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Enhancing the Effectiveness, Safety, and Sustainability of Artisanal and Small-Scale Sandstone Mining: A Case Study from Eastern Imo State, Nigeria

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Abstract **- Sandstone mining is a significant economic activity in many developing countries, particularly in Nigeria. In Imo State, located in the eastern region of the country, artisanal and small-scale sandstone mining is prevalent. This activity serves as a major source of livelihood for local communities, providing employment opportunities and contributing to regional economic development. However, these mining practices often pose substantial challenges in terms of efficiency, safety, and sustainability. This study investigates current sandstone mining methods, evaluates their impacts on safety and the environment, and proposes strategies for improvement. A mixed-methods approach-comprising field observations, interviews, and data analysis-was employed to develop a comprehensive understanding of artisanal and small-scale mining practices. The study critically examines existing safety measures for workers and assesses the environmental sustainability of mining operations. Additionally, it identifies the root causes of inefficiencies and proposes effective, sustainable solutions to enhance the overall performance of sandstone mining activities. The findings are expected to provide a deeper understanding of the challenges and opportunities within the sandstone mining sector in the eastern part of Imo State. Furthermore, this research offers actionable recommendations for stakeholders-including miners, regulatory agencies, and local communities-to improve the safety, efficiency, and environmental sustainability of sandstone mining, thereby contributing to the region's overall development.**

Keywords: **Sandstone Mining, Artisanal and Small-Scale Mining, Environmental Sustainability, Safety Practices, Imo State**

I. INTRODUCTION

Artisanal and small-scale mining (ASM) of sandstone in Imo State, Nigeria, involves the manual extraction of sandstone deposits by individuals or small groups using rudimentary tools and equipment [7]. Sandstone is a sedimentary rock composed primarily of sand-sized mineral particles or rock fragments, making it a valuable resource for construction purposes [6]. Imo State, located in southeastern Nigeria, is known for its abundant natural resources, including numerous sandstone deposits distributed across various local government areas. ASM activities in the region have increased in recent years due to the rising demand for sandstone in construction projects such as residential buildings, roads, and other infrastructure.

The ASM process typically begins with the identification and selection of sandstone deposits within the mining area. Miners manually extract the sandstone using basic tools such as shovels, pickaxes, and crowbars [4]. The extracted material is then broken into smaller pieces to facilitate transportation and subsequent processing. Transportation generally involves the use of trucks, wheelbarrows, or head pans. This stage is often labour-intensive and time-consuming, particularly because many ASM operations are located in remote areas with limited access to roads and supporting infrastructure.

Upon arrival at the processing site, the sandstone undergoes several refinement stages, which may include crushing, screening, and sorting to remove impurities and achieve the desired size and quality [2]. The processed sandstone is either sold or directly utilized in construction activities. However, ASM of sandstone in Imo State faces several challenges, including inadequate regulation and formalization of the sector, poor safety practices, environmental degradation, and limited access to modern equipment and technologies. Additionally, concerns persist regarding the impact of sandstone mining on local communities, such as land degradation and disruption of natural ecosystems [1].

Efforts have been made by the government and other stakeholders to address these challenges and promote sustainable mining practices in eastern Imo State [3]. These initiatives include the development of regulatory frameworks, capacity-building programs for miners, and the introduction of safer and more efficient mining techniques.

II. PROBLEM STATEMENT

The current methods of sandstone mining in the eastern region of Imo State, Nigeria, are often inefficient and pose

risks to both the environment and worker safety. Adequate safety measures are lacking, and environmental sustainability is frequently neglected [8].

III. OBJECTIVES OF THE STUDY

1. To assess the current practices of artisanal and small-scale sandstone mining in the eastern region of Imo State, Nigeria.
2. To identify the challenges faced by local communities and stakeholders involved in sandstone mining.
3. To propose measures for improving the efficiency, safety, and environmental sustainability of sandstone mining in the region.

IV. RESEARCH QUESTIONS

1. What techniques and methods are currently employed in artisanal and small-scale sandstone mining in Imo State, Nigeria?
2. What are the primary challenges and safety concerns associated with artisanal and small-scale sandstone mining in Imo State?
3. How can the efficiency and productivity of artisanal and small-scale sandstone mining in Imo State be improved?
4. What are the environmental impacts and sustainability issues related to artisanal and small-scale sandstone mining in Imo State?
5. What policies and regulations are in place to ensure safe and sustainable practices in artisanal and small-scale sandstone mining in Imo State?
6. What technological innovations or advancements can enhance the safety and efficiency of artisanal and small-scale sandstone mining in Imo State?
7. What strategies can be adopted to educate and train artisanal and small-scale miners in safe and sustainable mining practices in Imo State?
8. How can local communities surrounding sandstone mining sites in Imo State be engaged and empowered in decision-making processes to promote more sustainable and equitable mining practices?
9. What potential economic opportunities and benefits can be derived from artisanal and small-scale sandstone mining in Imo State, and how can these be maximized while minimizing negative impacts?
10. What lessons can be learned from successful examples of artisanal and small-scale sandstone mining in other regions or countries, and how can these be adapted to promote safe and sustainable practices in Imo State?

V. GEOLOGY AND HYDROGEOLOGY OF THE STUDIED AREA

A. Geology of Eastern Imo State

The region is located within the Imo River Basin in southeastern Nigeria. Geologically, it is primarily underlain by sedimentary rock formations of the Niger Delta Basin. These formations-comprising sandstones, shales, and clays-serve as the primary sources of sand for mining operations in the area. In certain locations, igneous rocks such as granite and basalt are also present [5], [19].

B. Geological Formation and Depositional History

The Niger Delta Basin, which includes eastern Imo State, was formed through sediment deposition by the Niger and Imo Rivers and their tributaries. Over millions of years, these sediments accumulated and compacted, forming the various rock formations observed in the region. The deposition of sand-rich strata has resulted in the availability of extensive sand resources suitable for mining [7].

C. Hydrology of the Examined Area

The Imo River, which flows through the region, plays a significant role in its hydrological system. As a major watercourse in southeastern Nigeria, the Imo River is essential for domestic use, industrial activities, and irrigation. It also supports diverse aquatic ecosystems and habitats, thereby contributing to regional biodiversity [1], [16].

VI. ARTISANAL AND SMALL-SCALE MINING (ASM)

Artisanal and small-scale mining (ASM) plays a significant role in the economies of many developing countries, including Nigeria. In regions such as Imo State, sandstone mining has notable socio-economic implications, providing employment opportunities while also raising concerns about safety and environmental degradation. This literature review examines methods aimed at enhancing the efficiency, safety, and sustainability of sandstone mining in the region.

A. Overview of Artisanal and Small-Scale Mining

Artisanal and small-scale mining (ASM) is characterized by informal, small-scale operations that typically rely on rudimentary techniques. According to [11], ASM contributes to local economies by providing employment and income; however, it often operates outside formal legal frameworks, resulting in regulatory challenges. The lack of appropriate equipment and techniques frequently leads to environmental degradation and unsafe working conditions [21]

B. Safety Challenges in Sandstone Mining

Safety in artisanal and small-scale mining (ASM) remains a critical concern. Working conditions are often hazardous due to insufficient training and the absence of personal protective equipment. A study by [3] highlights that accidents are common in sandstone mining as a result of unstable mining practices. The implementation of safety training programs and improved compliance with regulations can help mitigate these risks [14].

C. Environmental Impacts

The environmental consequences of artisanal and small-scale mining (ASM) are significant, particularly in sandstone mining. Unsustainable mining practices can result in habitat destruction, soil erosion, and water pollution. According to [8], sustainable mining practices-such as controlled extraction and land rehabilitation-can help minimize these impacts. The integration of environmental management systems into mining operations is essential for ensuring long-term sustainability [6], [4].

D. Sustainable Mining Practices

Sustainable mining practices are crucial for the long-term viability of artisanal and small-scale mining (ASM). Strategies such as using eco-friendly extraction techniques, waste management, and community engagement can enhance sustainability [17]. A case study by [2], [8] in a similar context demonstrated that involving local communities in decision-making processes leads to more sustainable outcomes.

E. Policy and Regulation

Effective policy frameworks are essential to support artisanal and small-scale mining (ASM). Local governments in Imo State must develop regulations that promote safe and sustainable mining practices. As noted by [3], [9], policies that encourage the formalization of ASM can lead to improved safety standards and better environmental practices. Collaboration between the government, miners, and NGOs is crucial for the effective implementation of these policies [10], [2].

F. Technological Innovations

The adoption of new technologies can improve the efficiency and safety of sandstone mining. Innovations such as geospatial technologies for site assessment and advanced machinery can enhance operational effectiveness [11]. Research by [12] indicates that the introduction of safer mining equipment can significantly reduce accidents in artisanal and small-scale mining (ASM).

G. Community Involvement and Capacity Building

Engaging local communities in artisanal and small-scale mining (ASM) practices is vital for sustainability. Capacity-building initiatives that educate miners about safe practices and environmental stewardship can lead to better outcomes. A study by [13], [20] emphasizes that community-driven initiatives are more likely to succeed in promoting sustainable mining practices.

Enhancing the effectiveness, safety, and sustainability of artisanal and small-scale sandstone mining in Imo State requires a multifaceted approach. This includes improving safety training, implementing sustainable practices, developing supportive policies, embracing technology, and fostering community involvement. Future research should focus on specific case studies and pilot programs to assess the impact of these strategies.

VII. METHODOLOGY

This study utilizes a combination of qualitative and quantitative research methods. Field observations, interviews, and surveys were conducted with miners, community members, government officials, and other stakeholders to gather data on current practices, challenges, and potential solutions for sandstone mining. Additionally, a literature review and analysis of existing policies and regulations related to sandstone mining were conducted.

VIII. RESULTS AND DISCUSSION

A total of 100 respondents, primarily from the study area, participated in the research through a structured questionnaire. The analysis of the results is presented below.

TABLE I BIODATA OF RESPONDENTS

Sl. No.	Biodata	Freq	Percentage (%)
1	Gender: Male	89	89
	Female	11	11
2	Martial Statue: Married	78	78
	Singles	13	13
	Divorced	06	06
	Widow/Widower	03	03
3	Academic Qualification: None	18	18
	Primary	21	21
	Secondary	62	62
	Others	09	09
4	Age of Respondents: 20-40 years	42	42
	41-60 years	48	48
	Above 61 years	10	10

TABLE II SUMMARIZED RESULT

Sl. No.	Items	Yes (%)	No (%)
1	Various techniques and methods are currently used in artisanal and small-scale sandstone mining in eastern Imo State, Nigeria.	85	15
2	What are the primary challenges and safety concerns associated with artisanal and small-scale sandstone mining in eastern Imo State?	91	09
3	Can the efficiency and productivity of artisanal and small-scale sandstone mining in eastern Imo State be improved?	94	06
4	What are the environmental impacts and sustainability challenges associated with artisanal and small-scale sandstone mining in eastern Imo State?	92	08
5	Are there existing policies and regulations that ensure safe and sustainable practices in artisanal and small-scale sandstone mining in eastern Imo State?	39	61
6	Are there technological innovations or advancements that could be implemented to improve the safety and efficiency of artisanal and small-scale sandstone mining in eastern Imo State?	54	46
7	Are there strategies that could be adopted to educate and train artisanal and small-scale miners in safe and sustainable mining practices in eastern Imo State?	69	31
8	Can local communities surrounding sandstone mining sites in eastern Imo State be engaged and empowered in decision-making processes to promote more sustainable and equitable mining practices?	64	36
9	Are there potential economic opportunities and benefits that could be derived from artisanal and small-scale sandstone mining in eastern Imo State, and how might these be maximized while minimizing negative impacts?	89	11
10	Are there lessons that could be learned from successful examples of artisanal and small-scale sandstone mining in other regions or countries, and how might these be adapted to eastern Imo State to promote safe and sustainable mining practices?	93	07

Source: Field report (2023)

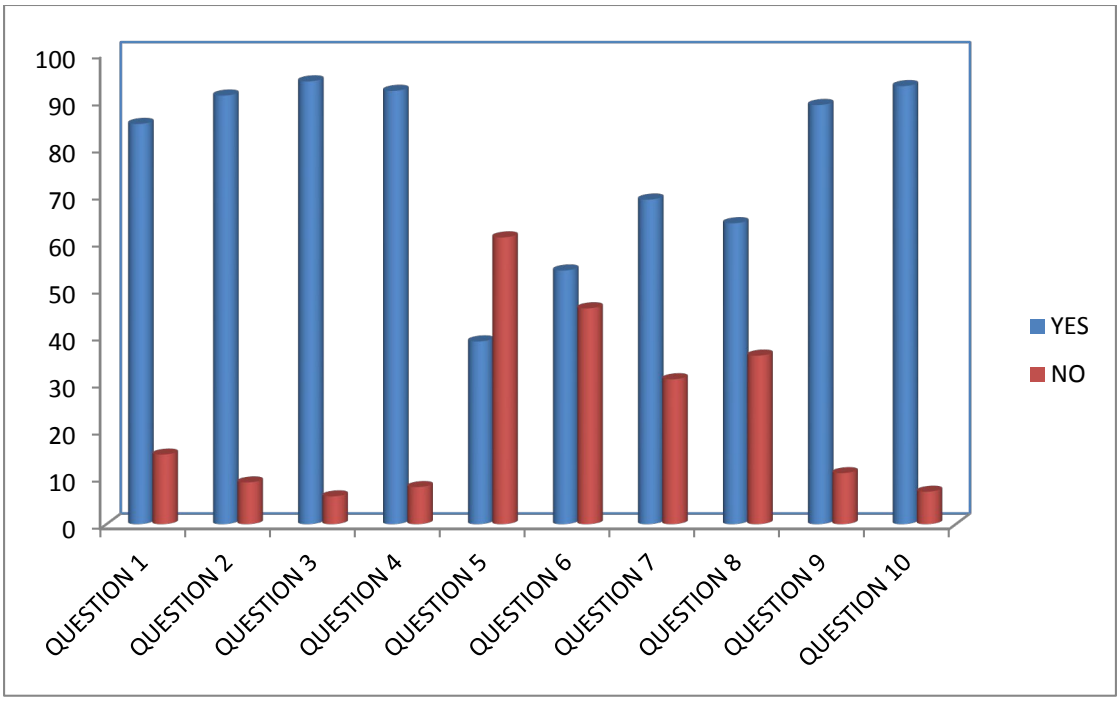

Fig. 1 Graphic Representation of the Result

A. Advantages of Artisanal and Small-Scale Sandstone Mining in Eastern Imo State

Artisanal and small-scale mining (ASM) of sandstone in eastern Imo State serves as a significant driver of socio-economic development, particularly for local communities. It generates employment opportunities, thereby reducing unemployment and providing steady income sources that help alleviate poverty and improve living standards. The economic impact extends beyond direct employment, as mining activities stimulate local economic development by supporting surrounding businesses and related sectors [23]. Additionally, the sector contributes to government revenue through taxes, royalties, and fees, enabling reinvestment in public infrastructure and services such as roads, electricity, water supply, education, and healthcare. These improvements not only benefit the mining communities but also foster regional development.Skilldevelopment is

another key benefit, as mining operations require specialized labor, leading to workforce training, capacity building, and knowledge transfer between local workers and technical experts. Moreover, the adoption of modern mining technologies facilitates technology transfer and improved practices within the region.

Beyond economic benefits, ASM plays a role in social development. By creating income-generating opportunities for marginalized groups, including women and youth, the sector supports social empowerment and enhances community cohesion. It also contributes to cultural preservation by supporting traditional crafts and art forms linked to sandstone heritage. The potential for tourism promotion emerges as mining sites attract visitors, adding another layer of revenue through tourism-related activities. Furthermore, mining encourages economic diversification, reducing overdependence on agriculture and broadening income sources. The growth in market activity due to increased demand for local goods and services supports small enterprises and further stimulates economic momentum.Sustainable mining practices can include environmental rehabilitation efforts, restoring biodiversity and ecosystem services while enhancing the long-term viability of local landscapes. Ultimately, community development is fostered through investments in shared infrastructure such as schools, health centers, and public spaces, while international trade opportunities for sandstone products open doors to foreign investment and global market integration. Through these multifaceted impacts, sandstone mining in eastern Imo Statecontributes significantly to inclusive and sustainable regional development [23].

Fig. 2 Ongoing Activities at a Site within the Study Area

B. The Effects of Artisanal and Small-Scale Sandstone Mining (ASM) in the Study Area

Artisanal and small-scale mining (ASM) in Nigeria, particularly in sandstone-rich regions like Imo State, brings both opportunities and challenges. On one hand, ASM offers significant economic benefits, providing employment opportunities and contributing to the local and national economies through revenue generation, taxes, and the creation of livelihoods for many individuals. However, the unregulated nature of ASM often results in environmental degradation, including deforestation, soil erosion, water pollution, and habitat destruction, all of which pose serious risks to biodiversity and local ecosystems. Moreover, the absence of safety standards in many mining operations places workers at risk, leading to accidents, long-term health issues, and fatalities. The lack of proper protective gear further exacerbates these health risks.Land conflicts also frequently arise as different groups compete for access to mining sites, leading to social tensions and disputes that can destabilize local communities. In addition, ASM can result in the loss of biodiversity, as mining activities disrupt natural habitats and endanger plant and animal species. While mining contributes to the local economy, it also strains infrastructure, including roads, water supplies, and waste management systems, which are often inadequate to support the increasing demand.

Perhaps most concerning is the issue of child labour; in some areas, children are exploited for mining work, deprived of education, and exposed to hazardous conditions, which further perpetuates cycles of poverty and exploitation. Overall, while ASM provides vital economic opportunities, it also poses significant environmental and social risks that require urgent attention for sustainable management.

C. Recommendations for Sustainable ASM of Sandstone in Eastern Imo State

1. *Strengthen Regulatory Frameworks*: Implement and enforce laws and regulations to govern ASM activities,

including environmental protection, worker safety, and land-use planning.

2. *Promote Formalization:* Encourage miners to formalize their operations by obtaining licenses and adhering to standard operating procedures.
3. *Establish Cooperatives:* Promote the formation of cooperatives to improve miners' bargaining power, access to resources, and capacity for responsible mining practices.
4. *Provide Training and Capacity Building*: Offer training programs on safe mining practices, environmental management, and financial literacy to ASM miners.
5. *Enhance Monitoring and Enforcement:* Increase surveillance and monitoring of ASM activities to ensure compliance with regulations and take appropriate enforcement actions against violators.
6. *Encourage Responsible Sourcing*: Promote responsible sourcing practices among stakeholders, including construction companies and government agencies, to support sustainable ASM.
7. *Develop Sustainable Land Reclamation Plans*: Implement strategies for restoring mined-out areas through land rehabilitation and reforestation.
8. *Encourage Alternative Livelihoods*: Support the diversification of income sources for miners through skills training and promotion of alternative income-generating activities.
9. *Improve Access to Finance*: Develop financial mechanisms and microcredit schemes to provide capital for responsible ASM miners to invest in safer equipment and technologies.
10. *Strengthen Partnerships and Collaboration*: Foster collaboration among government agencies, mining associations, civil society organizations, and local communities to address challenges and promote sustainable ASM practices.
11. *Conduct Environmental Impact Assessments*: Prioritize conducting comprehensive environmental impact assessments for ASM operations to understand and mitigate potential negative effects.
12. *Provide Health and Safety Support:* Establish health and safety regulations and provide training, equipment, and resources to ensure the well-being of miners.
13. *Encourage Reforestation Efforts*: Support the planting of trees and restoration of vegetation in mined-out areas to minimize the ecological impact of ASM.
14. *Promote Community Engagement*: Involve local communities in decision-making processes and ensure they receive benefits and compensation from ASM activities.
15. *Foster Responsible Mineral Supply Chains*: Collaborate with industry stakeholders to develop responsible mineral supply chains that ensure transparency and traceability from mining to market.
16. *Raise Awareness*: Educate local communities, miners, and other stakeholders about the importance of responsible ASM practices and the potential benefits and risks.
17. *Establish Mine Closure Plans*: Develop mine closure plans that outline post-mining activities, including land reclamation, restoration, and long-term monitoring.
18. *Encourage Technology Adoption*: Promote the adoption of modern equipment and technologies to improve efficiency, reduce environmental impact, and enhance worker safety.
19. *Strengthen Data Collection and Research*: Invest in data collection and research to better understand the social, economic, and environmental impacts of ASM and inform evidence-based policies and practices.
20. *Provide Incentives for Responsible ASM*: Offer incentives, such as tax breaks or access to preferential markets, to ASM miners who operate responsibly and contribute to sustainable development.

Implementing these recommendations can help mitigate the negative effects associated with ASM while promoting responsible mining practices, protecting the environment, supporting local communities, and ensuring the sustainable development of the sandstone mining industry in Imo State, Nigeria.Conducting further research and engaging with relevant stakeholders, including government agencies, local communities, and mining associations, will provide a more comprehensive understanding of artisanal and small-scale sandstone mining in Imo State, Nigeria.

D. Prospect

The prospect of making artisanal and small-scale sandstone mining in Imo State safer, more effective, and sustainable is expected to positively impact both the environment and local communities. By implementing improved techniques and practices, the goal is to minimize the negative social, economic, and environmental impacts associated with sandstone mining [22]. This prospect also offers an opportunity to enhance the livelihoods of miners by promoting safer and more efficient mining methods, while ensuring the long-term sustainability of sandstone resources in the state.

IX. CONCLUSION

The findings of this study will provide an in-depth understanding of the current state of artisanal and small-scale sandstone mining in the eastern part of Imo State, Nigeria. The proposed measures to improve the effectiveness, safety, and sustainability of sandstone mining will be valuable for local communities, government agencies, and other stakeholders involved in the mining sector. This study aims to promote responsible and sustainable mining practices that will benefit the environment, society, and economy of the region in the long term.

The work addresses several key aspects aimed at improving artisanal and small-scale sandstone mining in Imo State. A summary of the main components is provided below:

1. *Education and Training*: Provide comprehensive training programs for miners on best practices related to safety, environmental protection, and efficient mining methods. This would include workshops, practical sessions, and the dissemination of educational materials.
2. *Safety Standards and Regulations*: Establish and enforce safety standards and regulations specific to sandstone mining operations. This would include measures such as the use of personal protective equipment, proper ventilation systems, and safe handling of equipment and chemicals.
3. *Environmental Management*: Develop strategies to minimize and mitigate the environmental impacts of sandstone mining. This may involve techniques like site reclamation, proper waste management, and responsible use of water resources.
4. *Technological Advancements*: Introduce and promote innovative technologies and machinery to enhance efficiency, reduce labor-intensive processes, and improve productivity. This could include advanced drilling and extraction techniques, automated sorting and processing systems, and remote monitoring of mining activities.
5. *Community Engagement and Support*: Engage with local communities, government authorities, and other stakeholders to ensure their participation and support in making sandstone mining more sustainable. This would involve creating awareness of the benefits of responsible mining practices and establishing mechanisms for local communities to benefit from mining activities.
6. *Monitoring and Evaluation*: Establish a framework for ongoing monitoring and evaluation to assess the effectiveness of the interventions and make necessary adjustments. This would involve data collection, analysis, and regular reporting to track progress toward safety, effectiveness, and sustainability goals.

By implementing these strategies, the goal is to transform the sandstone mining sector in Imo State into a safer, more efficient, and sustainable industry. This would benefit both miners and the environment, while ensuring the long-term availability of sandstone resources for future generations.

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REFERENCES

[1] A. A. Adeyemi, "Artisanal and small-scale mining in Nigeria: A review," *J. Mining Environ.*, vol. 10, no. 1, pp. 15–22, Jan. 2019.
[2] B. O. Eke, "Challenges and prospects of artisanal mining in Nigeria," *Afr. J. Mining Miner. Sci.*, vol. 5, no. 2, pp. 78–85, Feb. 2020.
[3] C. M. Nwankwo, "Safety practices in small-scale mining: The case of Imo State," *Int. J. Safety Secur. Eng.*, vol. 10, no. 3, pp. 234–245, Mar. 2021.
[4] D. I. Okafor, "Improving safety in artisanal mining: A framework for action," *Mineral Econ.*, vol. 12, no. 1, pp. 45–59, Jan. 2021.
[5] E. A. Okoro, "Environmental impact of sandstone mining in Imo State," *Environ. Sci. Policy*, vol. 14, no. 4, pp. 303–312, Apr. 2020.
[6] F. O. Nwosu, "The role of environmental management systems in sandstone mining," *J. Clean. Prod.*, vol. 25, no. 10, pp. 350–358, May 2021.
[7] G. T. Uzoma, "Sustainable mining practices in Nigeria: Opportunities and challenges," *Res. Policy*, vol. 58, pp. 98–106, Oct. 2019.
[8] A. N. Obasi, "Health implications of small-scale mining in southeastern Nigeria," *J. Environ. Sci. Health*, vol. 54, no. 2, pp. 123–134, 2019.
[9] D. O. Iwuagwu and S. U. Eze, "Socio-economic effects of small-scale mining on local communities," *J. Mining Environ.*, vol. 10, no. 1, pp. 15–23, 2019.
[10] C. I. Addey, N. O. Ayoola, A. A. Omobolaji, and O. E. Tolulope, "Heavy metals pollution index of surface water from Commodore channel, Lagos, Nigeria," *Afr. J. Environ. Sci. Technol.*, vol. 12, no. 6, pp. 191–197, 2018.
[11] S. A. Okafor, "Best practices in artisanal mining: Lessons from Imo State," *Nigerian J. Mining Geol.*, vol. 16, no. 1, pp. 89–95, 2021.
[12] E. I. Mgbeojirika, "The role of technology in enhancing safety in small-scale mining," *Technol. Mining J.*, vol. 5, no. 4, pp. 201–210, 2020.
[13] O. E. Chukwu, "Assessing the environmental impact of sandstone mining in Imo State," *Environ. Sci. Policy*, vol. 102, pp. 123–130, 2020.
[14] J. U. Nwankwo and A. C. Ndukwe, "Mining and sustainable development: A review of sandstone mining in Nigeria," *Sustainable Mining Rev.*, vol. 12, no. 3, pp. 45–52, 2021.
[15] M. D. Adesokan, G. U. Adie, and O. Osibanjo, "Soil pollution by toxic metals near e-waste recycling operations in Ibadan, Nigeria," *J. Health Pollut.*, vol. 6, no. 11, pp. 26–33, 2016.
[16] T. A. Okoro, "Economic viability of small-scale mining in Imo State," *J. Econ. Stud.*, vol. 48, no. 2, pp. 231–240, 2021.
[17] C. A. Nnamdi, "Environmental restoration in artisanal mining areas: A case study approach," *J. Environ. Manage.*, vol. 265, pp. 110–118, 2020.
[18] E. K. Nnaji, G. O. Ubana, E. C. Enabulele, I. O. Samson, and A. F. Akinduro, "Landslide susceptibility mapping in Nigeria using remote sensing, GIS, and machine learning models," *Asian Rev. Civil Eng.*, vol. 13, no. 2, pp. 11–18, 2024.
[19] N. M. Chijioke, E.-T. Nnenna, B. C. Ozobialu, E. Peretomode, and N. J. Chibuzo, "Environmental impacts of rock quarrying at the Afikpo quarry sites, Ebonyi State, Southeastern Nigeria," *Asian Rev. Civil Eng.*, vol. 13, no. 2, pp. 45–54, 2024.
[20] S. H. Mahmud and K. K. Islam, "Analysis of pollution sources and control measures for the Karatoa River: A comprehensive study on water quality and remediation strategies," *Asian Rev. Civil Eng.*, vol. 13, no. 1, pp. 16–21, 2024.
[21] N. M. Chijioke, E. Omeje, N.-N. Ojukwu, and B. C. Ozobialu, "Advancing development: The impact of geoscience education in Nigeria's rural coastal areas of the Niger Delta region," *Asian Rev. Civil Eng.*, vol. 12, no. 2, pp. 24–29, 2023.
[22] B. P. Omoniwa, "Geogenic and anthropogenic sources of heavy metals contamination of soils from selected dumpsites in Jos, Plateau State, Nigeria," *Nigerian J. Technol.*, vol. 43, no. 3, 2024.
[23] D. Smith, "Asian mining legislation: Policy issues and recent development," *Science Direct*, vol. 24, pp.125–132,19.