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GUT HEALTH CRISIS? INVESTIGATING THE IMPACT OF OIL SPILLAGE ON MICROBIOME-RELATED DISEASES IN THE NIGER DELTA

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Abstract

Oil spillage remains a pressing environmental and public health concern in the Niger Delta region of Nigeria. While its ecological consequences are well documented, its impact on human gut health remains underexplored. This study investigates the relationship between chronic crude oil exposure and gut microbiome-related diseases in affected communities. Utilizing a cross-sectional design, the study assessed 600 adult residents from both oil-contaminated and control communities through environmental sampling, clinical evaluation, and 16S rRNA gene-based microbiome profiling. Results revealed significantly elevated levels of petroleum hydrocarbons and heavy metals in soil and water in exposed communities. These contaminants correlated with reduced microbial diversity, depletion of beneficial bacteria (e.g., *Bifidobacteria*, *Lactobacillus*), and increased abundance of pathogenic taxa (e.g., *Enterobacteriaceae*). Clinically, residents of contaminated areas reported higher rates of recurrent diarrhea, abdominal pain, bloating, and antacid use. Regression analysis identified environmental contaminants and low microbial diversity as significant predictors of gastrointestinal symptoms. These findings underscore the gut microbiome as a critical but overlooked dimension of environmental health, emphasizing the need for microbiome-centered surveillance, policy reform, and community-based interventions in oil-polluted regions.

Keywords: Oil spillage, gut microbiome, dysbiosis, Niger Delta, petroleum hydrocarbons, gastrointestinal health, environmental pollution, microbiome-related diseases, toxicology, environmental justice.

Introduction

The gut microbiome—comprising trillions of microorganisms residing in the human gastrointestinal tract—plays a crucial role in maintaining immune function, metabolic balance, and overall health (Lloyd-Price et al., 2022). In recent years, research has increasingly linked environmental pollutants to disruptions in microbial communities, resulting in microbiome-related diseases such as inflammatory bowel disease (IBD), obesity, and metabolic syndrome (Zhou et al., 2023). The Niger Delta region of Nigeria, known for its vast crude oil reserves, has witnessed decades of extensive oil exploration and spillage, raising serious concerns about environmental degradation and its public health implications (Nwankwo & Ogagarue, 2023).

Oil spillage introduces hydrocarbons, heavy metals, and other toxicants into soil and water sources, contaminating food chains and drinking water supplies (Adewuyi et al., 2022). These environmental toxins can alter gut microbial diversity and composition, contributing to dysbiosis—an imbalance in the microbial community associated with various chronic diseases (Ogunbanwo et al., 2023). Communities in the Niger Delta, frequently exposed to these pollutants, may therefore face a silent epidemic of gut microbiome disturbances, yet this dimension of oil pollution remains underexplored.

Given the strategic significance of the region to Nigeria's economy and the vulnerability of its populations, this study seeks to investigate the link between oil spillage and the prevalence of microbiome-related diseases. It aims to highlight environmental pollution not only as an ecological crisis but also as a potential driver of non-communicable health burdens. Understanding this relationship is vital for informing policy, health interventions, and environmental justice efforts in affected communities.

Problem Statement

The Niger Delta region of Nigeria, rich in biodiversity and natural resources, has long suffered from extensive oil exploration and frequent oil spillages. These environmental disasters have not only contaminated water bodies and soil but are increasingly being linked to public health crises (Aigbedion & Iyayi, 2021). While much attention has been given to respiratory and dermatological conditions associated with petroleum pollution, emerging evidence suggests that environmental toxins, including hydrocarbons, significantly alter the human gut microbiome, potentially leading to a rise in microbiome-related diseases such as inflammatory bowel disease (IBD), irritable bowel syndrome (IBS), metabolic disorders, and even neurological dysfunctions (Martinez et al., 2022; Zhang et al., 2023).

Studies show that environmental pollutants can disrupt microbial diversity and lead to dysbiosis—an imbalance in the gut microbiota that impairs immune function and metabolic regulation (Wang et al., 2022). In the Niger Delta, oil-contaminated food and water are daily realities for many rural and urban communities, yet there is a significant gap in localized research connecting these exposures to microbiome-related health outcomes. Despite mounting global data highlighting the microbiome's sensitivity to environmental changes, there is limited empirical research assessing how chronic oil pollution in the Niger Delta impacts gut health at the community level (Obasi et al., 2023).

This research is, therefore, necessary to fill this gap by exploring whether prolonged exposure to oil spill-affected environments in the Niger Delta correlates with the prevalence of microbiome-related diseases. Understanding this relationship is critical not only for developing public health interventions and environmental remediation policies but also for establishing a foundation for microbiome-focused health surveillance in ecologically vulnerable regions.

Literature Review

1 . Gut Microbiota and Human Health

Definition and Role of Gut Microbiota: The human gut microbiota refers to the diverse community of microorganisms, including bacteria, archaea, viruses, and fungi, residing primarily in the colon. It contains over 1,000 species, playing a pivotal role in maintaining host health (Rinninella et al., 2019). These microorganisms contribute significantly to immune system modulation, nutrient metabolism, and protection against pathogenic invasion. They aid in digesting complex carbohydrates, synthesizing vitamins like B and K, and maintaining the integrity of the gut barrier, which prevents systemic inflammation (Zmora et al., 2019).

Microbiome-Related Diseases: Disruption of the normal gut microbial balance, known as dysbiosis, has been linked to various diseases. These include gastrointestinal conditions such as irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD), as well as systemic disorders like obesity, metabolic syndrome, and type 2 diabetes (Wang et al., 2022). Additionally, dysbiosis has been implicated in neurodevelopmental and neurodegenerative disorders, including autism spectrum disorder (ASD) and Parkinson's disease, through the gut-brain axis (Cryan et al., 2020).

Factors Influencing Gut Health: Several factors influence the composition and function of the gut microbiota. Diet is a primary modulator; high-fiber, plant-based diets support microbial diversity, while high-fat, high-sugar diets reduce beneficial species (Conlon & Bird, 2015). Antibiotics can cause significant disruptions by eliminating both harmful and beneficial bacteria. Genetics also affect individual microbiota profiles, while environmental exposures, including pollutants and urban living, can contribute to dysbiosis and inflammation (Zhu et al., 2021).

2. Environmental Pollution and Gut Health

Mechanisms of Impact

Environmental pollutants such as heavy metals (e.g., lead, cadmium) and hydrocarbons (e.g., polycyclic aromatic hydrocarbons – PAHs) significantly disrupt gut microbiota composition and function. These contaminants can reduce microbial diversity, increase pathogenic bacteria, and impair intestinal barrier function, contributing to systemic inflammation and metabolic disorders (Shin et al., 2023). Heavy metals, for example, have been shown to induce oxidative stress and inflammation, altering microbial metabolites that are essential for host immunity and metabolism (Wang et al., 2022).

Empirical Studies

Recent human and animal studies provide empirical support for the link between pollution and microbiome disruption. A study by Jin et al. (2022) found that individuals living in highly polluted urban areas exhibited reduced gut microbial diversity and altered ratios of Firmicutes to Bacteroidetes, associated with inflammation and metabolic syndrome. Similarly, research on children exposed to high levels of airborne particulate matter revealed microbiome dysbiosis and increased gut permeability, suggesting long-term health risks (Liu et al., 2023).

Oil Spillage as an Environmental Stressor

Crude oil contains toxic components such as benzene, toluene, ethylbenzene, xylene (BTEX), and PAHs, which are known to disrupt biological systems. These substances can reach human populations through contaminated water and food sources. Chronic exposure to oil pollutants has been associated with intestinal inflammation, oxidative stress, and alteration of the gut microbial ecosystem (Abiodun et al., 2023). The ingestion or dermal absorption of these toxins may lead to dysbiosis—a condition where beneficial gut bacteria are diminished, allowing harmful microbes to proliferate and potentially impairing nutrient absorption and immune function (Okoye et al., 2022).

3. Oil Spillage in the Niger Delta: An Overview

Historical Context: Oil exploration in the Niger Delta began in the 1950s, with Shell-BP drilling the first successful well in Oloibiri in 1956. Since then, the region has become a major hub for Nigeria's oil production, contributing significantly to the national economy. However, oil spills have been a persistent issue, with thousands of incidents reported over the decades due to pipeline corrosion, sabotage, operational failures, and poor maintenance practices (Obi & Morvaridi, 2024). Despite Nigeria being one of the top oil producers in Africa, the Niger Delta communities have faced disproportionate environmental degradation and poverty.

Environmental and Health Impacts: Numerous studies have documented the extensive ecological damage caused by oil spillage in the region, including the destruction of mangroves, soil infertility, and contamination of water sources (Nriagu et al., 2023). Prolonged exposure to hydrocarbons has been linked to respiratory issues, skin diseases, and increased cancer risks among residents (Ordinioha & Brisibe, 2022). Biodiversity loss, especially of aquatic life, has also significantly disrupted the livelihoods of local fishing and farming communities.

Regulatory and Monitoring Gaps: The Nigerian regulatory framework, while extensive on paper, suffers from poor enforcement and political interference. Agencies such as the National Oil Spill Detection and Response Agency (NOSDRA) often lack the resources and autonomy to hold oil companies accountable (Okonkwo et al., 2023). Cleanup efforts are typically delayed or inadequate, with affected communities receiving little or no compensation. Moreover, environmental monitoring is sporadic, lacking both transparency and community involvement, which further undermines trust and effectiveness (Etemire, 2024).

4. Evidence Linking Oil Spillage to Gut Microbiome Disruption

Animal Studies and Toxicological Evidence:
Numerous animal studies have demonstrated the detrimental impact of petroleum hydrocarbons on gut microbiota. Research involving mice and zebrafish has

shown that exposure to crude oil components, such as polycyclic aromatic hydrocarbons (PAHs), disrupts gut microbial diversity, leading to dysbiosis characterized by the overgrowth of opportunistic pathogens and reduction in beneficial bacteria (Jin et al., 2021; Liu et al., 2022). These disruptions often correlate with inflammatory responses, impaired intestinal barriers, and systemic toxicity, suggesting a strong link between oil contaminants and gastrointestinal health.

Human Studies in Contaminated Regions:
In oil-contaminated regions, such as the Niger Delta, residents often report increased incidences of gastrointestinal disorders, including diarrhea, abdominal pain, and ulcers (Ordinioha & Brisibe, 2013). Though microbiome-specific studies remain limited, emerging research indicates potential microbial imbalance among populations with chronic hydrocarbon exposure (Okoye et al., 2022). For instance, urinary biomarkers of PAH exposure in children from these regions have been associated with inflammation and suspected changes in gut function, implying underlying microbiome disturbances (Amadi et al., 2021).

Case Studies and Community Health Assessments:
Field reports by NGOs and public health researchers have documented recurring gastrointestinal illnesses in oil-producing communities of the Niger Delta. Assessments by groups like Environmental Rights Action and Health of Mother Earth Foundation (HOMEF) indicate that chronic exposure to oil spills and contaminated water sources has resulted in increased rates of enteric diseases and malnutrition, particularly among children (ERA/FoEN, 2020). Although direct gut microbiome analyses are scarce, these health outcomes align with known consequences of microbial dysbiosis and suggest the need for urgent microbial health investigations in exposed populations.

Methods

Study Design

This study employed a comparative cross-sectional design to investigate the potential association between exposure to crude oil contamination and the prevalence of microbiome-related diseases among residents in the Niger Delta region of Nigeria. The design incorporated environmental sampling, clinical assessments, and microbiome profiling to examine differences between exposed and unexposed populations.

Study Area

The study was conducted in three oil-producing communities with a known history of oil spillage: Bodo (Rivers State), Otuabagi (Bayelsa State), and Ugborodo (Delta State). These were compared with three control communities from nearby non-contaminated inland areas with similar socioeconomic characteristics but no known history of oil contamination.

Study Population

The study targeted adult residents aged 18–65 years, with at least five years of continuous residence in the selected communities. Inclusion criteria required participants to be apparently healthy or with stable chronic conditions unrelated to gastrointestinal disorders. Exclusion criteria included recent antibiotic use (within three months), known inflammatory bowel diseases, or active gastrointestinal infections.

Sampling Technique and Sample Size

A multistage sampling approach was utilized. In the first stage, communities were purposively selected based on environmental contamination reports and proximity to oil infrastructure. In the second stage, systematic random sampling was applied to household listings to recruit participants. A total of 600 participants (300 exposed, 300 unexposed) were enrolled, based on power calculations targeting a medium effect size, 80% power, and 95% confidence level.

Data Collection Instruments and Procedures

1. Environmental Sampling

Soil and water samples were collected from each community and analyzed for polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), and heavy metals using gas chromatography-mass spectrometry (GC-MS) and atomic absorption spectroscopy (AAS) to confirm levels of contamination.

2. Clinical and Survey Data

A structured questionnaire gathered data on:

- Demographic and socioeconomic status
- Dietary patterns
- Frequency of gastrointestinal symptoms (e.g., bloating, diarrhea, constipation)
- History of antibiotic or antacid use
- Perceived exposure to polluted water or soil

Clinical evaluations included BMI measurement, blood pressure, and stool consistency scoring using the Bristol Stool Chart.

3. Microbiome Sampling and Analysis

Stool samples were collected using sterile kits and preserved in DNA/RNA Shield for transport. Microbiome analysis was performed through 16S rRNA gene sequencing on the Illumina MiSeq platform. Bioinformatics analysis was carried out using QIIME2 and DADA2 pipelines to identify microbial composition, diversity indices (Shannon, Simpson), and presence of pro-inflammatory or pathogenic taxa.

Data Analysis

Quantitative data were analyzed using SPSS Version 26. Descriptive statistics summarized demographics and exposure profiles. Chi-square tests and independent t-tests were used to compare categorical and continuous variables between exposed and control groups. Multivariate logistic regression examined predictors of gastrointestinal symptoms and microbial dysbiosis, adjusting for confounders such as age, diet, and water source.

Microbiome data were analyzed using R (phyloseq, vegan packages). Beta diversity was assessed using Bray-Curtis dissimilarity, and differences between groups were tested using PERMANOVA. Differential abundance of specific microbial taxa was analyzed using LEfSe (Linear Discriminant Analysis Effect Size).

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Ethical Considerations

Ethical approval was obtained from the Nigerian Institute of Medical Research Ethics Committee (NIMR/IRB/03/2024/121). All participants provided written informed consent prior to sample and data collection. Confidentiality was maintained, and participants with abnormal findings were referred for medical evaluation and follow-up.

Results

1. Demographic and Socioeconomic Characteristics

A total of 600 participants were enrolled: 300 from oil-contaminated (exposed) communities and 300 from control (unexposed) communities. The mean age was 39.8 ± 12.5 years, with no statistically significant age or gender difference between groups. However, the exposed group had lower educational attainment and income levels.

Table 1: Demographic Characteristics of Respondents (n = 600)

Variable	Exposed (n = 300)	Control (n = 300)	*p*-value
Mean Age (years)	40.2 ± 12.3	39.4 ± 12.7	0.412
Female (%)	164 (54.7%)	158 (52.7%)	0.631
Primary Education Only	198 (66.0%)	127 (42.3%)	<0.001
Monthly Income < ₦30,000	216 (72.0%)	144 (48.0%)	<0.001

2. Environmental Contamination Levels

Water and soil samples from exposed communities showed significantly elevated levels of hydrocarbons and heavy metals, exceeding WHO and national safety limits.

Table 2: Mean Environmental Contaminant Levels in Exposed vs. Control Communities

Contaminant	Exposed Sites	Control Sites	WHO Limit	*p*-value
Total Petroleum Hydrocarbons (mg/L)	15.8 ± 3.2	1.9 ± 0.5	0.2	<0.001
Lead (Pb) in Water (mg/L)	0.17 ± 0.05	0.03 ± 0.01	0.01	<0.001
PAHs in Soil (mg/kg)	9.2 ± 1.6	1.2 ± 0.4	0.5	<0.001

3. Prevalence of Gastrointestinal and Microbiome-Related Symptoms

The prevalence of recurrent diarrhea, bloating, and abdominal pain was significantly higher in the exposed group. Additionally, more participants from contaminated areas reported irregular bowel habits and use of antacids.

Table 3: Gastrointestinal Symptom Profile by Exposure Group

Symptom	Exposed (%)	Control (%)	*p*-value
Recurrent Diarrhea	112 (37.3%)	46 (15.3%)	<0.001
Frequent Bloating	138 (46.0%)	64 (21.3%)	<0.001
Abdominal Pain	95 (31.7%)	38 (12.7%)	<0.001
Irregular Bowel Movement	128 (42.7%)	51 (17.0%)	<0.001
Use of Antacids (weekly)	104 (34.7%)	39 (13.0%)	<0.001

4. Gut Microbiome Composition and Diversity

The microbial diversity (Shannon and Simpson indices) was significantly lower in the exposed group, indicating dysbiosis. There was overrepresentation of Proteobacteria and pathogenic Enterobacteriaceae, and underrepresentation of beneficial Bifidobacteria and Lactobacillus species.

Table 4: Alpha Diversity and Key Taxa Abundance

Metric / Taxa	Exposed (Mean ± SD)	Control (Mean ± SD)	*p*-value
Shannon Diversity Index	2.31 ± 0.43	3.12 ± 0.51	<0.001
Simpson Index	0.72 ± 0.06	0.85 ± 0.04	<0.001
% Bifidobacteria	4.5 ± 1.2	9.8 ± 2.4	<0.001
% Enterobacteriaceae (path.)	18.6 ± 4.9	6.3 ± 2.1	<0.001

5. Regression Analysis of Predictors of Dysbiosis Symptoms

Multivariate logistic regression showed that exposure to contaminated water, PAH levels, and low microbial diversity were strong predictors of gastrointestinal symptoms ($p < 0.01$).

Table 5: Logistic Regression Predicting GI Symptoms (n = 600)

Predictor	Odds Ratio (OR)	95% CI	*p*-value
Water TPH > 5 mg/L	2.89	1.95–4.26	<0.001

Low Shannon Diversity (<2.5)	3.42	2.11–5.54	<0.001
PAHs in Soil > 5 mg/kg	2.26	1.48–3.43	<0.001
Age (per year increase)	1.01	0.99–1.04	0.210

Discussion

This study provides compelling evidence that chronic exposure to crude oil pollution in the Niger Delta is significantly associated with microbiome disruption and an increased burden of gastrointestinal (GI) symptoms among residents. The findings highlight a previously underexplored public health pathway: the environmental degradation of oil-producing communities translating into internal physiological imbalances, particularly gut dysbiosis.

Environmental Contaminants and Microbiome Health

Environmental analysis confirmed dangerously high levels of total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs), and heavy metals in exposed communities—substances known to interfere with microbial ecosystems. This contamination was significantly correlated with reduced gut microbial diversity and overrepresentation of potentially pathogenic taxa like Enterobacteriaceae, a finding consistent with studies linking PAHs and heavy metals to inflammatory and metabolic disorders (Zhang et al., 2018; Bailey et al., 2021).

Dysbiosis and Gastrointestinal Symptoms

A striking feature of the exposed group was the prevalence of GI symptoms such as bloating, recurrent diarrhea, and irregular bowel movements. These symptoms mirrored the microbial imbalances observed—specifically, depletion of beneficial microbes like Bifidobacteria and Lactobacillus, which are known to maintain intestinal integrity, modulate inflammation, and support digestion. Reduced Shannon and Simpson indices among exposed individuals confirm a loss of microbial diversity, which has been linked to heightened vulnerability to conditions such as irritable bowel syndrome (IBS), inflammatory bowel disease (IBD), and even mental health disturbances (Carding et al., 2015).

Vulnerabilities of Exposed Populations

The study also revealed that the exposed population was disproportionately affected by low income and educational attainment, which may amplify the health impacts of environmental exposure through poor diet, limited access to clean water, and lack of health literacy. These factors likely exacerbate microbiome disruption by weakening nutritional defenses and increasing reliance on contaminated resources for drinking, cooking, and sanitation.

Microbiome as an Emerging Health Frontier

These results reinforce the microbiome as a critical mediator of environmental toxicity, particularly in vulnerable communities. It also opens the door for microbiome-based biomarkers to serve as early warning systems in environmental health surveillance. The differential abundance of microbial species found here suggests that gut profiling may help monitor and mitigate long-term impacts of oil pollution before irreversible clinical conditions develop.

Strengths and Limitations

Strengths of the study include the integration of environmental testing, microbiome sequencing, and clinical assessment, providing a holistic picture of environmental health dynamics. Limitations include the cross-sectional design, which prevents causal inference, and the reliance on self-reported symptoms, which may be subject to recall bias. Additionally, the study did not explore longitudinal effects, which are crucial for understanding chronic disease trajectories.

Implications for Policy and Public Health

- Environmental remediation is urgently needed to reduce contaminant levels and prevent further microbial disruption in human and ecological systems.
- Health authorities should integrate gut health monitoring into environmental health assessments in oil-producing areas.
- The findings support policy shifts toward recognizing microbiome-related diseases as part of the noncommunicable disease (NCD) burden in Nigeria's Niger Delta.
- There is also a case for community-level probiotic and nutrition interventions to restore microbiome balance in at-risk populations.

Conclusion

This study has demonstrated a clear association between chronic exposure to oil pollution in the Niger Delta and adverse gut health outcomes, including altered microbiome composition and increased gastrointestinal symptoms. Residents of oil-impacted communities exhibited significantly lower microbial diversity, a greater abundance of pro-inflammatory taxa, and a higher prevalence of dysbiosis-related health complaints compared to their unexposed counterparts. These findings suggest that microbiome disruption is a critical, yet often overlooked, pathway through which environmental pollution affects human health.

The convergence of environmental degradation, microbial imbalance, and limited healthcare access further compounds the vulnerability of these populations, potentially contributing to the growing burden of noncommunicable diseases in the region. This study underscores the urgency of recognizing gut health as an environmental justice issue in oil-producing areas.

Recommendations

Based on the findings, the following key recommendations are proposed:

- Environmental Policy and Remediation
    - Immediate implementation of cleanup and remediation programs in oil-polluted communities, with periodic environmental monitoring of TPHs, PAHs, and heavy metals in water and soil.
- Public Health Surveillance
    - Integration of microbiome health screening into routine health assessments for residents of oil-impacted regions, with a focus on early detection of dysbiosis-related diseases.
- Community Education and Nutrition Programs
    - Launch community-based education campaigns to promote dietary practices that support gut health (e.g., high fiber intake, fermented foods).
    - Provide access to affordable probiotics and prebiotics as part of health interventions in affected areas.
- Research and Longitudinal Monitoring
    - Support for longitudinal studies to establish causal links between chronic oil exposure and long-term health outcomes, including metabolic, immune, and mental health effects mediated through the microbiome.
- Multisectoral Collaboration
    - Encourage collaboration between environmental agencies, public health institutions, local governments, and civil society to develop sustainable, community-informed responses to oil-related health crises.

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