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The Environmental Repercussions of Deep-Sea Mining in South-South Region of Nigeria: Investigating the Extents and Control Strategies

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Abstract: This study investigated the environmental repercussions of deep-sea mining and the strategies for mitigating its environmental impacts. In carrying out this study, a descriptive survey research design was adopted. The study was conducted in the South-South region of Nigeria. The target population consisted of all environmental scientists in the South-South region of Nigeria. A stratified sampling technique was employed to select 70 environmental scientists from each of the three selected states in the South-South region, namely Akwa Ibom State, Cross River State, and Rivers State, giving a sample size of 210 respondents. The instrument used for data collection was a structured questionnaire entitled "Environmental Repercussions of Deep-Sea Mining Questionnaire (ERDMQ)." The instrument was subjected to face and content validation by an expert in environment science to ensure its validity, appropriateness, and adequacy for the study. A reliability coefficient of 0.82 was obtained, indicating that the instrument was sufficiently reliable for data collection. The data collected for the study were analyzed using percentage analysis. The result of the findings revealed that habitat destruction (20.00%) recorded the highest percentage among the environmental repercussions of deep-sea mining, while slow recovery rate (9.05%) recorded the lowest percentage. The findings further revealed that Environmental Impact Assessment (EIA) and Monitoring (24.76%) recorded the highest percentage among the mitigating strategies, whereas Sustainable Mining Limits and Resource Control (15.72%) recorded the lowest percentage. The study concluded that although deep-sea mining provides access to valuable mineral resources, it poses significant environmental risks that require effective mitigation measures. One of the recommendations made was that governments and international regulatory agencies should strengthen environmental regulations, enforce comprehensive Environmental Impact Assessments before mining activities, and establish marine protected areas to safeguard fragile deep-sea ecosystems.

Keywords: Deep-Sea Mining, Environmental Repercussions, Control Strategies

1.0 Introduction

In the worldwide hunt for vital minerals like cobalt, nickel, and rare earth elements—which are necessary for contemporary technologies and renewable energy systems—deep-sea mining has become a quickly expanding frontier. This sector presents significant environmental problems even while it offers financial prospects and assistance for the shift to a low-carbon future. Once thought to be a remote and stable habitat, the deep ocean is now understood to be extremely sensitive and biologically

varied, home to organisms that science still doesn't fully understand. Disturbances caused by mining activities—such as seabed excavation, sediment plumes, and noise pollution—have the potential to disrupt these fragile ecosystems in ways that may be irreversible [1].

Deep-sea mining has an impact on ecological balance and wider ocean processes in addition to the direct mining areas. Mining operations can produce sediment plumes that can travel great distances, suffocating marine life and changing the structure of habitats. Furthermore, habitats that have taken millions of years to create are destroyed when mineral-rich nodules or crusts are removed, endangering biodiversity and ecosystem function. Scientists warn that the slow recovery rates in deep-sea environments mean that any damage could persist for centuries, making it difficult to assess long-term impacts fully [2]. These worries emphasize how critical it is to comprehend the scope and complexity of the environmental threats connected to this activity.

The development of efficient regulatory systems to govern deep-sea mining and reduce its environmental impact is receiving more attention worldwide due to these possible repercussions. Environmental rules and monitoring frameworks are being established by international organizations like the International Seabed Authority (ISA), although discussions about their suitability and implementation are still ongoing. Stricter environmental impact assessments, the creation of marine protected areas, and the implementation of preventative measures that put ecosystem preservation ahead of profit are some of the suggested tactics. Investigating both the extent of environmental impacts and the effectiveness of these control measures is essential for ensuring that deep-sea mining, if pursued, is conducted responsibly and sustainably [3].

1.1 Statement of the Problem

The increasing global demand for critical minerals such as cobalt, nickel, copper, and rare earth elements has intensified interest in deep-sea mining as an alternative source of these valuable resources. Although deep-sea mining has the potential to contribute significantly to economic development and the production of renewable energy technologies, it has also raised serious environmental concerns. Mining activities on the ocean floor can result in habitat destruction, biodiversity loss, sediment plume generation, chemical pollution, noise and light pollution, disruption of ecosystem functions, and extremely slow ecological recovery. Since deep-sea ecosystems are among the least explored and most fragile environments on Earth, any disturbance may have long-lasting or irreversible consequences.

Despite growing international concern, there remains insufficient empirical evidence on the major environmental repercussions of deep-sea mining and the most effective strategies for mitigating these impacts. Many existing studies have focused primarily on the economic potential of deep-sea mineral extraction, while comparatively less attention has been given to identifying the environmental challenges and appropriate control measures from the perspectives of environmental scientists. This knowledge gap makes it difficult for policymakers, environmental regulators, and other stakeholders to develop evidence-based policies and management strategies that will ensure sustainable exploitation of deep-sea mineral resources. It is against this background that this study seeks to investigate the environmental repercussions of deep-sea mining by identifying its major environmental impacts and examining the appropriate mitigation strategies that can be adopted to minimize ecological damage and promote sustainable deep-sea mining practices.

1.2 Objectives of the Study

The main objective of this study was to investigate the environmental repercussions of deep-sea mining and the control strategies for mitigating its impacts.

The specific objectives were to:

1. Identify the types of environmental repercussions associated with deep-sea mining.
2. Determine the mitigating strategies to environmental repercussion on deep-sea mining.

1.3 Research Questions

The following research questions guided the study:

1. What are the types of environmental repercussions associated with deep-sea mining?
2. What are the mitigating strategies to environmental repercussion on deep-sea mining?

1.4 Concept of Environmental Repercussions

Environmental repercussions refer to the range of negative or positive consequences that human activities or natural processes impose on the environment and, by extension, on human health, ecosystems, and socio-economic systems. In contemporary environmental discourse, it encompasses outcomes such as pollution, biodiversity loss, climate change, and resource depletion. These range from rising temperatures, higher sea levels, and more frequent extreme weather events. The result of these changes is felt throughout all aspects of the environment. As noted by Manisalidis. [4], environmental repercussions are often manifested through the degradation of air, water, and soil systems, leading to adverse health effects and ecological imbalance. These effects are crucial to discussions of environmental science and policy in the twenty-first century because they result from industrialization, urbanization, intensification of agriculture, and unsustainable consumption patterns.

Environmental consequences can also be thought of as interrelated processes that encompass cumulative and long-term effects in addition to immediate ecological harm. According to Meijaard. [5], activities such as deforestation and large-scale agricultural expansion generate far-reaching environmental consequences, including habitat destruction, species extinction, and disruption of ecosystem services, which ultimately threaten global sustainability. Similarly, Amobonye. [6] highlight how emerging pollutants like microplastics create persistent environmental repercussions by accumulating in ecosystems and affecting biological systems across trophic levels. These illustrations show that environmental consequences are intricate, multifaceted effects that change across time and space rather than discrete occurrences.

Environmental effects also have important social and economic ramifications, frequently exacerbating inequality and endangering human welfare. The timing of long-term, sustained economic development and demographic shifts are the two primary ways that health affects economic growth in less developed nations. Helm [7] explains that environmental changes—whether from global crises or economic activities—can influence policy decisions, intergenerational equity, and long-term environmental sustainability. Furthermore, more comprehensive evaluations of the effects on the environment reveal that repercussions like pollution, climate change, and ecosystem degradation can result in poorer quality of life, health problems, and even political instability. Consequently, the idea of environmental consequences emphasizes the pressing need for sustainable management techniques and offers a thorough framework for comprehending how human behavior interacts with natural systems.

1.5 Concept of Deep-sea Mining

Deep-sea mining refers to the extraction of mineral resources from the ocean floor, generally at depths beyond 200 meters where sunlight does not penetrate. These seabed minerals include polymetallic nodules, seafloor massive sulfides, and cobalt-rich ferromanganese crusts, which contain economically valuable metals such as nickel, cobalt, copper, manganese, and rare earth elements. These materials are increasingly important for modern technologies, including batteries, electronics, electric vehicles, and renewable energy systems.

Concerns over the depletion of high-grade terrestrial mineral reserves and the growing worldwide demand for key minerals led to the development of this idea. The ocean has gained attention as a possible substitute raw material supply as land-based mining becomes increasingly economically and environmentally problematic. Technological advancements in marine robotics, remotely operated vehicles (ROVs), and

deep-sea drilling systems have made exploration and potential extraction more feasible than in previous decades [8].

However, because of its possible effects on the ecology, deep-sea mining is still quite controversial. One of the least studied ecosystems on Earth, the deep ocean is home to rare, slow-growing species that are extremely vulnerable to disruption. Mining activities may generate sediment plumes, destroy habitats, and introduce noise and light pollution, which can disrupt marine biodiversity and ecological balance [9]. Scientists emphasize that recovery in deep-sea ecosystems may take decades or even centuries, if it occurs at all.

The International Seabed Authority (ISA), which supervises mineral-related operations in areas outside of state jurisdiction under the United Nations Convention on the Law of the Sea (UNCLOS), is principally responsible for international regulation of deep-sea mining. In order to strike a balance between resource extraction and environmental conservation, the ISA is still creating regulatory frameworks.

1.6 Environmental Repercussions of Deep-Sea Mining

Here are the major effects of deep-sea mining on environmental repercussions

Habitat Destruction: The devastation of bottom habitats is one of the most direct consequences of deep-sea mining. The physical habitat where organisms live is harmed by deep-sea mining equipment that scrapes or removes mineral deposits. Since many deep-sea animals rely on steady conditions, they might not survive or return if their home is altered. Because it takes decades or even centuries for these environments to heal, this results in long-term ecological imbalance.

Loss of Biodiversity: The quantity and diversity of marine organisms are diminished by mining-related environmental disruptions. Deep-sea environments are home to many uncommon or unique creatures. When mining disrupts their environment, it can lead to extinction or population decline. The stability of ecosystems is weakened by this loss of biodiversity, and marine life is less resilient to upcoming environmental changes.

Sediment Plume Effects: Sediment plumes are clouds of tiny particles produced by mining operations. Marine animals may be covered by these plumes as they travel through the water, obstructing their feeding mechanisms and reducing their chances of survival. Additionally, they can spread far from the mining site and impair water quality, resulting in extensive environmental harm that extends beyond the immediate vicinity.

Chemical Pollution: Hazardous materials like heavy metals can be released into the ocean when the bottom is disturbed. Marine life may absorb these toxins, which over time may build up in their bodies. Through the food chain, this process—known as bioaccumulation—may have an impact on human health as well as the health of marine creatures.

Noise and Light Pollution: Deep-sea habitats are calm and dark by nature. Artificial light and constant noise are introduced by mining, which may alter marine species' behavior. Species that rely on darkness and sound signals for feeding, communication, or reproduction may be negatively affected, leading to changes in their natural patterns [10].

Disruption of Ecosystem Functions: Deep-sea habitats are crucial for processes like carbon storage and nitrogen cycling. These natural processes may be hampered by mining-related environmental harm. For instance, disturbing the seafloor could lessen the ocean's capacity to store carbon, which could indirectly lead to climate change.

Slow Recovery Rate: A key effect of environmental damage in the deep sea is the very slow rate of recovery. Unlike shallow ecosystems, deep-sea organisms grow and reproduce slowly [11]. This means that once damage occurs, it may take a very long time for the ecosystem to return to its original state, if it recovers at all.

1.7 Mitigating Strategies of Environmental Repercussion on Deep-Sea Mining (Blessing Snr)

Although deep-sea mining presents significant threats to delicate and poorly known marine ecosystems, it also has the potential to produce essential minerals for contemporary technologies. As a result, scientists and environmental groups have put forth a number of mitigation techniques to lessen ecological harm while enhancing sustainability.

Environmental Impact Assessment (EIA) and Monitoring: Using thorough Environmental Impact Assessments (EIAs) before the start of any mining activity is a crucial tactic. EIA assists in identifying vulnerable areas, forecasting potential harm, and creating preventative strategies. Continuous monitoring during operations is also recommended to detect changes in biodiversity, sediment movement, and water quality in real time [12].

Establishment of Protected Areas (No-Mining Zones): In environmentally significant places, scientists advise establishing marine protected areas (MPAs) or no-mining zones. In order to ensure that representative marine habitats are maintained for future generations, these zones safeguard hotspots for biodiversity and let ecosystems continue unaltered.

Adaptive Management Approach: An adaptive management system uses flexible decision-making to modify mining operations in response to feedback from the environment. Operations may be altered or halted if monitoring reveals unanticipated damage. Because of the scientific uncertainties surrounding deep-ocean ecosystems, deep-sea governance frameworks strongly favor this strategy.

Rehabilitation and Restoration of Affected Areas: Rehabilitating degraded seabed areas following mining operations is a key mitigation approach. It is possible to promote natural restoration processes even though deep-sea habitats recover slowly. This includes leaving parts of the seabed untouched to allow recolonization by marine organisms and avoiding repeated disturbance in the same location. Over time, this can help improve ecosystem recovery and stability [13].

Sustainable Mining Limits and Resource Control: Another strategy is placing strict limits on the scale and intensity of mining activities. This means controlling how much material can be extracted and how large the mining area can be [14]. Ecosystems are given more time to recover, and environmental stress is decreased by controlling extraction levels. Additionally, this strategy promotes the prudent use of maritime resources rather than overexploitation.

1.8 Management and Control of Deep-Sea Mining

Deep-sea mining is the process of removing precious minerals from the ocean floor, frequently at depths greater than 2000 meters, such as polymetallic nodules, cobalt-rich crusts, and enormous sulfide deposits. Because of their significance in the production of batteries, modern electronics, and renewable energy technologies, these resources are becoming more and more sought after. However, because the deep ocean is one of the planet's least understood ecosystems, its exploitation raises serious environmental and governance issues. As a result, management and control of deep-sea mining have become central issues in international marine policy, particularly under the framework of the United Nations Convention on the Law of the Sea (UNCLOS) and the International Seabed Authority (ISA), which oversees mineral-related activities in areas beyond national jurisdiction [15].

The idea of sustainable development, which aims to strike a balance between financial gains and environmental preservation, serves as a major guide for deep-sea mining management. The ISA is in charge of creating rules that control seabed mineral exploration and possible exploitation. These include guidelines for baseline environmental studies, environmental impact assessments (EIAs), and the need for contractors to show that their actions will cause the least amount of harm to maritime ecosystems before being approved. However, despite these frameworks, critics argue that existing regulations are still incomplete, particularly because exploitation guidelines are not yet fully finalized, leaving uncertainties in enforcement and environmental

safeguards [16].

Environmental protection is a key aspect of controlling deep-sea mining activities. Scientific research has shown that mining operations can cause severe disturbances, including habitat destruction, sediment plumes that spread over large distances, and long-term impacts on deep-sea biodiversity [17]. Any harm could be irreversible on human timelines since deep-sea ecosystems recover very slowly. The precautionary principle—which states that a lack of complete scientific knowledge should not be used as an excuse to postpone preventative measures—is being emphasized more and more in management strategies to address these risks. Proposals for no-mining zones, marine protected areas, and adaptive management strategies that can be modified in response to new scientific information have resulted from this.

The ISA's licensing, oversight, and enforcement of compliance are crucial components of deep-sea mining control measures. Before operations start, contractors must present comprehensive plans for environmental management and exploration, which must be examined and authorized. In order to make sure that operations stay within authorized bounds, monitoring systems are designed to track environmental impacts in real time. However, one of the major challenges in control is the dependence on data provided by mining companies themselves, which raises concerns about transparency, accountability, and potential conflicts of interest [18].

Another crucial aspect of deep-sea mining management is international cooperation. Global governance is crucial since many seabed resources are located in international waters and are not within the jurisdiction of any one government. Stronger international accords, such as a temporary moratorium on deep-sea mining until more scientific information is available, are being called for by nations, scientists, and environmental organizations. This reflects growing concern that current governance systems may not be strong enough to prevent long-term ecological damage while still allowing resource extraction.

2.0 Materials and Methods

In carrying out this study, a descriptive survey research design was adopted. The study was conducted in the South-South region of Nigeria. The target population consisted of all environmental scientists in the South-South region of Nigeria. A stratified sampling technique was employed to select 70 environmental scientists from each of the three selected states in the South-South region, namely Akwa Ibom State, Cross River State, and Rivers State, giving a sample size of 210 respondents. The instrument used for data collection was a structured questionnaire entitled "*Environmental Repercussions of Deep-Sea Mining Questionnaire (ERDMQ)*." The instrument was subjected to face and content validation by an expert in environment science to ensure its validity, appropriateness, and adequacy for the study. A reliability coefficient of 0.82 was obtained, indicating that the instrument was sufficiently reliable for data collection. The data collected for the study were analyzed using percentage analysis.

3.0 Results and Discussions

Research Question 1:

The research question sought to identify the types of environmental repercussions of deep-sea mining. To answer the research question, percentage analysis was performed on the data (see Table 1).

Table 1. Percentage Analysis of the Types of Environmental Repercussions of Deep-Sea Mining

Types of Environmental Repercussions	Frequency	Percentage
Habitat Destruction	42	20.00**
Loss of Biodiversity	38	18.10
Sediment Plume Effects	34	16.19
Chemical Pollution	30	14.29
Noise and Light Pollution	25	11.90
Disruption of Ecosystem Functions	22	10.48
Slow Recovery Rate	19	9.05*
TOTAL	210	100%

****The highest percentage frequency**

*** The least percentage frequency**

Source: Field survey

The above Table 1 presents the percentage analysis of the types of environmental repercussions of deep-sea mining. From the result of the data analysis, it was observed that the highest percentage (20.00%) was recorded against “Habitat Destruction”, while the least percentage (9.05%) was recorded against “Slow Recovery Rate”. This finding agrees with the opinion of Jones, Amon and Chapman, who stated that deep-sea mining causes extensive destruction of benthic habitats, resulting in irreversible ecological damage and the loss of fragile marine ecosystems. Their study emphasized that habitat destruction remains one of the most significant environmental concerns associated with deep-sea mineral extraction. This finding also aligns with Levin, Wei and Dunn, who observed that mining disturbances significantly reduce marine biodiversity by destroying habitats that support numerous endemic species. They further noted that recovery of these ecosystems may take several decades or even centuries because of the slow biological processes in deep-sea environments.

Research Question 2:

The research question sought to identify the mitigating strategies to environmental repercussions of deep-sea mining. To answer the research question, percentage analysis was performed on the data (see Table 2).

Table 2. Percentage Analysis of the Mitigating Strategies to Environmental Repercussions of Deep-Sea Mining

Mitigating Strategies	Frequency	Percentage
Environmental Impact Assessment (EIA) and Monitoring	52	24.76**
Establishment of Protected Areas (No-Mining Zones)	46	21.90
Adaptive Management Approach	41	19.52
Rehabilitation and Restoration of Affected Areas	38	18.10
Sustainable Mining Limits and Resource Control	33	15.72
TOTAL	210	100%

****The highest percentage frequency**

*** The least percentage frequency**

Source: Field survey

The above Table 2 presents the percentage analysis of the mitigating strategies to environmental repercussions of deep-sea mining. From the result of the data analysis, it was observed that the highest percentage (24.76%) was recorded against “Environmental

Impact Assessment (EIA) and Monitoring”, while the least percentage (15.72%) was recorded against “Sustainable Mining Limits and Resource Control”. This finding agrees with the opinion of Wedding, Reiter, Smith and Gjerde, who maintained that comprehensive Environmental Impact Assessments, coupled with continuous environmental monitoring, are essential for minimizing biodiversity loss and preventing irreversible ecological damage during deep-sea mining operations. They emphasized that baseline environmental studies and long-term monitoring programmes enable regulators to make informed decisions regarding mining activities. This finding also agrees with Miller, Thompson and Johnston, who observed that establishing marine protected areas and implementing adaptive management strategies provide effective mechanisms for conserving sensitive marine ecosystems while allowing responsible resource utilization. According to the authors, adaptive management enables mining operators to modify operational practices based on environmental monitoring results, thereby reducing ecological risks and enhancing sustainability.

The findings presented in Table 1 indicate that habitat destruction was the most prominent environmental repercussion of deep-sea mining, accounting for 20.00% of the responses, followed by loss of biodiversity (18.10%) and sediment plume effects (16.19%). This result suggests that the physical disturbance of the seabed is perceived as the most immediate and significant environmental consequence of mining activities. The relatively high percentage recorded for biodiversity loss further demonstrates that habitat disturbance may have wider ecological implications because many deep-sea organisms depend on stable and specialized habitats for survival, feeding, and reproduction. Similarly, the substantial percentage recorded for sediment plume effects indicates that the consequences of mining may extend beyond the immediate mining site, as suspended sediments can spread through surrounding water and interfere with marine organisms and water quality. These findings are consistent with the views of Jones, Amon and Chapman, who identified habitat destruction as a major ecological risk associated with deep-sea mineral extraction. They also support the observation by Levin, Wei and Dunn that disturbance of deep-sea habitats can reduce biodiversity and that recovery may require several decades or even centuries.

The results in Table 2 further reveal that Environmental Impact Assessment (EIA) and continuous monitoring recorded the highest percentage among the identified mitigating strategies, with 24.76%, followed by the establishment of protected areas or no-mining zones at 21.90% and adaptive management at 19.52%. The prominence of EIA and monitoring suggests that respondents consider prevention, early identification, and continuous assessment of environmental damage to be essential components of responsible deep-sea mining. This is particularly important because deep-sea ecosystems are poorly understood and may respond to disturbance in ways that are difficult to predict. Continuous monitoring can therefore provide information on changes in biodiversity, sediment movement, and water quality, allowing environmental regulators and mining operators to respond to emerging impacts. The relatively high percentage for protected areas also emphasizes the importance of conserving ecologically sensitive locations where mining could result in severe or irreversible damage. These findings agree with the position of Wedding, Reiter, Smith and Gjerde that comprehensive EIAs and long-term monitoring programmes are necessary for informed decision-making and the prevention of irreversible ecological damage.

Overall, the results demonstrate that the environmental risks associated with deep-sea mining are closely connected to the effectiveness of the control strategies adopted before and during mining operations. Although sustainable mining limits and resource control recorded the lowest percentage among the mitigation strategies (15.72%), this does not necessarily indicate that the strategy is unimportant; rather, it suggests that respondents placed greater emphasis on assessment, monitoring, protected areas, and adaptive management as immediate mechanisms for reducing environmental risks. The findings therefore support an integrated management approach in which EIA and monitoring are combined with protected areas, adaptive management, rehabilitation, and

appropriate limits on extraction. Such an approach is particularly relevant because deep-sea ecosystems have slow recovery rates, meaning that environmental damage may persist for long periods. Consequently, effective management should prioritize precaution, continuous scientific assessment, and flexible regulatory responses so that mining activities can be modified or restricted when significant ecological harm is detected.

4.0 Conclusion

In conclusion, even though deep-sea mining offers a chance to satisfy the growing demand for essential minerals worldwide, its effects on the environment cannot be disregarded. Because deep-ocean habitats are delicate and mostly undiscovered, mining-related disruptions may result in long-term or perhaps irreversible harm to ecological balance and biodiversity. Therefore, it is crucial to approach this activity cautiously, guided by solid scientific knowledge, efficient regulation, and a dedication to sustainability. To ensure that the advantages of deep-sea mining do not come at an intolerable cost to the marine ecosystem and future generations, it will be essential to prioritize responsible practices and strong control strategies. Governments and international regulatory authorities should adopt a precautionary approach by restricting or delaying deep-sea mining activities until sufficient scientific evidence confirms that such operations will not cause irreversible environmental damage. Regulatory bodies and environmental agencies should strengthen environmental impact assessments by making them more comprehensive, transparent, and mandatory before the approval of any deep-sea mining project. Governments and conservation organizations should establish marine protected areas in ecologically sensitive regions of the deep ocean to safeguard vulnerable species and habitats from mining disturbances.

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