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The Hidden Crisis: How Oil Extraction in the Niger Delta Is Fueling a Public Health Emergency

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Abstract

Rationale: The Niger Delta, home to over 30 million people, is one of the world's most resource-rich regions, contributing approximately 90% of Nigeria's oil revenues. However, it faces severe environmental degradation, with oil extraction activities resulting in widespread pollution. Hydrochemical analyses have shown that levels of petroleum hydrocarbons and heavy metals in both surface and groundwater sources exceed international safety standards by up to 200% in certain areas. These pollutants, affecting water, soil, and air, directly lead to chronic health conditions, including gastrointestinal diseases, respiratory illnesses, and neurological disorders in over 60% of the population, according to local health surveys. Despite these figures, environmental degradation in the Niger Delta is rarely framed as a public health emergency, overlooking the direct health consequences and exacerbating socioeconomic inequities. The region's governance failures and fragmented regulatory systems have compounded these problems, creating a critical need for systemic intervention. **Objective:** This study aims to reframe environmental degradation in the Niger Delta as a public health emergency and proposes the Integrated Environmental-Health Accountability Framework (IEHAF) to address the multi-dimensional health impacts of pollution. The goal is to establish a com-

prehensive model that links ecological damage to morbidity, mortality, and socioeconomic hardship, emphasizing interdisciplinary research and policy reform. **Methods:** We conducted a conceptual synthesis by analyzing existing data from environmental epidemiology, hydrochemistry, biodiversity loss, and health systems research to develop the IEHAF framework. This synthesis was based on a review of over 150 peer-reviewed studies, government reports, and community health surveys. We focused on three domains: 1) Environmental Toxicity and Ecological Collapse, 2) Human Exposure, Vulnerability, and Adaptation, and 3) Institutional Accountability and Policy Inertia. The framework provides an analysis of how multi-pollutant exposure leads to health inequities and long-term socioeconomic consequences, supported by empirical data on pollutant concentrations and health outcomes in the Niger Delta. **Results:** The IEHAF framework reveals that pollution is not only an environmental issue but also a central determinant of health inequity. By integrating environmental, health, and economic systems, it provides a holistic view of the long-term effects of extractive practices. The framework identifies how institutional inertia and policy fragmentation have deepened the crisis, resulting in intergenerational poverty and exacerbating health disparities. **Conclusions:** Reframing environmental degradation as a public health emergency is essential to shift policy responses from reactive to proactive. IEHAF offers a structured approach to integrate environmental governance, health surveillance, and social protection, which are critical for sustainable development in the region. **Recommendations:** Policymakers should adopt IEHAF in regulatory frameworks, ensure health outcomes are integrated into extractive licensing, and mandate systematic health screenings for affected communities. Researchers should focus on long-term evaluations of IEHAF, while civil society must advocate for community-led environmental monitoring and corporate accountability. **Health Statement:** Chronic exposure to pollutants in the Niger Delta leads to long-term health burdens, including gastrointestinal disorders, respiratory diseases, and neurological damage. IEHAF stresses the need for early intervention, health surveillance, and integrated policies to protect vulnerable populations.

Keywords

Pollution Exposure, Environmental Health, Public Health Emergency, Integrated Environmental-Health Accountability Framework (IEHAF), Governance, Socioeconomic Inequity, Multi-Pollutant Exposure, Health Surveillance, Extractive Industries, Niger Delta

1. Introduction

The Niger Delta, one of the world's most resource-rich regions, has been the epicenter of oil and gas extraction for over five decades. While the region contributes significantly to Nigeria's national revenue, it simultaneously bears the heavy burden of environmental degradation [1]-[8], with oil spills, gas flaring, groundwater

contamination, and soil toxicity becoming normalized aspects of daily life [9]-[15]. These environmental impacts have resulted in widespread ecological destruction, disrupting local livelihoods, agricultural systems, and the health of millions of people [16]-[26]. Despite the mounting evidence of environmental harm, the profound implications for public health remain significantly underappreciated, both within national policy frameworks and the global health discourse [16]-[26]. Numerous studies have documented the link between extractive industries and environmental pollution, yet there remains a stark absence of robust, integrated models that address the full scale of public health implications [27]-[35]. The Niger Delta's ongoing health crisis, driven by these environmental pollutants, is not merely a regional issue but a global concern with broader implications for public health, policy, and development [36] [37]. Existing environmental and health frameworks often treat pollution as a distinct environmental or regulatory issue rather than a systemic public health crisis [38]-[46]. This separation of environmental damage from its health consequences has limited the ability to address the compounded and often invisible burden faced by communities in the Niger Delta. Pollution's effects are rarely considered through the lens of chronic, multi-pollutant exposure that impacts public health over time. Exposure pathways, such as contaminated drinking water, toxic food chains, and air pollution from gas flaring, lead to complex health conditions, including gastrointestinal diseases, respiratory issues, and neurological impairments [28] [47]-[73]. However, the true burden extends beyond direct morbidity to include disruption of local livelihoods, food insecurity, displacement, and heightened psychological stress. These interconnected issues not only exacerbate public health risks but also entrench socioeconomic inequalities and perpetuate cycles of poverty [74]-[78]. This gap in understanding the cumulative effects of environmental degradation on health has perpetuated a fragmented approach to policy responses, which typically focus on isolated instances of ecological damage without addressing the systemic, long-term consequences for human health. What remains largely unknown is how environmental degradation in the Niger Delta, specifically related to extractive practices, translates into complex health outcomes over time, particularly in resource-dependent communities. While the environmental effects of oil extraction have been extensively documented, the linkage between these ecological changes and direct health burdens remains poorly understood. This gap is compounded by the lack of integrated policy frameworks that connect environmental health with broader social determinants such as poverty, access to healthcare, and social protection. Many existing studies focus on isolated environmental or health impacts, but few have proposed an integrative model that captures the multi-dimensional nature of these challenges. By addressing these research gaps, we can better understand the full scope of the public health crisis and ensure that future policy responses are more holistic and targeted at preventing further harm. This perspective paper is both timely and necessary as it aims to provide an integrated framework that links extractive practices directly to public health outcomes through

identifiable causal pathways. In response to this significant gap in research, we introduce the Integrated Environmental-Health Accountability Framework (IEHAF), a novel synthesis of environmental science, public health, and governance perspectives. IEHAF aims to reconceptualize environmental degradation in the Niger Delta as a public health emergency that demands urgent policy attention and systemic reform. The primary objective is to demonstrate how extractive economies in the Niger Delta have generated an invisible health burden, highlighting the need for comprehensive health surveillance, preventive measures, and governance reforms. By framing the environmental crisis as a public health issue, this paper aims to guide policymakers, researchers, and practitioners toward an integrated, sustainable approach to health and environmental governance in the Niger Delta and similar regions worldwide.

2. Methods

This manuscript adopts a conceptual synthesis approach, drawing from interdisciplinary sources across environmental science, public health, and governance literature. It synthesizes existing research and frameworks to propose the Integrated Environmental-Health Accountability Framework (IEHAF), linking environmental degradation in the Niger Delta to public health outcomes. This perspective piece aims to consolidate and build on existing knowledge rather than systematically review or analyze empirical studies.

2.1. Source Identification and Selection

Sources were identified through systematic searches of several academic databases, including PubMed, Scopus, and Google Scholar. Key terms such as "Niger Delta", "oil extraction", "environmental health", "pollution exposure", "health inequities", and "Health Impact Assessment" were used to locate relevant studies, reports, and policy documents. Inclusion criteria focused on publications that:

1) Address the health impacts of environmental degradation in the Niger Delta, specifically oil extraction.

2) Provide evidence on the links between ecological damage, public health, and socioeconomic disparities.

3) Include case studies, reviews, or conceptual frameworks relevant to environmental health, governance, and public health emergency frameworks.

Excluded were sources that focused primarily on unrelated geographic regions, studies that did not address public health outcomes linked to environmental degradation, and publications that lacked a clear link between governance structures and health implications.

2.2. Approach

The selected sources were examined through the lens of systems-level thinking, which highlights the interconnectedness of ecological damage, public health risks, and governance failures. The manuscript synthesizes findings from environmen-

tal epidemiology, hydrochemistry, biodiversity loss, and social determinants of health to build a comprehensive framework that links environmental exposure in the Niger Delta to chronic health conditions and socio-economic inequities. This approach does not rely on quantitative data or meta-analysis but instead integrates key concepts from existing models like Health Impact Assessments (HIA), One Health, and environmental justice frameworks, adapting them to the unique context of the Niger Delta.

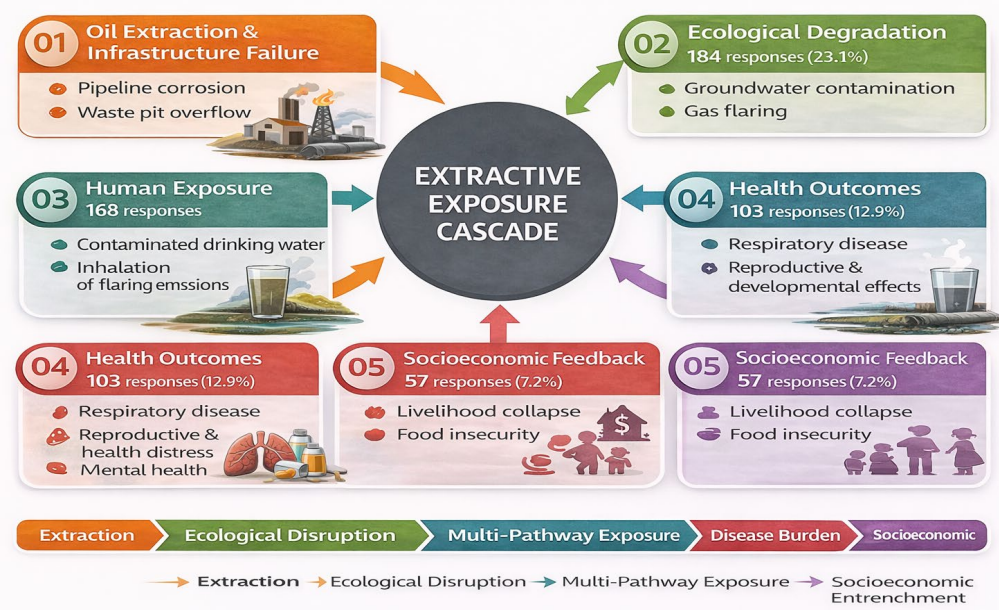
3. The Core Argument: The Integrated Environmental-Health Accountability Framework (IEHAF)

3.1. Genesis and Positioning of IEHAF

The health crisis unfolding in the Niger Delta is not a result of isolated oil spills or episodic contamination events; rather, it is a predictable outcome of a deeply embedded extractive system. This system is characterized by chronic hydrocarbon releases, groundwater contamination, regulatory fragmentation, and entrenched socioeconomic vulnerability that has systematically undermined both environmental and public health standards over decades [79]-[100]. While the region's environmental degradation has been extensively documented, its full impact on human health has not been adequately integrated into mainstream health policy. Central to this failure is the role of water systems, both surface and groundwater, as the most persistent and consequential exposure pathway for local populations [101]-[104]. Pollutants from oil extraction seep into these water sources, becoming vehicles for the transmission of toxic chemicals, which significantly elevate risks for waterborne diseases, heavy metal toxicity, and chronic health conditions [105]-[118]. Existing environmental assessments in the Niger Delta have consistently reported elevated concentrations of petroleum hydrocarbons, heavy metals, and other toxicants in drinking water sources [119]-[142]. However, these findings are often presented in isolation, without clear integration into a comprehensive public health framework. This fragmentation in data presentation obscures the real health consequences of the contamination, which are not only limited to immediate morbidity but extend to long-term effects such as economic productivity loss, food insecurity, and intergenerational vulnerability. Chronic exposure to pollutants exacerbates underlying socioeconomic challenges, perpetuating a cycle of poverty and poor health outcomes. **Figure 1** below illustrates how the environmental degradation resulting from oil extraction in the Niger Delta directly feeds into these multi-dimensional health burdens, highlighting the systemic links between ecological damage and public health risks.

As depicted in **Figure 1**, the figure conceptualizes the flow of contaminants from extraction practices to public health outcomes, demonstrating the broader implications for communities reliant on compromised environmental systems. To address this complex issue, the Integrated Environmental-Health Accountability Framework (IEHAF) was developed. The framework synthesizes evidence from environmental toxicology, hydrochemical assessments in oil-producing commu-

nities, and public health studies linking multi-pollutant exposure to chronic disease [36]-[46]. In addition, it incorporates governance and regulatory analyses that expose structural accountability failures in the region's environmental oversight. Unlike conventional environmental risk assessments that typically focus on pollutant thresholds and compliance with legal limits, IEHAF is a normative, systems-level decision framework. It shifts the central question from "Are pollutant levels above permissible limits?" to "How does chronic, multi-pathway exposure, within a structurally unequal extractive system, translate into cumulative health injustice and social inequities?" This reframing is critical in understanding not just the toxicological impact but also the broader sociopolitical dimensions that exacerbate these health risks.



Source: Author design, 2026.

Figure 1. The integrated framework of the extractive exposure cascade.

3.2. IEHAF as a Normative Decision Framework

By incorporating both environmental science and public health research, IEHAF provides a more holistic approach to health risk assessment. It transcends traditional risk assessments by recognizing the interdependencies between environmental degradation, governance failures, and health outcomes. The framework, therefore, functions as an accountability lens rather than just a monitoring tool. It seeks to identify where governance breakdowns amplify public health risks and where structural reforms are most needed. For example, existing studies have shown that regulatory loopholes and insufficient enforcement of environmental standards exacerbate the health impacts of oil pollution in the Niger Delta [143]-[152]. IEHAF highlights these governance failures, pushing for a more transparent and accountable regulatory framework that includes local communities in decision-making processes. Table 1, presented below, outlines the key contaminants

commonly found in water sources and their associated health implications, reinforcing the need for comprehensive, long-term health monitoring. Unlike traditional tools, IEHAF integrates both environmental monitoring and health surveillance into a unified framework that not only detects contamination but also traces its long-term health consequences. This integrated approach allows for a more accurate understanding of how environmental hazards translate into public health crises, thereby informing more effective health policies and regulatory measures. For example, by identifying the cumulative impact of pollution on childhood health, reproductive outcomes, and long-term chronic diseases, IEHAF can provide a roadmap for early intervention strategies and public health preparedness.

3.3. Moving beyond Remediation: A Call for Structural Reform

Ultimately, the IEHAF calls for more than just remediation; it advocates for structural reform at both the regulatory and policy levels. The framework posits that unless governance structures are overhauled to ensure accountability, compliance, and transparency, the cycle of contamination and health inequity will persist. It proposes that environmental impact assessments (EIAs) be integrated with health impact assessments (HIAs) as part of the licensing process for all extractive activities [153]. This dual approach, which combines environmental protection with health surveillance, could transform the governance landscape in the Niger Delta. Moreover, it provides a framework that is not only applicable to the Niger Delta but also to other extractive regions where resource extraction undermines public health and exacerbates socioeconomic disparities [36] [37]. Thus, IEHAF complements environmental monitoring by providing a conceptual and policy tool that highlights the institutional responsibility for public health. As such, it serves as a vital instrument in the push toward sustainable and equitable extractive practices. The framework's introduction into the discourse surrounding environmental health in oil-producing regions represents a paradigm shift, one that emphasizes prevention, early detection, and accountability, rather than waiting for disasters to strike before responding.

4. Comparison of IEHAF with Existing Frameworks

The Integrated Environmental-Health Accountability Framework (IEHAF) offers a unique, systems-level approach to addressing the environmental health crisis in regions impacted by extractive industries like the Niger Delta. While it shares common goals with frameworks such as Health Impact Assessment (HIA), One Health, and environmental justice/accountability frameworks, IEHAF is distinguished by several key decision points and operational features:

4.1. Health Impact Assessment (HIA)

- **HIA** typically focuses on evaluating the potential health effects of proposed policies or projects before they are implemented. It is largely reactive and con-

ducted prior to any health or environmental damage occurring.

- **IEHAF**, on the other hand, operates as a normative framework designed to address ongoing public health crises caused by long-term environmental degradation, specifically in regions where industrial pollution has already occurred. While HIA assesses potential impacts, IEHAF links existing environmental damage to long-term health outcomes, advocating for proactive interventions and sustainable governance reforms that continue throughout the lifespan of the extractive operations.

4.2. One Health

- **One Health** is a holistic approach that recognizes the interconnectedness of human, animal, and environmental health. It is often applied in contexts where zoonotic diseases or ecosystem health are central concerns.
- **IEHAF** expands this interdisciplinary approach by focusing on chronic, multipathway exposure to environmental toxins and the disproportionate health burden placed on vulnerable human populations. While One Health considers the environmental, animal, and human health intersections, IEHAF is particularly concerned with health inequities driven by extractive industries and governance failures. Its unique contribution lies in framing pollution exposure not only as an ecological issue but as a central determinant of health inequity that requires institutional accountability.

4.3. Environmental Justice/Accountability Frameworks

- **Environmental justice frameworks** focus on ensuring that marginalized communities are not disproportionately affected by environmental hazards and advocate for equitable access to environmental resources and protection.
- **IEHAF** complements these frameworks by providing a comprehensive and actionable tool that links environmental governance to health outcomes, making it a more operational tool for ensuring that environmental justice leads to concrete health interventions. While environmental justice frameworks emphasize equity, IEHAF places significant emphasis on accountability mechanisms that trigger health interventions based on environmental exposure levels and health surveillance.

4.4. Unique Decision Points of IEHAF

- **IEHAF** uniquely integrates environmental health monitoring and health outcomes tracking into a single, holistic decision framework that triggers actionable reforms such as health screenings, licensing conditions, and regulatory interventions based on observed environmental health threats.
- Unlike the other frameworks, IEHAF specifically targets extractive industries as a driving force behind environmental degradation and health inequities, proposing normative decision-making that shifts the focus from mere environmental compliance to an integrated health and governance approach.

5. Defining "Public Health Emergency" and Triggering IEHAF

In the context of this manuscript, "public health emergency" refers to a situation in which environmental degradation, particularly caused by oil extraction activities in the Niger Delta, leads to significant, widespread, and sustained health consequences for affected populations. This designation is grounded in the severity, scale, and persistence of the health risks posed by long-term exposure to pollutants such as hydrocarbons, heavy metals, and toxic gases. A public health emergency in this case is characterized by:

1) Chronic, multi-pollutant exposure: Long-term, sustained exposure to toxic substances from oil extraction, such as petroleum hydrocarbons, heavy metals, and combustion by-products, which have been shown to contribute to chronic health conditions.

2) Widespread health impacts: A high burden of diseases that are linked directly to environmental pollution, including respiratory issues, gastrointestinal disorders, neurological impairments, and reproductive health problems, with disproportionate effects on vulnerable populations (children, pregnant women, and the elderly).

3) Inequitable health outcomes: The exacerbation of health inequities, particularly in resource-dependent communities that lack the infrastructure, healthcare, or economic means to mitigate these effects.

The **Integrated Environmental-Health Accountability Framework (IEHAF)** is designed to identify, assess, and address such public health emergencies by integrating environmental, health, and governance data into a cohesive, actionable framework. When triggered, IEHAF would:

1) Escalate health surveillance: If pollution levels exceed established thresholds or if epidemiological studies identify significant health trends in affected communities, IEHAF would trigger an escalation of health surveillance activities. This would include the deployment of health screening programs, particularly focusing on vulnerable populations, and the establishment of longitudinal health monitoring systems to track the progression of health conditions linked to environmental pollutants.

2) Implement health screening and intervention programs: IEHAF would call for the implementation of health screening programs to detect early signs of pollution-related diseases, such as respiratory illnesses, gastrointestinal disorders, and neurological conditions. This could include mobile health clinics in high-risk areas, particularly for marginalized communities, and biomonitoring programs to track exposure levels.

3) Regulate and enforce corrective actions: In cases where oil extraction activities contribute significantly to health risks, IEHAF could trigger regulatory mechanisms, such as licensing suspension conditions, which would limit or halt extraction activities until adequate measures are put in place to address the public health emergency. Additionally, IEHAF advocates for comprehensive environmental assessments that include public health metrics, ensuring that health risks

are factored into any new or ongoing extractive activities.

4) Prioritize accountability and policy reform: IEHAF would also highlight the need for governance reforms to address regulatory gaps that allow extractive industries to operate with limited accountability for public health. This would include the creation of liability mechanisms that require extractive industries to fund health interventions and support the long-term health monitoring of affected populations.

6. The Environmental-to-Health Pathway in Extractive Regions

The environmental-to-health pathway in extractive regions like the Niger Delta is characterized by a cascading series of events that links oil extraction activities to health outcomes through multiple ecological and human exposure mechanisms. As outlined in **Figure 1**, this cascade begins with oil extraction and infrastructure failure, continues through ecological degradation, and ultimately leads to a range of health outcomes and socioeconomic impacts. The integration of these distinct stages reveals how the extractive economy directly affects public health through environmental contamination and how these effects are compounded by systemic governance failures and socioeconomic vulnerabilities. Understanding this pathway is critical in framing oil extraction as a public health crisis rather than just an environmental issue:

1) Oil Extraction & Infrastructure Failure: The first stage in the environmental-to-health pathway is the extraction process itself, which includes significant infrastructure failures. Pipeline corrosion, wellhead leakage, and gas flaring are common occurrences that release hazardous substances into the environment. In addition, waste pit overflow often leads to uncontrolled discharges of toxic substances into both land and water systems. These operational failures expose the surrounding environment to chemicals that can persist for long periods, thereby ensuring that communities remain exposed to harmful toxins [27]-[37]. These pollutants initiate a chain reaction of environmental degradation that ultimately reaches the human population.

2) Ecological Degradation: Following the initial contamination, ecological degradation occurs through the contamination of groundwater, surface water, hydrocarbon loading, and soil toxicity. Biodiversity collapse is another consequence of these pollutants, as aquatic and terrestrial ecosystems are severely affected by the introduction of hydrocarbons, heavy metals, and other toxic chemicals [1]-[15]. These ecological changes are particularly significant in the Niger Delta, where many local communities rely on fishing, agriculture, and water resources for their livelihoods. As Eli *et al.* [34] highlight, water contamination in particular serves as the central transmission mechanism, linking oil extraction activities to health risks that affect the most vulnerable populations. This environmental degradation sets the stage for a multi-faceted public health crisis, as ecosystems and human health become increasingly interconnected.

3) Human Exposure Pathways: The next stage in the pathway involves human exposure to contaminants through several key pathways. The most direct and immediate form of exposure is through contaminated drinking water, which is often the primary source of water for many communities in the Niger Delta. Additionally, polluted fisheries and food chains contribute to chronic exposure, as aquatic organisms accumulate contaminants such as petroleum hydrocarbons and heavy metals. Inhalation of flaring emissions from gas flaring and dermal contact during occupational activities in contaminated environments also exacerbate exposure risks. As Saliu *et al.* [28] point out, these exposure pathways are not merely environmental parameters; they are the core mechanisms through which extractive activities translate into chronic disease burdens, particularly for vulnerable populations who have limited capacity to mitigate exposure.

4) Health Outcomes: The health consequences of these multiple exposure pathways are far-reaching and multifaceted. Immediate health outcomes include gastrointestinal disorders, caused by the ingestion of contaminated water, and respiratory diseases linked to inhaling the fumes from gas flaring. Over time, exposure to heavy metals such as lead and cadmium can lead to neurological damage, kidney failure, and developmental issues. In addition to these physical health outcomes, there are growing concerns about reproductive and developmental effects in communities living in proximity to extractive operations. As mental health distress rises due to both physical illness and the economic hardships caused by environmental degradation, these health outcomes further compound the vulnerabilities of affected populations [79]-[95]. **Figure 1** provides a visual representation of these interlinked health risks, illustrating how exposure pathways lead to a range of health issues that further strain already fragile healthcare systems.

5) Socioeconomic Feedback: The final stage in the extractive exposure cascade is the socioeconomic feedback loop, where health deterioration is tied directly to economic decline. As livelihoods collapse due to environmental damage and the loss of agricultural and fishing income, affected communities experience escalating food insecurity. This economic decline, coupled with distress migration, which is often a result of the collapse of local economies, leads to broader socioeconomic instability. Reduced productivity, both at the individual and community level, contributes to intergenerational poverty [36] [37], as future generations inherit the compounded effects of environmental pollution and health decline. This feedback loop highlights the urgency of addressing environmental degradation as a public health issue, emphasizing that prevention and remediation must be part of a larger strategy for socioeconomic recovery in the Niger Delta [1]-[8].

Thus, **Figure 1** encapsulates the complex interaction between environmental degradation, human exposure, and health outcomes, ultimately leading to deep-rooted socioeconomic consequences. By understanding this pathway, policymakers and public health officials can better grasp the severity of the Niger Delta's environmental and health crisis, moving beyond immediate remediation efforts to implement long-term sustainable development and public health strategies that

account for the full scope of these intertwined issues.

7. Multi-Pollutant Exposure and Water Contamination as the Central Health Determinant

Water systems in the Niger Delta, essential for local populations' survival, also amplify the risks of chronic public health issues linked to extractive activities. These systems, increasingly contaminated by pollutants such as petroleum hydrocarbons and heavy metals, exceed permissible standards in many communities [96]-[104]. Hydrochemical analyses consistently show high levels of contamination in both surface and groundwater sources, exposing local populations to significant risks from water used for drinking, cooking, and agriculture [154]-[162]. However, the health crisis cannot be understood in isolation from the broader context of multi-pollutant exposure, which intensifies the impact of any single contaminant. The challenge is compounded by systemic failures in infrastructure, including a lack of alternative potable water sources and inadequate municipal treatment facilities, leaving contaminated water as the only available resource for many communities [119]-[142]. Informal water storage practices further exacerbate the exposure risk, as untreated water stored in containers continuously exposes the population to harmful pollutants, especially in the absence of affordable bottled water. This continuous exposure, as pollutants persist in both the environment and water sources year-round, leads to long-term health outcomes, including gastrointestinal diseases, neurological impairments, and cancer [28] [163] [164]. The cumulative burden is particularly severe in communities reliant on fishing and farming, as pollutants bioaccumulate through the food chain, contaminating both fish and agricultural produce. Toxins like petroleum hydrocarbons and heavy metals accumulate across trophic levels, reaching higher concentrations in fish and crops, and further impacting human health when consumed [1]-[8]. Thus, the failure to address water contamination compounds both health risks and economic insecurity, reinforcing a vicious cycle of poverty and health decline [36] [37] [74] [76]. To tackle this, IEHAF identifies three interconnected domains: 1) Environmental Toxicity, which accounts for contaminants introduced by extractive activities; 2) Human Exposure, detailing the pathways through which communities come into contact with toxins; and 3) Health Burden, which tracks the chronic diseases and disabilities resulting from prolonged exposure. By placing water contamination at the core of these interactions, IEHAF emphasizes that the issue is not solely one of environmental management, but one of public health governance. Effective health policies must integrate environmental monitoring and regulation to reduce the multi-pollutant exposure central to the region's health crisis. In conclusion, multi-pollutant exposure and water contamination are fundamental to the health challenges in the Niger Delta. The cumulative burden of these pollutants is exacerbated by a lack of infrastructure and economic constraints. By addressing these issues within an integrated health framework, IEHAF provides a clear approach to understanding and mitigating the long-term

health consequences of environmental degradation in extractive regions. The framework highlights that prevention, accountability, and integrated health-environmental policies are essential for reducing the public health risks associated with water contamination and multi-pollutant exposure.

8. Strengthening the Causal Pathway Claims

The environmental degradation caused by oil extraction in the Niger Delta has led to a variety of documented toxic exposures that significantly impact human health. The following section outlines the causal pathway from exposure to health outcomes, distinguishing between global environmental epidemiology and Niger Delta-specific evidence.

8.1. Documented Exposures in the Niger Delta

The Niger Delta has been heavily impacted by oil extraction activities, resulting in widespread environmental contamination. Some of the primary sources of pollution include:

- **Oil spills**: Frequent pipeline leaks and ruptures, which release hydrocarbons into the environment, particularly affecting surface water, groundwater, and soil. Studies have shown elevated concentrations of petroleum hydrocarbons, such as benzene, toluene, ethylbenzene, and xylene (BTEX) compounds, in local water supplies and sediments [59] [74].
- **Gas flaring**: Ongoing combustion of natural gas at oil fields results in the release of particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NOx), and polycyclic aromatic hydrocarbons (PAHs), all of which contribute to air pollution and pose health risks [47] [48] [58] [65] [72] [73].
- **Heavy metals**: Oil extraction and refining processes lead to the accumulation of heavy metals like lead (Pb), cadmium (Cd), and mercury (Hg) in local ecosystems, which contaminate drinking water, soil, and food chains [22] [32] [33] [50] [52]-[54].

8.2. Established Exposure-Health Associations from Environmental Epidemiology

Numerous studies globally have linked the exposure to pollutants like hydrocarbons, heavy metals, and particulate matter to a variety of adverse health outcomes. These include:

- **Respiratory diseases**: Exposure to air pollutants such as $PM_{2.5}$ and NOx is strongly associated with asthma, bronchitis, and emphysema. This is well-documented in environmental epidemiology, particularly in regions with high levels of industrial pollution [47] [48] [58] [65] [72] [73] [84] [93] [133].
- **Neurological disorders**: Long-term exposure to heavy metals, especially lead and cadmium, has been linked to neurodevelopmental delays in children and neurological damage in adults. Cadmium exposure, for instance, is also associated with kidney damage and hypertension [105]-[107] [118] [119] [127].

- **Cancer risks**: Prolonged exposure to benzene and PAHs has been widely established as a risk factor for various cancers, particularly lung cancer and leukemia [55] [57] [62] [66]-[71] [124] [125].
- **Gastrointestinal disorders**: Consuming contaminated water and food, especially fish contaminated with petroleum hydrocarbons and heavy metals, is a significant cause of gastrointestinal diseases like gastroenteritis and typhoid fever [10]-[17].

8.3. Niger Delta-Specific Health Outcome Evidence

While the global evidence on exposure-health associations is important, the Niger Delta has unique health outcomes driven by its specific environmental conditions:

- **Water contamination**: Local studies show that the Niger Delta population is at high risk for gastrointestinal diseases due to petroleum-contaminated drinking water. Children in these areas suffer disproportionately from stunted growth and cognitive impairments linked to chronic exposure to lead and cadmium from polluted water and food sources [10]-[17].
- **Respiratory problems**: The local population, especially those living near gas flaring sites, has an elevated incidence of respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD). Research specific to the Niger Delta links these conditions to elevated levels of air pollution from gas flaring [47] [48] [58] [65] [72] [73] [84] [93].
- **Reproductive health impacts**: Women in the Niger Delta experience higher rates of miscarriages, preterm births, and low birth weights, which are strongly correlated with exposure to air pollutants from gas flaring and water contamination from oil spills [59] [74].
- **Increased poverty-related diseases**: Chronic exposure to environmental pollutants has worsened poverty in the Niger Delta, with a direct link between environmental damage and socioeconomic hardships, including food insecurity and displacement [75]-[77].

The causal pathway from environmental exposure to public health outcomes in the Niger Delta can be understood in two main ways: globally, through established epidemiological associations, and locally, through Niger Delta-specific health data. While the global evidence supports the links between pollutants and various diseases, the Niger Delta's specific health impacts underscore the urgency of addressing environmental degradation as a public health emergency. IEHAF seeks to build on both sets of evidence, applying a systems approach to integrate health data with environmental monitoring for more effective interventions and policy action in the region.

9. The Three Core Domains of IEHAF

9.1. Domain I: Environmental Toxicity and Ecological Collapse

The first domain of the Integrated Environmental-Health Accountability Framework (IEHAF) focuses on environmental toxicity and ecological collapse, which

results from the sustained introduction of pollutants such as hydrocarbons, heavy metals, and combustion by-products into aquatic and terrestrial systems. These pollutants can cause long-term environmental damage, impairing ecosystem function and reducing the region's ability to support healthy human populations and wildlife. The introduction of these contaminants into the environment often results in structural ecosystem impairment, which means that the natural systems that support biodiversity, human health, and ecological services (e.g., water purification, food production, and carbon sequestration) are severely compromised.

9.1.1. Niger Delta-Specific Manifestations

In the Niger Delta, the effects of environmental toxicity are particularly pronounced:

- Persistent groundwater hydrocarbon contamination is one of the most visible signs of extractive industry-related pollution. Oil spills and pipeline leaks result in hydrocarbons seeping into groundwater, rendering it undrinkable and dangerous for both humans and wildlife.
- Heavy metal accumulation in soil and water has also been documented, particularly lead, cadmium, and zinc, which are released into the environment through the flaring of natural gas, improper disposal of toxic waste, and ongoing oil spills. These metals accumulate over time, leading to soil and water toxicity that affects food production, water sources, and overall ecosystem health.
- The loss of mangrove ecosystems is another major consequence, as the mangroves act as vital buffers against storm surges, provide habitats for biodiversity, and contribute to water purification. However, they are being destroyed by oil spills, land reclamation projects, and deforestation.
- Fisheries decline is particularly devastating for communities that rely on fish as their primary food source. Contaminated waterways have caused fish populations to decrease, reducing the availability of both protein and livelihoods for many local people.

9.1.2. Guiding Accountability Questions

To address environmental toxicity and its far-reaching consequences, the following questions should be asked:

- Are water monitoring systems longitudinal and transparent? Ensuring that water quality is consistently monitored over time and that data is made available to the public is crucial for understanding the long-term impacts of contamination.
- Do remediation standards account for cumulative toxicity? Remediation efforts must not only address immediate pollution but also take into account the cumulative effects of long-term exposure to multiple contaminants.
- Is ecosystem restoration linked to health surveillance metrics? Restoration projects should be designed to not only rehabilitate ecosystems but also track their progress in improving health outcomes, such as reductions in waterborne diseases or improvements in food security.

9.2. Domain II: Human Exposure, Vulnerability, and Behavioral Adaptation

The second domain focuses on how ecological damage translates into human disease through various exposure pathways. This is influenced by poverty, infrastructure deficits, and adaptive survival strategies that communities adopt in response to environmental degradation. While the introduction of pollutants into the environment is harmful in itself, the extent of harm to human health is magnified by social factors that dictate the degree of exposure and the vulnerability of populations. Poor communities often lack the means to avoid or mitigate exposure, resulting in disproportionate health impacts.

9.2.1. Critical Pathways

Several critical pathways exist through which communities are exposed to pollutants:

- Drinking untreated borehole or surface water is one of the most immediate pathways of exposure. Many communities in the Niger Delta rely on groundwater and surface water sources that have been contaminated by oil spills, gas flaring, and other extractive activities.
- Consuming contaminated fish is another direct exposure pathway. The contamination of aquatic ecosystems by petroleum hydrocarbons and heavy metals leads to the bioaccumulation of toxins in fish, which are then ingested by the local population.
- Inhalation of gas flaring emissions exposes nearby communities to toxic gases and particulate matter, leading to chronic respiratory problems.
- Occupational exposure during artisanal activities, such as fishing, farming, and working in contaminated oil fields, increases the likelihood of direct exposure to harmful pollutants.

9.2.2. Amplifiers of Risk

The health risks associated with these exposure pathways are compounded by several factors:

- Weak primary healthcare systems make it difficult for local populations to receive timely diagnosis and treatment for diseases caused by environmental contamination. Without proper healthcare infrastructure, the population is more susceptible to chronic conditions and infections.
- The absence of toxicological screening means that many health issues related to pollution go undiagnosed, and individuals who are exposed to harmful toxins may not receive appropriate treatment or preventative care.
- Socioeconomic constraints limit the ability of local communities to avoid exposure. For example, in many cases, people cannot afford bottled water or water filtration systems, forcing them to rely on contaminated sources.

9.2.3. Guiding Questions

To address the human health risks posed by environmental exposure, the follow-

ing questions should be asked:

- Are vulnerable groups (pregnant women, children, fisherfolk) systematically screened? Vulnerable groups must be identified and prioritized for health screening to detect early signs of illness due to environmental exposure.
- Is safe water access treated as a health intervention? Access to clean water should be considered a public health intervention, requiring investment in infrastructure and regular water quality assessments.
- How do livelihood losses alter dietary and exposure patterns? Understanding how the collapse of local industries (e.g., fishing) affects dietary habits and exposure to pollutants is essential for developing targeted health interventions.

9.3. Domain III: Institutional Accountability and Policy Inertia

The third domain focuses on the failure of governance structures to effectively prevent, monitor, or remediate environmental contamination. The root cause of continued exposure to harmful pollutants in the Niger Delta is not just environmental damage but structural failures in regulatory frameworks, enforcement mechanisms, and public health systems.

9.3.1. Structural Failures

Several key structural failures perpetuate the problem:

- Fragmented regulatory oversight exists because multiple agencies are often responsible for regulating environmental health, leading to inconsistencies and inefficiencies in enforcement.
- Weak enforcement mechanisms mean that even when environmental regulations are in place, they are often not adequately enforced, allowing polluting companies to continue harmful practices without consequence.
- Delayed remediation responses have led to a slow recovery from oil spills and other environmental disasters. Despite the evidence of contamination, the process of cleaning up polluted areas is often delayed or inefficient, prolonging exposure for local communities.
- Limited community participation in monitoring results in a lack of local accountability and representation in decision-making processes. Communities should have the right to participate in environmental monitoring and hold both the government and corporations accountable for their actions.

9.3.2. Guiding Questions

To address governance failures and improve accountability, the following questions should be considered:

- Who bears legal and financial responsibility for long-term health monitoring? Identifying the parties responsible for funding and conducting long-term health surveillance is essential for ensuring that the impacts of contamination are consistently monitored.
- Are health-cost externalities internalized into extractive licensing? Extractive industries must be held accountable for the health costs they impose on local

populations, which should be incorporated into the licensing and regulatory framework.

- Is environmental data publicly accessible and independently verified? Transparent access to data is essential for holding companies and regulators accountable. Publicly available, verified environmental data would allow communities to better understand the risks they face and advocate for action.

These three domains, environmental toxicity, human exposure, and institutional accountability, are interconnected and collectively shape the public health crisis in the Niger Delta. By addressing these domains, IEHAF offers a comprehensive framework for understanding and mitigating the environmental health risks posed by extractive industries. Through preventive measures, stronger regulatory frameworks, and community participation, the region can begin to address the deep-rooted health inequities caused by environmental degradation (Table 1 below).

Table 1. Documented water contaminants and associated health implications in the Niger delta.

Contaminant Category	Primary Extractive Source	Environmental Medium	Exposure Pathway	Biological Mechanism/ Toxicodynamics	Documented/ Associated Health Effects	Population Groups Most Affected	Long-Term Public Health Implication
Petroleum Hydrocarbons (e.g., BTEX, PAHs, TPH)	Oil spills, pipeline leaks, artisanal refining	Surface water, groundwater, sediments	Drinking water, dermal absorption, ingestion of contaminated fish	Lipophilic bioaccumulation; hepatic enzyme disruption; oxidative stress	Gastrointestinal disorders (nausea, vomiting), liver toxicity (hepatocellular damage, cirrhosis), skin rashes, carcinogenic risk (from PAHs)	Fishing communities, children, pregnant women	Long-term liver disease burden, skin cancer incidence, systemic environmental contamination effects
Heavy Metals (Pb, Cd, Zn, Hg)	Produced water discharge, oil drilling effluents, soil leaching	Groundwater, surface water, aquatic biota	Drinking water, food chain bioaccumulation (fish, crops)	Lead (Pb) neurotoxicity (blood-brain barrier); Cadmium (Cd) renal tubular damage, zinc bioaccumulation	Neurodevelopmental delay (Pb), renal impairment (Cd), hypertension, reproductive toxicity, gastrointestinal disturbances	Children (neurodevelopment), women of reproductive age (pregnancy, fetal exposure)	Chronic kidney disease prevalence, developmental disabilities, elevated blood pressure rates
Combustion By-products (SO_2, NOx, $PM_{2.5}$, Black Carbon)	Gas flaring, petroleum refining	Air, water deposition, soil	Inhalation, ingestion of contaminated rainwater	Pulmonary inflammation; oxidative stress; placental vascular impairment	Respiratory disease (asthma, bronchitis, emphysema), adverse pregnancy outcomes (low birth weight, preterm birth), cardiovascular disease	Infants, elderly, pregnant women, individuals with pre-existing respiratory conditions	Increased maternal-child morbidity and mortality, chronic respiratory disease rates, cardiovascular risks
Polycyclic Aromatic Hydrocarbons (PAHs)	Incomplete combustion (oil burning, flaring)	Surface water, food chain, sediment	Ingestion of contaminated fish and shellfish, dermal exposure	DNA adduct formation; mutagenic properties; carcinogenic risk	Carcinogenic risk (skin, lung, bladder cancer), immunotoxicity, oxidative damage	Fishing communities, workers in oil industries	Increased lifetime cancer risk, immune suppression, birth defects linked to PAH exposure
Salinity & Total Dissolved Solids (TDS)	Produced water discharge, seawater intrusion, brine from drilling	Groundwater, surface water	Drinking water, irrigation, consumption of contaminated fish	Osmotic imbalance; renal stress; hypertension	Hypertension, dehydration, kidney strain	Rural households, farmers reliant on shallow wells for water	

Continued

Endocrine Disrupting Chemicals (EDCs)	Petrochemical effluents, industrial additives	Surface water, groundwater	Drinking water, food chain	Hormonal receptor interference, thyroid disruption, gonadal impairment	Fertility issues, menstrual irregularities, developmental abnormalities	Adolescents, women of reproductive age	Long-term reproductive health decline, increase in endocrine-related cancers
Microbial Contamination (due to infrastructure damage)	Flooded oil-impacted sites, damaged boreholes	Groundwater, surface water	Oral ingestion	Gastrointestinal infection pathways	Cholera, diarrheal disease, typhoid fever, gastroenteritis	Children under five, immunocompromised individuals	Persistent waterborne diseases, hospital burden, stunted growth and cognitive development in children
Cyanides & Chemical Additives	Illegal refining, petrochemical discharges	Surface water, soil	Dermal exposure, oral ingestion	Inhibition of cellular respiration; hypoxia	Acute poisoning symptoms, neurological impairment (headaches, dizziness), dizziness	Local communities near artisanal refineries	Acute toxicity episodes, high emergency care burden

Source: Adapted from Morufu *et al.,* [10]; Olalekan *et al.,* [12]; Raimi & Sawyerr [13].

10. Implementation: Measurable Indicators for IEHAF

The Integrated Environmental-Health Accountability Framework (IEHAF) requires a robust system of monitoring and implementation to ensure the effective integration of environmental and health data. To support the application of IEHAF, the following measurable indicators are proposed for each domain, with clearly identified roles for responsible stakeholders.

10.1. Domain I: Environmental Toxicity and Ecological Collapse

- **Measurable Indicators**:
  - **Water Quality Indicators**: Levels of petroleum hydrocarbons, heavy metals (e.g., lead, cadmium), and **toxins** (e.g., PAHs) in drinking water sources [10]-[17].
  - **Soil Contamination**: Measurement of hydrocarbon content, heavy metal concentrations, and toxic by-products in agricultural soils [1]-[8] [30] [64] [108].
  - **Air Quality Monitoring**: Concentrations of $PM_{2.5}$, NOx, and SO_2 near gas flaring sites [47] [48] [58] [65] [72] [73] [84] [93] [133].
  - **Biodiversity Loss**: Monitoring changes in aquatic and terrestrial biodiversity, focusing on the decline of species dependent on contaminated ecosystems (e.g., fish, mangroves) [1]-[8] [64].
- **Responsible Entities**:
  - **Environmental Protection Agencies** (e.g., National Environmental Standards and Regulations Enforcement Agency (NESREA), State-level Environmental Agencies) for water and soil monitoring.
  - **Local Government Authorities** for air quality monitoring.
  - **Academic and Research Institutions** for conducting biodiversity surveys.

- **Community-based Monitoring Groups** for providing data on local ecological changes.

10.2. Domain II: Human Exposure, Vulnerability, and Behavioral Adaptation

- **Measurable Indicators**:
  - **Exposure Proxies**:
    - **Biomonitoring** of pollutants in human blood and urine samples (e.g., lead, cadmium, BTEX compounds).
    - **Health Surveillance Data**: Incidence rates of respiratory diseases, gastrointestinal disorders, and neurological conditions in local populations.
  - **Vulnerability Indicators**:
    - Proportion of the population dependent on contaminated water sources or agricultural produce from polluted soils.
    - **Socioeconomic Indicators**: Rates of poverty, food insecurity, and displacement.
- **Responsible Entities**:
  - **Public Health Agencies** (e.g., Nigerian Ministry of Health, WHO) for health surveillance and biomonitoring.
  - **Local Healthcare Facilities** and **NGOs** for providing health screening and data collection on disease incidence.
  - **Community Health Workers** and **Local Health Organizations** for documenting exposure and vulnerability levels.
  - **Civil Society Organizations (CSOs)** to track and report on local socioeconomic conditions.

10.3. Domain III: Institutional Accountability and Policy Inertia

- **Measurable Indicators**:
  - **Regulatory Compliance**: Frequency and effectiveness of environmental impact assessments (EIAs), including health risk projections, for extractive projects.
  - **Institutional Response Times**: Time taken to implement remediation measures after environmental disasters (e.g., oil spills, gas flare-related health crises).
  - **Public Accountability Metrics**: Availability of publicly accessible environmental and health data; the existence of community-led monitoring systems and legal accountability mechanisms for corporate actors.
- **Responsible Entities**:
  - **Regulatory Bodies** (e.g., NESREA, National Oil Spill Detection and Response Agency (NOSDRA)) for overseeing compliance and ensuring timely responses to pollution.
  - **Local and National Governments** for enforcing policies and ensuring that industries are held accountable.

- **Independent Environmental Monitoring Organizations** for evaluating the effectiveness of monitoring efforts and data transparency.
- **Civil Society Groups** and **Community Organizers** for advocating for greater institutional accountability and supporting transparency.

Thus, the Implementation of IEHAF relies on clear measurable indicators that allow for effective monitoring and data collection across each of its three domains. To ensure success, the roles of various stakeholders, including government agencies, research institutions, health organizations, and local communities, must be clearly delineated. By engaging these groups and ensuring transparent data reporting, IEHAF can effectively bridge the gap between environmental degradation and public health outcomes, guiding actionable policies and interventions in the Niger Delta.

11. Tightening Policy Translation: Institutional Bottlenecks and IEHAF's Mechanisms

Effective policy implementation in the Niger Delta faces significant challenges due to institutional bottlenecks that hinder environmental health governance. These bottlenecks include overlapping mandates, enforcement gaps, and data access constraints, which limit the effectiveness of current frameworks in addressing the public health crisis caused by oil extraction [59] [74]. The Integrated Environmental-Health Accountability Framework (IEHAF) is designed to overcome these obstacles through targeted mechanisms that improve coordination, enforcement, and data transparency.

11.1. Institutional Bottleneck: Overlapping Mandates and Regulatory Fragmentation

- **Problem**: In the Niger Delta, multiple agencies are responsible for regulating environmental protection, public health, and industrial activities, but their mandates often overlap or conflict. For example, **NESREA** (National Environmental Standards and Regulations Enforcement Agency) is responsible for enforcing environmental regulations, while **NOSDRA** (National Oil Spill Detection and Response Agency) focuses on oil spill management. However, these agencies often lack clear coordination, leading to fragmented enforcement and slow responses to pollution events.

- **IEHAF Mechanism**: **Integrated Regulatory Oversight**
  - IEHAF proposes creating a centralized coordination body that brings together agencies such as NESREA, NOSDRA, and the Ministry of Health to align efforts in regulating environmental health. This body would act as a single point of contact for environmental and health monitoring, improving decision-making and ensuring consistency across the regulatory framework.
  - Additionally, IEHAF encourages the integration of health and environmental impact assessments (EIAs), ensuring that health considerations are included in all regulatory decisions related to extractive industries.

11.2. Institutional Bottleneck: Enforcement Gaps and Lack of Compliance

- **Problem**: Despite the presence of environmental regulations, enforcement remains weak, with industries often bypassing compliance requirements. For example, gas flaring continues unabated in many areas of the Niger Delta, despite its known health impacts, because of lax enforcement and a lack of penalties for violations. This weak enforcement is compounded by a lack of accountability for companies causing environmental damage.

- **IEHAF Mechanism: Audit Authority and Liability Instruments**
  - IEHAF proposes the establishment of an independent audit authority tasked with ensuring compliance with both environmental and health standards. This authority would have the power to conduct unannounced inspections, enforce fines, and suspend licenses for companies that fail to comply with regulations.
  - To further ensure accountability, IEHAF recommends the creation of a health liability framework where extractive industries are financially responsible for the health costs they impose on local populations. This would include the creation of a compensation fund for communities affected by pollution, funded by a levy on extractive industries, ensuring that companies bear the full costs of their operations' health impacts.

11.3. Institutional Bottleneck: Data Access Constraints and Transparency Issues

- **Problem**: One of the major barriers to effective governance in the Niger Delta is the lack of transparency and accessibility of environmental and health data. Pollution monitoring data is often siloed within different agencies, and there is limited sharing of information between regulatory bodies, health agencies, and the public. This lack of data transparency hampers decision-making and public accountability.

- **IEHAF Mechanism: Single Data-Sharing Protocol and Public Access**
  - IEHAF advocates for the development of a single data-sharing protocol that would centralize environmental and health data in an open-access database. This protocol would allow for real-time sharing of pollution levels, health surveillance data, and remediation efforts between government agencies, researchers, and the public.
  - Public access to this data would be ensured through online platforms and community-based monitoring systems, where local communities could also report environmental hazards. This would empower local populations to hold both the government and companies accountable for their environmental health impacts.

By identifying and addressing these institutional bottlenecks, IEHAF offers concrete mechanisms to improve coordination, compliance, and transparency in environmental health governance. The centralized coordination body, audit au-

thority, and data-sharing protocol proposed by IEHAF would enhance the capacity of regulatory bodies to enforce policies effectively, while ensuring that local communities and stakeholders are actively involved in monitoring and reporting on environmental health issues.

12. From Exposure to Economic Entrenchment: The Extractive Poverty Loop

The environmental damage caused by extractive industries in the Niger Delta extends far beyond ecological destruction and health burdens; it also leads to the economic entrenchment of poverty [75]-[77]. This is exemplified by the Extractive Poverty Loop, a cycle in which environmental degradation, particularly pollution, exacerbates health risks, which in turn leads to economic loss and further poverty (see **Figure 2** below). The extractive industries do not only produce environmental externalities; they create deep, self-reinforcing structural health inequities. These inequities are both a cause and effect of poverty, as communities struggle to break the cycle of poor health, economic decline, and increased vulnerability to future environmental harms. The Extractive Poverty Loop can be understood as a process in which exposure to pollution not only results in immediate health issues but also catalyzes long-term economic hardship that is passed down through generations.

1) Pollution reduces fish catch and crop yield: In regions where, local populations rely heavily on fishing and agriculture, contamination of water and soil leads to declining yields. Pollutants such as hydrocarbons, heavy metals, and toxic by-products from gas flaring disrupt aquatic ecosystems, making fishing increasingly unproductive. Similarly, polluted soils, laden with toxic metals, impair crop growth, leading to food insecurity and loss of livelihood [163]-[175].

2) Households incur out-of-pocket medical costs: Health issues resulting from exposure to pollutants, such as gastrointestinal diseases, respiratory illnesses, and neurological impairments, impose heavy financial burdens on households. In many cases, local healthcare systems are weak or nonexistent, forcing families to pay out-of-pocket for medical treatment. This expenditure on healthcare diverts scarce financial resources, further limiting families' ability to invest in productive activities or escape poverty [85]-[90].

3) Reduced work capacity lowers income: As health deteriorates from prolonged exposure to environmental contaminants, work capacity diminishes. Workers, particularly those in informal or subsistence sectors like fishing and farming, find themselves unable to maintain full productivity. Illness, particularly chronic conditions resulting from toxic exposure, leads to absenteeism or early retirement, reducing household income and perpetuating the poverty cycle [74] [76].

4) Children withdrawn from school: One of the most devastating effects of poverty exacerbated by pollution is the withdrawal of children from school. Families facing food insecurity, health crises, and economic hardship often prioritize immediate survival over long-term educational goals. As a result, children are

taken out of school to help support the household or care for sick relatives, diminishing future prospects and trapping families in a cycle of poverty and low educational attainment. This dynamic has intergenerational consequences, as children who miss education are less likely to break out of the poverty cycle in adulthood [36] [37].

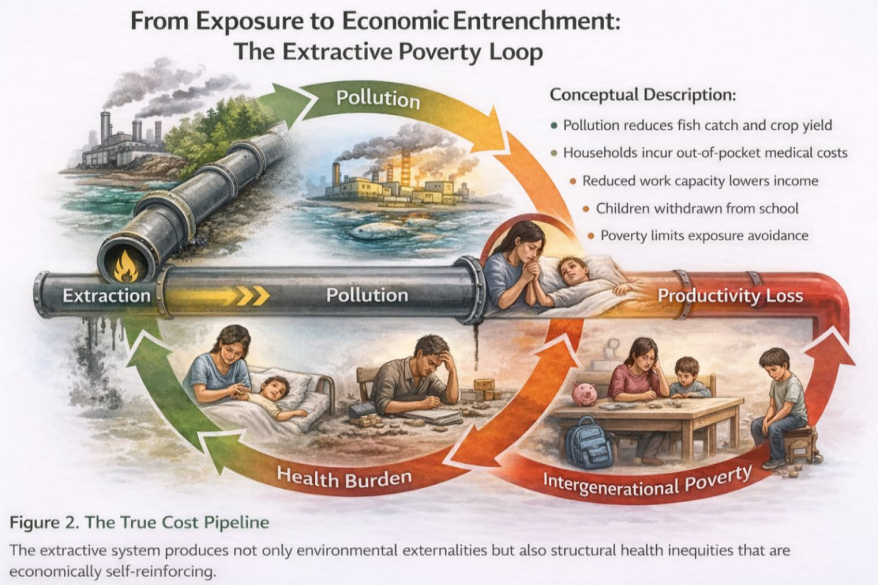
5) Poverty limits exposure avoidance: Finally, poverty itself limits the ability of communities to mitigate exposure to pollutants. In the Niger Delta, many households cannot afford the costs of water filtration, safe housing, or healthcare services that would allow them to avoid exposure to contaminated water or air. Moreover, impoverished households are often forced to rely on contaminated water sources because they lack access to cleaner alternatives. As pollution levels rise and resources become more constrained, the vulnerability to future exposure only increases, perpetuating the cycle.

6) Cycle repeats: This extractive poverty loop is not only self-reinforcing but also intergenerational. As children grow up in households affected by pollution, poor health, and economic hardship, they inherit the same structural vulnerabilities. The cycle of poverty, poor health, and environmental exposure is thus passed down, making it difficult for affected communities to break free from their current conditions. These dynamic highlights the urgent need for systemic reform to address both environmental and socio-economic inequities.

13. The Extractive System: Environmental Externalities and Economic Inequity

The extractive industries in the Niger Delta produce not only environmental externalities, such as pollution, but also economic externalities that exacerbate existing health inequities. As pollution from oil extraction directly impacts local health and livelihoods, the resulting economic loss in the form of lower productivity, reduced agricultural yields, and higher healthcare costs reinforces the entrenched poverty faced by many communities. The extractive system becomes self-perpetuating, as pollution and poverty act as feedback loops, further degrading the environment and hindering economic recovery. Moreover, the Niger Delta's reliance on extractive industries for economic sustenance compounds these challenges. The oil and gas sector has created a dependence on resource extraction, leaving local communities vulnerable to the economic fluctuations of the sector. As environmental damage worsens, the communities that depend on these resources for survival are left with few alternative livelihoods or resilience strategies. The overall economic and health vulnerability of these communities makes them particularly susceptible to the adverse effects of both local environmental degradation and global economic shifts [56]-[78]. The Extractive Poverty Loop described is not an isolated phenomenon but rather a systemic issue that calls for a holistic approach to environmental and economic reform. Without addressing both the environmental pollution and its societal impacts, the Niger Delta will continue to face a future of persistent health crises, economic stagnation, and

worsening poverty (see Table 2 below). The integration of public health initiatives, environmental remediation, and economic diversification into policy is critical to breaking this cycle and providing long-term sustainable development for the region [176]-[193].



Source: Author design, 2026.

Figure 2. The true cost pipeline.

Table 2. Health and economic pathways linking water contamination to poverty in the Niger delta.

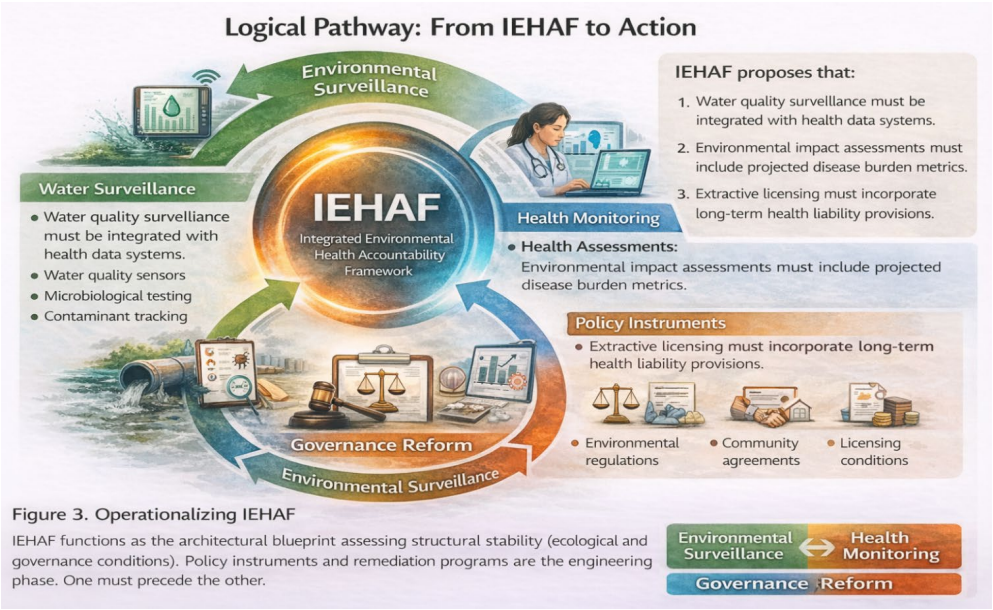
Pathway	Environmental Trigger	Immediate Health/Economic Impact	Intermediate Household-Level Effect	Long-Term Structural Consequence	Intergenerational Implication
Contaminated Water Ingestion	Hydrocarbon spills, heavy metal contamination, microbial pollution	Acute gastrointestinal illness, dermatological conditions, toxic exposure	Recurrent medical visits; school absenteeism; temporary work loss	Chronic disease burden (renal disease, liver dysfunction, neurodevelopmental delay); rising healthcare costs	Reduced cognitive attainment in children; diminished lifetime earning potential
Fisheries Collapse	Oil spills, sediment contamination, mangrove destruction	Decline in fish catch; immediate income loss among artisanal fishers	Reduced household protein intake; coping strategies (borrowing, asset sales)	Food insecurity; malnutrition; collapse of local blue economy	Stunting, impaired child development, long-term poverty transmission
Agricultural Yield Decline	Soil salinization, polluted irrigation water, acid deposition	Reduced crop productivity; harvest losses	Increased food prices; dietary compromise; rural indebtedness	Entrenched rural poverty; migration to urban informal settlements	Loss of agrarian livelihood skills; youth unemployment cycle
Healthcare Expenditure	Pollution-induced morbidity (respiratory, renal, reproductive disorders)	Out-of-pocket medical spending; catastrophic health expenditure	Household financial strain; diversion of education funds; borrowing at high interest	Asset depletion; deepened poverty; inability to invest in livelihood recovery	Persistent socioeconomic disadvantage; limited upward mobility

Continued

Reduced Labor Productivity	Chronic illness; occupational exposure to polluted environments	Fatigue, absenteeism, reduced physical capacity	Lower household income; unstable employment	Reduced regional GDP contribution; suppressed economic growth	Structural underdevelopment of oil-producing communities
Maternal and Child Health Impacts	Exposure to heavy metals, PAHs, air pollutants	Low birth weight; preterm birth; childhood infections	Increased caregiving burden; higher healthcare utilization	Elevated maternal and infant mortality rates; weakened human capital base	Lifelong health vulnerabilities; diminished educational attainment
Psychosocial Stress & Displacement	Environmental loss, livelihood collapse, forced migration	Anxiety, depression, social conflict	Community fragmentation; erosion of social capital	Regional instability; weakened governance trust	Cycles of marginalization and social exclusion

Source: Adapted from Perekibina *et al.,* [74]; Anthony *et al.,* [76]; Morufu *et al.* [77].

14. Logical Pathway: From IEHAF to Action



Source: Author design, 2026.

Figure 3. Operationalizing IEHAF.

The Integrated Environmental-Health Accountability Framework (IEHAF) provides a comprehensive, systems-level approach to understanding and addressing the interconnected issues of environmental degradation and public health in the Niger Delta. While the framework provides a conceptual blueprint, it must be translated into concrete actions that drive systemic change. The logical pathway from IEHAF to action involves integrating environmental surveillance, health monitoring, and governance reform to create a unified approach that addresses both ecological damage and its long-term health impacts. As de-

picted in Figure 3, the pathway emphasizes the need for comprehensive monitoring and policy reforms to bridge the gap between environmental data and health outcomes, thereby fostering a proactive rather than reactive response to environmental health crises.

14.1. Environmental Surveillance

At the core of IEHAF is the integration of environmental surveillance with health data systems. The framework proposes that continuous monitoring of environmental pollutants, including petroleum hydrocarbons, heavy metals, and particulate matter from gas flaring, should be linked directly to health surveillance data. This integrated approach will allow policymakers to not only track pollution levels in the environment but also monitor how these pollutants translate into health outcomes such as gastrointestinal diseases, respiratory conditions, and neurological disorders. By aligning environmental and health monitoring systems, the framework ensures that real-time data is available to guide public health interventions. Furthermore, the surveillance systems must be transparent and publicly accessible, allowing local communities, researchers, and policymakers to identify emerging health risks before they escalate into larger crises [176]-[198]. As Saliu *et al.* [28] emphasize, data sharing between environmental agencies and health authorities is essential for creating an informed response to environmental health challenges. This collaborative monitoring will improve early detection and enable timely interventions, such as the provision of clean water, health screenings, or targeted treatments for affected populations.

14.2. Environmental Impact Assessments (EIAs)

Another crucial element of IEHAF is the inclusion of health metrics in Environmental Impact Assessments (EIAs). Traditionally, EIAs assess the environmental damage caused by extractive projects but rarely account for the long-term health burdens that result from pollution exposure. IEHAF proposes that projected disease burden metrics, such as the anticipated incidence of diseases related to contaminated water, air, and food, be incorporated into these assessments. This will help to quantify the human cost of environmental degradation and provide a more comprehensive picture of the consequences of extractive practices. By integrating health data into the EIA process, extractive industries will be required to consider the public health implications of their activities upfront. This will also help ensure that remediation strategies are designed not only to restore ecosystems but also to address the health disparities caused by pollution. For instance, if an oil spill is projected to increase the risk of waterborne diseases in a community, the EIA will incorporate measures to mitigate this risk, such as the provision of alternative water sources or health interventions [143]-[153].

14.3. Extractive Licensing and Health Liabilities

The third key aspect of operationalizing IEHAF involves integrating long-term

health liability provisions into the extractive licensing process. Currently, extractive industries are often held accountable for environmental damage, but the health consequences of their actions are rarely factored into the licensing agreements. IEHAF proposes that future extractive licenses include specific provisions for long-term health monitoring, health remediation, and financial responsibility for any health impacts caused by pollution [1]-[15]. This can include establishing health reserves or compensation funds for affected communities, which would cover the costs of medical care, lost income due to illness, and relocation costs for displaced populations. Including health liabilities in the extractive licensing process ensures that companies are held accountable for the long-term impact of their activities on both the environment and public health. It also incentivizes companies to adopt cleaner technologies and better safety practices to reduce pollution and associated health risks [194]-[198]. This shift toward proactive environmental-health governance will ultimately lead to more sustainable and socially responsible extractive industries.

14.3.1. IEHAF as an Architectural Blueprint

IEHAF functions as an architectural blueprint that assesses the structural stability of both the ecological and governance conditions in extractive regions. Just as an architect would design a building with consideration for long-term stability, IEHAF takes a long-term view of environmental and public health impacts, assessing the root causes of exposure and vulnerability. However, the blueprint alone is not enough. It must be followed by policy instruments and remediation programs that function as the engineering phase, the actual building of a system that can withstand the pressures of industrial exploitation and environmental degradation [1]-[8] [163] [164]. Just as in any construction project, the engineering phase (*i.e.*, policy implementation and remediation) must follow the architectural design (*i.e.*, IEHAF). The framework provides the structure for action, but it is through policy reform and governance improvements that the framework can be operationalized and made effective. This means that environmental surveillance, health monitoring, and regulatory reform must work in tandem to create a cohesive response that addresses both the symptoms and causes of the environmental health crisis in the Niger Delta [133]-[145].

14.3.2. The Need for Systemic Reform

In conclusion, the logical pathway from IEHAF to action requires systemic reform across multiple sectors. By integrating environmental surveillance, health data systems, EIAs, and extractive licensing, IEHAF provides the tools necessary to bridge the gap between ecological health and human well-being (see **Table 3** below). The framework emphasizes that proactive health measures, rather than reactive ones, should be the guiding principle for managing the environmental and health consequences of extractive industries. Through these reforms, IEHAF offers a comprehensive path forward that addresses the deep-rooted health inequities in the Niger Delta, ensuring that environmental health is central to

sustainable development.

Table 3. Policy translation matrix: from environmental exposure to structural health justice in the Niger delta.

Actor	Immediate Action (Short-Term Response)	Intermediate Institutional Shift	Structural Reform (Long-Term Transformation)	Intended Public Health Outcome
Policymakers (Federal & State Governments)	Mandate integrated water-health surveillance; enforce transparent reporting of spills and flaring	Harmonize environmental, petroleum, and public health regulations; allocate budget lines for environmental health	Embed long-term health liability and remediation trust funds in extractive contracts; adopt polluter-pays enforcement mechanisms	Reduced exposure burden; institutional accountability; prevention-oriented governance
Public Health Agencies	Establish toxicological screening programs in oil-producing communities; deploy mobile clinics	Integrate environmental exposure indicators into routine health information systems; strengthen disease surveillance	Develop regional environmental health registries and longitudinal cohort monitoring systems	Early detection of chronic disease; life-course exposure tracking; improved health equity
Environmental Regulatory Bodies	Conduct independent water and soil quality audits; enforce compliance thresholds	Digitalize environmental monitoring systems; require cumulative impact assessments	Institutionalize health-inclusive Environmental Impact Assessments (EIAs) with projected disease burden metrics	Evidence-based regulation; reduced cumulative toxic exposure
Researchers & Academic Institutions	Quantify multi-pollutant cumulative risk; conduct biomonitoring studies	Develop interdisciplinary exposure-disease models linking ecology and economics	Model intergenerational economic burden of pollution; establish predictive risk mapping frameworks	Stronger causal evidence; policy-relevant burden-of-disease estimates
Civil Society & Community Organizations	Community-based water monitoring; risk communication campaigns	Participatory environmental governance platforms; social accountability reporting	Strategic litigation, transparency advocacy, and extractive revenue tracking	Empowered communities; improved environmental justice outcomes
Oil & Extractive Corporations	Immediate spill response and remediation; disclose emission inventories	Adopt transparent ESG reporting tied to measurable health indicators	Internalize environmental health costs; establish independent remediation and compensation funds	Corporate accountability; reduced long-term liability
International Partners & Donors	Technical support for exposure assessment and surveillance	Fund integrated environmental-health data systems	Support structural reforms aligned with global environmental justice frameworks	Strengthened institutional capacity; sustainable development alignment

Source: Adapted from Suleiman *et al.* [16].

15. Discussion

15.1. Navigating Governance Tensions, Power Asymmetries, and Framework Limitations

15.1.1. Navigating Tensions: Environmental vs. Economic Interests

The Integrated Environmental-Health Accountability Framework (IEHAF) confronts a significant tension in governance structures: the conflict between envi-

ronmental sustainability and economic interests tied to extractive industries. This is particularly evident in regions like the Niger Delta, where oil extraction is vital to both local and national economies. However, the public health costs associated with environmental degradation are often externalized, leaving local communities to bear the burden while the national economy continues to profit from the extraction of resources [153]. The paradox lies in the fact that the wealth generated from resource extraction undermines the long-term economic stability and public health of these regions. Studies have shown that the health costs of pollution, including respiratory diseases, cancers, and waterborne illnesses, not only affect local communities but also reduce workforce participation and productivity, which in turn impacts national economic growth [148]-[162]. This dynamic exacerbates health inequities and perpetuates injustice, as the most vulnerable populations continue to suffer the consequences of the wealth generated by industries that should benefit the entire nation.

15.1.2. Power Asymmetries and Policy Implementation

A major challenge in the Niger Delta is the power imbalance between multinational extractive industries and local communities. These industries, along with government entities, wield considerable political and economic influence, often at the expense of environmental and health concerns. This disproportionate power undermines local governance structures and marginalizes the voices of the communities most affected by environmental degradation. As noted by Saliu *et al.* [28], the lack of effective community participation in environmental monitoring and policy-making exacerbates the situation, leaving local populations with little ability to influence decisions affecting their health and environment. IEHAF advocates for a participatory governance model, where community-led initiatives like water monitoring and environmental litigation empower local actors to demand accountability from corporations and governments. By giving communities a direct voice in decision-making, IEHAF aims to create a more equitable governance system responsive to the needs of those most impacted by extractive activities.

15.1.3. Limitations of IEHAF

While IEHAF represents a significant step forward in integrating environmental health with social justice, it is not without limitations. One of the primary challenges is its status as a conceptual framework. While it offers a powerful tool for understanding the complex interactions between environmental degradation, public health, and socioeconomic inequities, its operationalization will require further research to fill critical gaps. For instance, more comprehensive data is needed on the long-term health outcomes of chronic exposure to multiple pollutants, which is difficult to obtain due to limited health surveillance systems in the Niger Delta. Additionally, the lack of coordinated environmental monitoring and data-sharing mechanisms hinders the development of comprehensive health profiles for affected populations. The longitudinal nature of both environmental

damage and health outcomes complicates immediate action, as the effects of pollution may not manifest as chronic diseases like cancer or neurological damage until years later. This challenge is further exacerbated by cultural inertia and entrenched interests in both government and corporate sectors, which may resist implementing frameworks that threaten existing economic structures. The political economy of the Niger Delta, characterized by extractive industries, government corruption, and community marginalization, complicates the framework's operationalization. Despite these challenges, IEHAF provides a solid foundation for future policy-making, health interventions, and advocacy, offering a pathway for systemic change that addresses longstanding inequities in the region.

16. Conclusion & Call to Action

16.1. Reaffirmation of IEHAF's Urgency

The environmental health crisis in the Niger Delta demands urgent action. This crisis is a public health emergency that undermines the health, productivity, and future prosperity of the region's population. Oil extraction, with its accompanying pollution, causes chronic diseases, exacerbates socioeconomic inequities, and hinders sustainable development. The impacts of extractive industries extend beyond environmental damage, affecting health systems, economic stability, and social fabric, creating a cycle of poverty and vulnerability. If not addressed, these issues will perpetuate environmental destruction, poor health, and intergenerational poverty. The Integrated Environmental-Health Accountability Framework (IEHAF) provides a critical tool to frame this crisis within the public health paradigm. By recognizing environmental degradation as a key component of public health, IEHAF offers a roadmap to address health inequities and calls for systemic reform and preventive measures. It is not just a conceptual framework; it is a practical tool to guide policy, health interventions, and regulatory reform. Without adopting this framework, the Niger Delta will continue to suffer from unchecked industrial pollution and health disparities. Immediate action is necessary to reverse these trends and improve the quality of life for affected communities.

16.2. Audience-Specific Calls to Action

- **For policymakers**: Now is the time to integrate IEHAF principles into environmental regulation. Policymakers must adopt IEHAF as a foundational framework for regulating extractive industries, ensuring that health outcomes are integrated into licensing agreements and operational standards. This would hold industries accountable for both environmental damage and its direct health impacts, encouraging the adoption of sustainable practices and mandating health and environmental monitoring for long-term remediation.
- **For health practitioners**: Systematic screening for pollution-related diseases is essential. Health professionals should focus on chronic conditions linked to pollutants like hydrocarbons and heavy metals, and establish longitudinal health registries to track cumulative health impacts. Community health edu-

cation programs should raise awareness of pollution risks and promote preventive measures.

- **For researchers**: The immediate priority is evaluating IEHAF's application in real-world contexts through pilot studies in affected communities. Researchers should focus on refining the framework, facilitating cross-disciplinary collaboration, and building local capacity for data collection and analysis, enabling communities to track their health and environmental conditions.
- **For civil society and community leaders**: Grassroots environmental monitoring and advocacy are critical for holding both governments and corporations accountable. Local communities should be empowered to lead monitoring efforts, utilizing tools like water quality assessments and environmental reporting platforms. They must also advocate for better healthcare access and alternative livelihoods in polluted areas, fostering a more just system of environmental governance.

IEHAF offers a foundation for transforming how we address environmental degradation in extractive economies. By framing environmental damage as a public health crisis, we can break the cycle of exploitation, pollution, and poverty that has plagued regions like the Niger Delta for decades. Through the integration of environmental health, governance reform, and community empowerment, we can create a future where public health and sustainable development go hand in hand. Immediate action, through policy adoption, public health interventions, research innovation, and community advocacy, will ensure a better future for the Niger Delta and other resource-dependent regions. Together, we can build a world where natural resource benefits are shared equitably and public health is safeguarded.

17. Recommendations

17.1. Short-Term Recommendations

1) Integrate Environmental Surveillance with Health Monitoring

Immediate action is needed to establish longitudinal environmental surveillance programs that track pollution levels (e.g., hydrocarbons, heavy metals) in real-time and link these with health data systems. This integration will enable the monitoring of how environmental pollutants directly affect public health, focusing on the most vulnerable communities in extractive regions. Policymakers and environmental agencies should prioritize this as part of public health infrastructure.

2) Incorporate Health Metrics in Environmental Impact Assessments (EIAs)

Governments should mandate that extractive companies include projected health outcomes related to pollution in their Environmental Impact Assessments (EIAs). This will ensure that public health risks are considered during project approval, promoting the inclusion of health burden metrics such as expected disease rates from exposure to pollutants, particularly in areas prone to resource extraction.

17.2. Mid-Term Recommendations

1) Establish Health Liabilities in Licensing Agreements

Future extractive industry licensing agreements should require companies to establish health compensation funds for affected communities. These funds should cover medical expenses for pollution-related diseases and provide for long-term health monitoring programs to track the cumulative effects of exposure to contaminants. Holding corporations accountable for their long-term health impacts will ensure that the true costs of pollution are reflected in their operations.

2) Strengthen Governance and Accountability Mechanisms

Governments must enhance regulatory oversight by implementing regular audits, ensuring community-led monitoring systems, and enforcing transparency measures. Policymakers should establish clear accountability frameworks where extractive companies must report on both environmental and health impacts regularly, with penalties for non-compliance. Active community participation in governance and decision-making should be a core principle to ensure that policies reflect the needs of affected populations.

17.3. Long-Term Recommendations

1) Empower Local Communities for Environmental Monitoring and Advocacy

In the long term, local communities must be equipped with the tools and capacity to actively monitor and advocate for environmental health. Governments should support grassroots initiatives focused on water quality monitoring and health assessments, allowing local populations to hold both governments and corporations accountable for their environmental and health responsibilities. Partnerships with civil society organizations will further amplify the voices of affected communities, advocating for stronger regulations that prioritize public health and sustainable development.

2) Integrate Environmental Health into Regional Development Planning

Long-term policy should embed environmental health considerations into regional planning, including infrastructure, education, and economic diversification programs. By aligning environmental protection with socioeconomic development, the region can reduce dependency on extractive industries, mitigate chronic health risks, and build resilient communities that are both environmentally sustainable and economically empowered.

18. Health Significance

The Integrated Environmental-Health Accountability Framework (IEHAF) bridges the gap between environmental degradation and public health inequities in regions affected by extractive industries. In the Niger Delta, industrial pollution from oil extraction leads to chronic health conditions, such as gastrointestinal diseases, respiratory issues, and neurological disorders. These health problems are directly linked to pollution from contaminated water, food chains, and air. However, the cumulative health impacts are often underestimated due to a lack of integrated mon-

itoring between environmental pollution and health outcomes. IEHAF emphasizes that water contamination, often overlooked as merely an environmental issue, is a central health determinant in affected communities. As pollution increases in both surface and groundwater, the health burden, measured in morbidity, mortality, and economic loss, grows exponentially. This creates a cycle where economic instability is exacerbated by the health costs of pollution, limiting the community's ability to address the root causes of degradation. Households are forced to spend large portions of their income on medical expenses, lose productivity due to illness, and suffer reduced income from agriculture and fisheries. By operationalizing IEHAF, we shift from reactive policies to a proactive, systems-level approach that treats pollution as a central health threat. This includes integrating health metrics into environmental assessments, strengthening health surveillance systems, and ensuring that extractive industries are financially accountable for the long-term health impacts of their operations. IEHAF also underscores the socioeconomic dimensions of the health crisis, highlighting that vulnerable populations, especially those dependent on fishing and farming, are disproportionately affected by contamination. These health vulnerabilities are compounded by economic marginalization. The framework calls for restoring health justice by holding corporations and governments accountable, ensuring that sustainable development takes precedence over short-term economic interests. In summary, IEHAF offers a comprehensive framework for linking environmental degradation to public health outcomes. By shifting focus from isolated health interventions to a broader environmental-health governance model, it aims to break the cycle of pollution-induced illness and socioeconomic disadvantage, offering hope for a healthier, more resilient future for the Niger Delta and similar regions. Thus, graphically it is represented as Figure 4.

Source: Author design, 2026.

Figure 4. Integrated environmental-health accountability framework (IEHAF): bridging environmental degradation and public health.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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