They offer the best chance to shift the political discourse in favour of more extensive, strict, and effective controls of soil pollution from oil and gas production, storage, and transportation activities.

The political economy of U.S. oil and gas production can also be affected by a shift in the political discourse. Production of these resources does not need to decrease. It does need to be done in a more deliberate, environmentally conscientious, and sustainable manner. Some of the revenues generated by the industry can be used to enhance monitoring activities, to increase safeguards against accidental releases of pollutants, and to fund remediation activities. There are examples for how this can be done from laws directed towards reducing the environmental impacts of other mineral extraction activities, such as the Surface Mining Control and Reclamation Act, which has been in force in the U.S. since 1977. If new technologies can be used effectively to raise awareness, change public attitudes, and increase political demand for soil pollution reduction, there is hope that effective measures to protect soils from oil and gas industry generated pollutants can be developed and implemented effectively.

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