ASSESSMENT OF THE ENVIRONMENTAL IMPACTS OF QUARRYING AND RECLAMATION POSSIBILITIES IN SOUTHEASTERN NIGERIA

LWS 548 Major Project Proposal

By

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June 2023.

DEDICATION

This project is dedicated to the glory of God. His unending grace has guided me through every step of this journey. I extend my heartfelt tribute to my beloved late father, Mr. James Mbagwu, whose unwavering love for learning ignited and fueled my pursuit.

ACKNOWLEDGMENT

I would like to thank Prof. Les Lavkulich, the Program Director of MLWS, for his invaluable support and guidance. Your kind words and unwavering encouragement have made this journey smoother. Thank you, Les.

Thank you so much, Julie Wilson, and the entire MLWS team, for the support throughout the duration of this program.

I also want to acknowledge the Mastercard Foundation Scholarship Program (MCFSP) family at UBC for the excellent support system and for making my dream come true.

I also extend my heartfelt appreciation to my dear children, Kaosi, Ifechukwu, and Ifunanya (Joan). Thank you for your understanding and patience during times when Mama had to work. To my incredible husband, Stephen Nduba, I am immensely grateful for your unwavering support and constant encouragement throughout this journey. My love for you knows no bounds, My Desire.

Lastly, I want to extend a special appreciation to my mother, siblings, and extended family for their unwavering support. Their steadfast presence has genuinely exemplified the adage that it takes a village.

EXECUTIVE SUMMARY

This report provides a comprehensive analysis of the environmental impacts of aggregate quarrying activities in southeastern Nigeria, focusing on water resources, soil quality, air quality, and wildlife. Through thoroughly examining quarrying practices, a case study analysis, and an evaluation of reclamation techniques, this study addresses the environmental consequences and proposes sustainable solutions for the region.

The study highlights the significant effects of quarrying on water resources, which has negatively impacted local communities access to clean water. Soil degradation due to quarrying activities has also resulted in the loss of fertile agricultural land, affecting farmers' livelihoods, and contributing to food insecurity.

By assessing reclamation techniques, such as topsoil replacement, revegetation, grading, and water management, the study identifies effective strategies for restoring degraded land and promoting ecosystem recovery. These techniques offer numerous benefits, including the re-establishment of native plant species, the prevention of soil erosion, the improvement of soil fertility, and the creation of visually appealing landscapes that blend with the natural surroundings.

To mitigate the environmental impacts of quarrying, several recommendations are proposed. These include providing adequate compensation and alternative livelihoods to affected communities, enforcing environmental management policies, implementing rehabilitation and restoration efforts, and adopting best practices and technologies to minimize environmental harm.

However, the study acknowledges limitations due to the availability and quality of data related to regional quarrying activities. Access to comprehensive and reliable data is crucial for a more accurate assessment of the impacts and the formulation of targeted solutions.

Overall, this study will serve as a valuable resource for stakeholders involved in quarrying activities, including the local communities, miners, and government. By prioritizing the implementation of the study's findings and recommendations, southeastern Nigeria can work towards sustainable quarrying practices, ecosystem restoration, and the long-term well-being of the region and its communities.

1.0 INTRODUCTION

Imagine a region where the tranquility of nature is disrupted by the booming sounds of quarrying, where once lush landscapes are transformed into barren wastelands, and the harmony between human activities and the environment is disrupted by the detrimental impacts of quarrying. This is the reality faced by southeastern Nigeria, where quarrying activities have left lasting environmental impacts. This report delves into the depths of this issue, exploring the direct and indirect consequences of quarrying and proposing innovative reclamation techniques that hold the promise of restoring the region's natural beauty and promoting sustainable development.

Quarrying is the process of extracting rock, gravel, or other minerals from the Earth's surface, usually for construction purposes. It involves extracting rocks and minerals from the Earth by breaking them into smaller pieces. As a form of land use, it affects the environment in many forms. As the ecosystem is connected as a nexus, these activities affect all system components. With a focus on the economic values gained and little or no strict guidance on reclamation, the environmental impacts are neglected, which over time spirals out of hand: Loose soil leading to rapid erosion and degradation, less vegetation, and loss of natural hydrologic function. (Kalu & Ogbonna, 2021).

As a form of mining, Quarrying is an important economic activity in many countries, especially in developing regions where it provides raw materials for construction, agriculture, and other industries. However, quarrying also has significant environmental impacts that must be addressed and mitigated.

According to an article in quarrymagazine.com (2020), quarrying and aggregate mining, which unearth rocks, sand, gravel, and other vital materials from the Earth's surface, are fundamental to fueling construction projects and infrastructure development worldwide. However, the far-reaching impact of these activities extends beyond meeting the demands of our ever-expanding societies. It encompasses a complex interplay of economic growth, environmental preservation, and social well-being. From the economic benefits and employment opportunities to the environmental concerns and social consequences, the global perspective on quarrying and aggregate mining reveals a crucial need for sustainable

practices and responsible resource management. Delving into the intricacies of this multifaceted industry uncovers the challenges and opportunities it presents on a global scale.

From an economic standpoint, these activities contribute to the growth of national and regional economies (Eyankware et al., 2020). Aggregate demand remains high due to ongoing urbanization and infrastructure development worldwide. As a result, quarrying operations play a vital role in providing essential construction materials. They create employment opportunities, generate revenue by selling extracted materials, and stimulate economic development. According to a Statista report, the mining and quarrying market in the United Kingdom was worth 18.4 billion British pounds in 2020, highlighting the sector's economic significance (Statista, 2022).

As a developing country, Nigeria is included in this race. The need for infrastructural development and the increasing population has continued to necessitate increased activity in this industry. Therefore, aggregates are needed to serve as building materials for construction, landscaping, road building, and cement production. They are extracted by quarrying and mining from lands and even water bodies. Concrete constitutes the primary construction material in this part of the world. This brings about an increase in the development of mine sites where these aggregates are quarried. The socioeconomic impacts are significant as they have contributed immensely to enhancing the economy at local, state, and federal levels in Nigeria by creating employment and contributing to the local economy by providing raw materials to meet many of society's needs. (Baah-Ennumh et al. 2019).

Kalu and Ogbonna (2021) state, "Quarry products are increasingly demanded for industrial, domestic, agricultural and other purposes to satisfy the needs of the rapidly growing population." Quarrying activities in the Southeastern region of Nigeria have increased significantly over the past decade, leading to both economic benefits and environmental impacts. (National Bureau of Statistics, January 2015). According to Statista, in 2021, about six percent of Nigeria's GDP was generated by the mining and quarrying sector, while the most prominent contribution was generated by crude oil and natural gas, which contributed around 5.6 percent to the GDP. Even with these socioeconomic benefits of quarrying operations, when quarrying operations become unregulated without the best sustainable

practice in view, adverse effects on the environmental resources become unavoidable. (Akanwa et al, 2016, Omosanya, K.O. & Ajibade, O.M. (2011).

Quarrying has yet to be regulated sufficiently from both legal and illegal acts and operations. Despite having laid down Environmental safety laws and regulations, as adopted by governments of nations the world over to protect the environment from such hazards, they are, however, operators of quarries who abuse these laws to maximize profit. (Eyankware et al., 2020).

The Southeastern region of Nigeria is one of the regions where quarrying is prevalent and widespread covering about 75,000 km^2 and comprising five (5) states: Abia, Anambra, Ebonyi, Enugu, and Imo, and several local and indigenous communities. Nigeria's deposits of these minerals and aggregates are mainly ancient, as there was no glaciation in this region. The region has diverse geological formations that host minerals such as limestone, granite, sandstone, marble, lead, zinc, clay, coal, iron ore, gold, and gemstones. (National Bureau of Statistics: Nigerian Mining and Quarrying Sector January 2015). These resources have attracted many quarry operators who exploit them for various purposes such as manufacturing, construction, and export to foreign countries. It also has rich vegetation and soil, which supports agricultural activities, with some significant crops being rice, maize, cassava, yams, plantains, and vegetables. This area is characterized by high levels of economic activity (agriculture and quarrying).

Quarrying has been practiced in southeastern Nigeria for a long time, dating back to the colonial era when it was used for building materials and road construction. It has also contributed to the region's economic development, providing employment and income for many people. However, as mentioned earlier, quarrying has also caused significant environmental impacts, such as land degradation, water pollution, air pollution, noise pollution, and biodiversity loss. These impacts affect not only the quarry workers but also the residents of the surrounding communities who depend on these natural resources for their daily income.

For instance, quarrying operations in the Enugu State of southeastern Nigeria have led to the depletion of water bodies, such as rivers and streams. The loss of these vital water resources has severely impacted local communities' access to clean water, disrupting their daily lives

and jeopardizing their well-being. Similarly, in Abakiliki, Ebonyi State, the relentless extraction of limestone from quarries has resulted in the degradation of fertile agricultural land, directly affecting farmers' livelihoods and exacerbating food insecurity in the region. (Akanwa et al., 2016) These real-world examples illustrate the urgency and importance of addressing the environmental and social impacts of quarrying in southeastern Nigeria.

The National Bureau of Statistics (2015) recorded about 1,800 registered quarries as of 1996. These quarries provide a source of employment for local communities and contribute to economic development. However, this extraction has been associated with several negative impacts on the environment and human health. High degrees of particulate matter released from blasting have caused water pollution, impacting the aquatic environment and water bodies. (Ajibade et al., 2022, Omosanya & Ajibade, 2011).

This report focuses on identifying the amount of land disturbed by these activities and the importance of returning the land to a more sustainable ecologically diverse state. The environmental impacts of quarrying in the region are identified through an impact assessment, and challenges and opportunities faced regarding the communities where these activities are carried out and identified. Potential reclamation strategies to restore and rehabilitate the affected areas and procedures to address them are developed, recommended, and implemented. Understanding these impacts and reclamation possibilities is crucial for sustainable development and preserving the environment in Southeastern Nigeria. The outputs of this study will be helpful for researchers, policymakers, and communities in southeastern Nigeria, as well as other regions facing similar challenges. This analysis will also provide valuable information for the government and industry stakeholders in making informed decisions on the sustainable management of embedded natural resources.

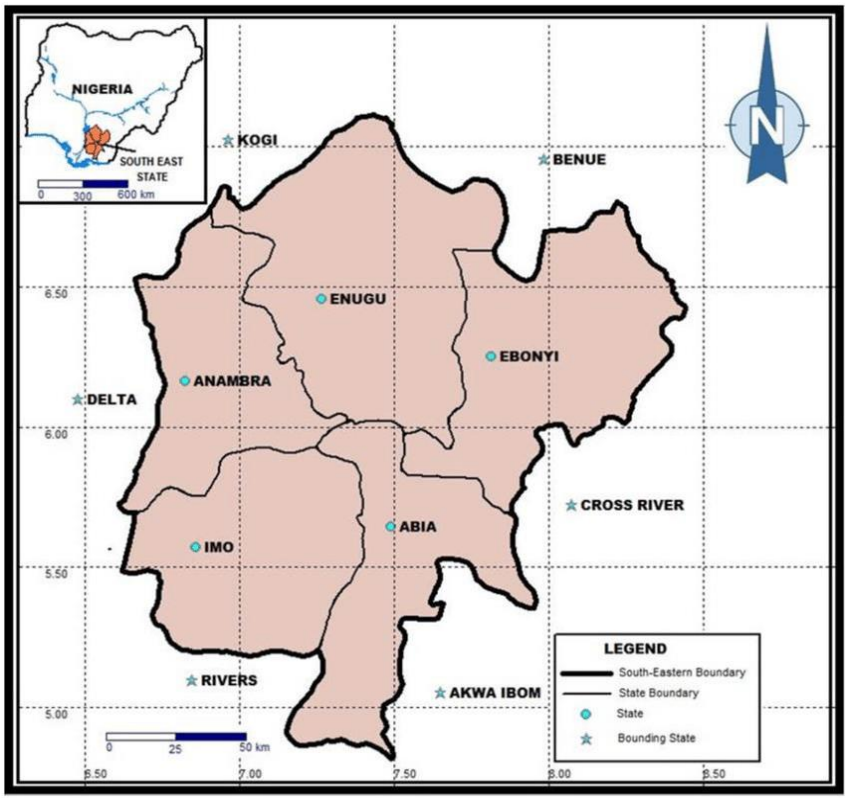

Fig. 1: Map of Southeastern Nigeria

1.1 Objectives

This project assesses the environmental impacts of quarrying on the natural environment, including the effects on water resources, soil quality, air quality, and wildlife, in southeastern Nigeria and explores the potential reclamation strategies that can be adopted to restore the degraded lands and ecosystems and thus make suggestions for innovative reclamation techniques for–the target audience, the stakeholders (locals, miners, and government). Specific objectives in achieving this aim include:

- To evaluate the impacts of quarrying on the environment, such as habitat destruction, biodiversity loss, and ecosystem disruption.
- To conduct a case study in southeastern Nigeria and analyze its environmental and socioeconomic consequences.
- To examine the different reclamation techniques and approaches that can be applied to rehabilitate quarried lands and ecosystems.

- To assess the feasibility and suitability of reclamation strategies for quarry sites in southeastern Nigeria.
- To evaluate the potential reclamation benefits to the environment.

1.2 Methods

To achieve the above objectives, the following methods will be followed:

- A comprehensive review of existing literature, research papers, reports, and case studies related to quarrying activities, environmental impacts, and reclamation strategies in southeastern Nigeria and other relevant regions was conducted. This provides a comprehensive understanding of the topic and establishes a baseline for the study.

- A review of 'Select Specific Quarry Sites' in southeastern Nigeria and conduct a detailed case study analysis. This involved analyzing historical data, environmental monitoring records, and socioeconomic data related to the selected quarry sites and to assessed the environmental and socioeconomic consequences of quarrying activities, including habitat destruction, biodiversity loss, water and air pollution, and socioeconomic changes in local communities.

- Conduct a review of reclamation techniques and approaches employed globally for restoring quarried lands and ecosystems. Evaluate their effectiveness in similar environmental contexts and assess their applicability to southeastern Nigeria. Techniques included; topsoil replacement, re-vegetation, habitat restoration, and water management strategies.

The project is expected to contribute to the existing knowledge on the environmental effects of quarrying and to provide practical recommendations for improving quarrying practices and restoring degraded lands in southeastern Nigeria.

2.0 Environmental Impacts of Quarrying

Quarrying operations have various environmental impacts that can be classified into two groups based on their source of impact: direct and indirect (Ozcan et al., 2012). Direct impacts result from the physical disturbance of land and vegetation by quarrying activities and

processes. Indirect impacts arise from the secondary effects of quarrying on the environment, such as changes in hydrology, climate, soil quality, and wildlife. Land degradation and habitat destruction occur as vegetation cover is removed, and wildlife habitats are destroyed. Soil erosion is a common consequence, impacting agricultural productivity in surrounding areas. Water pollution can result from sedimentation and contamination, depleting water resources. Additionally, air pollution from dust and vehicle emissions poses health hazards to nearby communities. Loss of biodiversity and the degradation of ecosystem services further exacerbate the impacts of quarrying.

2.1 Description of quarrying activities and processes

Quarrying activities in southeastern Nigeria involve different methods depending on the type and quality of rock or mineral extracted (Akanwa et al., 2016). The most common methods are blasting, drilling, crushing, screening, washing, sorting, stockpiling, and transporting. These methods generate waste materials, such as overburden, spoil heaps, tailings, slurry, dust, noise, and vibrations.

Blasting involves using explosives to break large rocks into smaller, easily handled, and transported pieces. Blasting is used primarily for hard rocks such as granite and marble. Blasting produces shock waves that propagate through the air and ground, causing noise and vibrations that can affect nearby structures and residents.

Drilling involves using machines or tools to create holes in rocks for placing explosives or extracting samples. Drilling is used for both hard and soft rocks such as limestone and clay. Drilling produces dust that can be dispersed by wind or water runoff.

Crushing involves using machines or devices to reduce rocks or minerals into smaller sizes or particles. Crushing is used for both hard and soft rocks such as granite and coal. Crushing produces dust that can be emitted into the air or mixed with water.

Screening involves using sieves or meshes to separate rocks or minerals into different sizes or grades according to their quality or use. Screening is used for both hard and soft rocks, such as sandstone and lead zinc. Screening produces dust that can be released into the air or washed away by water.

Washing involves using water to remove impurities or unwanted materials from rocks or minerals. Washing is used primarily for soft rocks such as clay and sandstone. Washing produces a slurry that consists of water mixed with fine rock or mineral particles.

Sorting involves using manual or mechanical methods to separate rocks or minerals into different categories based on their color, shape, density, or magnetic properties. Sorting is mainly used for metallic minerals such as gold and lead-zinc. Sorting produces waste materials that are discarded or stored in piles.

Stockpiling involves storing rocks or minerals in heaps or mounds until they are ready for use or sale. Stockpiling is used for both hard and soft rocks such as granite and limestone. Stockpiling can cause land degradation and deforestation by occupying large land areas and removing vegetation.

Transporting involves moving rocks or minerals from the quarry site to the processing plant or the market. Transporting is done by using trucks, conveyors, railroads, or pipelines. Transport can cause noise and air pollution by emitting exhaust gases and dust.

2.2 Assessment of the Direct Impacts on the Environment

The direct impacts of quarrying on the environment can be summarized as follows:

1. Land degradation and deforestation

Quarrying causes land degradation and deforestation by clearing vegetation, removing topsoil, altering landforms, and creating waste dumps. Land degradation reduces the productive capacity and aesthetic value of land, while deforestation reduces the carbon sequestration and oxygen production functions of forests. Carbon sequestration can be explained as capturing carbon dioxide (CO_2) from the atmosphere and subsequently storing it. Carbon sequestration can help mitigate climate change by reducing the amount of CO_2 in the atmosphere contributing to global warming. Land degradation and deforestation also increase the risk of soil erosion, landslides, floods, and droughts.

National Bureau of Statistics (2020) posits that mining and quarrying activities have resulted in the loss of about 2,000 hectares of forest land in southeastern Nigeria between 1990 and 2015. This represents about 0.4 percent of the total forest cover in the region.

2. Sedimentation, Soil erosion, and loss of fertile agricultural land

Quarrying causes soil erosion and sedimentation by exposing bare soil to wind and water erosion, disturbing natural drainage patterns, and increasing runoff and surface flow. Soil erosion removes fertile soil and organic matter from the land, while sedimentation deposits fine soil and rock particles in water bodies. Soil erosion and subsequent sedimentation affect the quality and quantity of water resources, as well as aquatic life and habitats.

According to Eyankware et al. (2021), quarrying activities have caused high levels of heavy metal contamination in sediment, soil, and dust particulates across the rock quarrying districts of the Oban Massif in southeastern Nigeria. The study found that the concentrations of iron, manganese, copper, lead, zinc, cadmium, chromium, nickel, and arsenic exceeded the permissible limits for environmental quality standards.

Aggregate mining activities destroy the natural landscape and vegetation cover, loss of topsoil, nutrient depletion, and reduced soil fertility. This also creates large pits and dumps that alter the landform and affect the drainage patterns. Land degradation reduces the aesthetic value and productivity of the land and poses a threat to food security and biodiversity. Fertile agricultural land is also lost as more and more land is taken away from agriculture and used for quarry activities. This leads to a decrease in the economic benefits of agriculture and reduces food security. And as Naeth et al. (2021) stated soil degradation can lead to the loss of native vegetation and wildlife habitat, the invasion of exotic species, the alteration of nutrient cycles and ecosystem services, and the increase of greenhouse gas emissions.

If the lands are not restored or reclaimed there will be a relative decrease in food production and security in this region. Mata Melodi (2020) reported that quarrying activities in Abeokuta, Ogun state, have reduced the photosynthetic activity, growth, and yield of crops such as cassava, yam, maize, and plantain. The dust and gaseous emissions from the quarry sites damage the plant's leaves, stems, roots, and fruits.

3. Water pollution and depletion

Quarrying causes water pollution and depletion by contaminating surface water and groundwater with chemicals, metals, nutrients, pathogens, and suspended solids, altering the hydrological cycle and water balance and reducing the availability and accessibility of water resources. (Eyankware et al.,2020) Water pollution affects the health and safety of humans, animals, and plants that depend on water for drinking, irrigation, recreation, or other purposes.

According to Eyankware et al. (2020), quarrying activities have negatively affected the geochemistry of water resources around active and abandoned mines and quarries in Ebonyi State in southeastern Nigeria. The study found that mining activities have caused acid mine drainage that lowers the pH and increases the acidity of water resources. The study also found that water resources around mining sites have high concentrations of dissolved solids, hardness, alkalinity, chloride, sulfate, nitrate, phosphate, iron, manganese, copper, lead, zinc, cadmium, chromium, nickel, arsenic, mercury, cobalt, selenium, and uranium.

4. Noise and air pollution

Quarrying causes noise and air pollution by generating loud sounds and vibrations from blasting, drilling, crushing, screening, washing, sorting, stockpiling, and transporting activities, emitting dust particles, gases, fumes, odors, and aerosols from quarry operations and processes.

Noise pollution affects the hearing ability and psychological well-being of humans and animals exposed to these high noise levels for prolonged periods (Naeth et al., 2021, Obasi et al., 2019).

Air pollution affects the respiratory health and immune system of humans, animals, and plants that inhale polluted air. Air pollution also contributes to global warming and climate change by increasing greenhouse gas emissions. Air pollution reduces visibility and causes a nuisance to nearby residents.

According to Nwibo et al. (2019), quarry workers and residents of quarrying communities in Abakaliki in southeastern Nigeria have experienced major ocular problems due to exposure to dust and noise from quarry operations. Naeth et al. (2021) stated that noise pollution can

cause stress, anxiety, depression, hypertension, headache, tinnitus, and hearing loss in humans and animals exposed to excessive noise.

2.3 Evaluation of indirect impacts on the Environment

The quarrying activities in Southeastern Nigeria also indirectly affect the environment, by such activities as habitat destruction and fragmentation, loss of biodiversity, and disruption of ecosystem services.

1. **Habitat Destruction and Fragmentation:** Habitat destruction and fragmentation occur when large areas of land are cleared for quarrying, leaving behind patches of isolated habitats that cannot support the same diversity and abundance of species as before. Removing these essential environmental components disrupts the habitat's balance, rendering it unsuitable for many plant and animal species. fragmentation also disrupts migration patterns and hinders the movement of species, leading to their displacement and isolation.(Lameed & Adetoro, 2004)

2. **Loss of Biodiversity**: Loss of biodiversity results from reducing or eliminating native flora and fauna due to habitat loss, degradation, or disturbance. According to Lameed and Ayodele (2010), damage to biodiversity remains one of the most significant adverse impacts of quarrying on the environment. Losing connectivity between habitats further reduces the gene flow and increases the risk of local extinctions. According to Taye and Brown-Wood (2016), quarry activities affect biodiversity in diverse ways. It can disturb plant growth by settling on leaves and hinder photosynthesis, thus disrupting food chains.

3. **Disruption of Ecosystem Services**: Disruption of ecosystem services refers to the impairment or loss of the natural functions and benefits that ecosystems provide to humans and other living beings, such as soil formation, climate regulation, and pollination.

The destruction of vegetation and topsoil also disrupts water purification processes and can lead to water pollution and altered flow patterns. This disruption can lead to increased sedimentation and the release of pollutants into nearby water bodies, impairing water quality and affecting aquatic ecosystems. Moreover, the disturbance of natural drainage patterns can result in altered water flow, contributing to flooding or droughts in the surrounding areas.

Additionally, quarrying negatively impacts pollinator populations, affecting the pollination of plants and crops. Many plant species rely on pollinators such as bees, butterflies, and birds for successful reproduction. However, quarrying can destroy the pollinators' floral resources and nesting habitats, leading to declining populations. Reduced pollinator abundance and diversity can have far-reaching consequences, as it hampers the pollination of wild plants and crops, affecting ecosystem resilience and agricultural productivity. (Kovács-Hostyánszki et al., 2017).

Furthermore, removing organic matter and disrupting nutrient cycling processes can impair the growth and health of plant species, ultimately impacting ecosystem productivity. Removing vegetation and topsoil eliminates important organic matter and nutrient-rich layers that support nutrient cycling. As a result, the nutrient availability in the surrounding soil decreases, negatively impacting the growth and vitality of remaining plant species. This disruption in nutrient cycling can cascade through the ecosystem, affecting the overall productivity and functioning of the ecosystem.

3.0 Case Study: Quarrying in Ebonyi State, Southeastern Nigeria

Ebonyi is one of the five states in Southeastern Nigeria. The State is situated between longitudes 7° 30' and 8° 30'E and latitudes 5 ° 40' and 6 °54'N. It has a land area of 5,935 sq. Km and it has a population of 2,176, 947 based on the 2006 census. It has an annual growth rate of 3.5% per annum. (National Population Commission, 2006). The population is largely rural, and predominantly farmers with major crops being rice, yam, and cassava. As well as salt harvesting from its famous salt lakes.

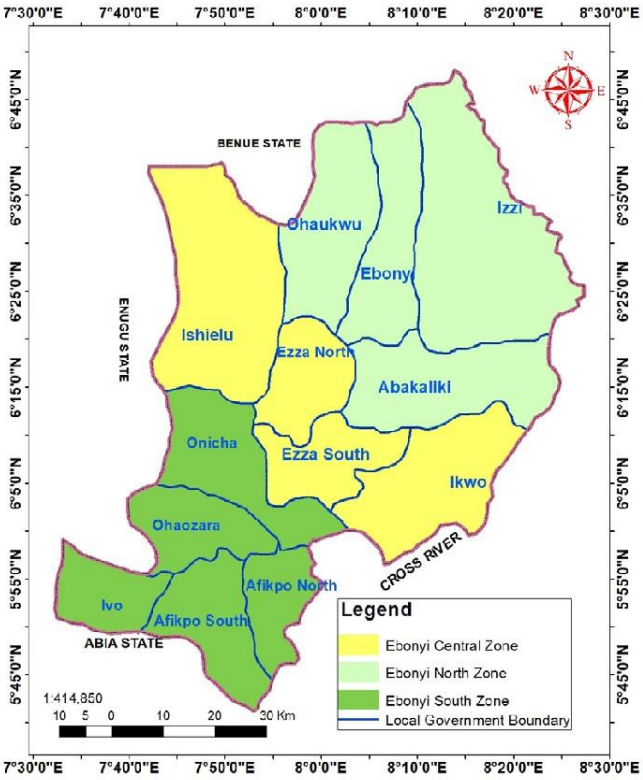

Fig. 2: Map of Ebonyi state showing Local Government Areas.

Ebonyi State has a long-standing and dynamic quarrying industry that originated in the 1950s, as Chima et al. (2010) documented. Over the years, this industry has witnessed substantial growth, with approximately 400 private operators actively engaged in quarrying operations with over 27 mines (both legal and illegal) dotted across the state. These operators collectively produce an impressive annual output of over 100,000 metric tonnes of stone materials (Ministry of Solid Minerals, 2007). The abundance of natural resources in the State is attributed to its geologic formation, highlighted by Edet et al. (2011), which has resulted in a surplus supply of valuable resources.

According to research by Akanwa et al (2016), there has been large-scale exploitation of limestone and granite in Ebonyi State with 402.855 hectares of arable lands that have been affected by rock quarrying. The data for the study were collated and analyzed for 27 quarry locations selected from six local government areas where quarrying activities are heavily concentrated and currently active; collected through direct field observations, oral

interviews, photographs, and measurements. Land use maps and satellite imagery were obtained to interpret alongside ground-truthing by site visitation.(Akanwa et al., 2016)

Active Quarry L.G.A Areas	Total Area of vegetation lost by Quarry pits	% of area occupied by the quarry pits	Total Area of L.G.As
Ohaukwu	1,157,050m^2	28.7	597,010,762m^2
Ishielu	377,325m^2	9.3	1,043,345,732m^2
Ivo	1,422,000m^2	35.2	322,711,402m^2
Afikpo north	595,350m^2	14.7	553,091,458.5m^2
Ezza North	323,825m^2	8.0	328,019,911m^2
Izzi	153,000m^2	3.7	1,156,262,332m^2
Total	4,028,550m^2	100	4,000,441,598m^2

Table 1: Excavated Vegetation by Quarrying Activities. Source: Akanwa et al. 2016.

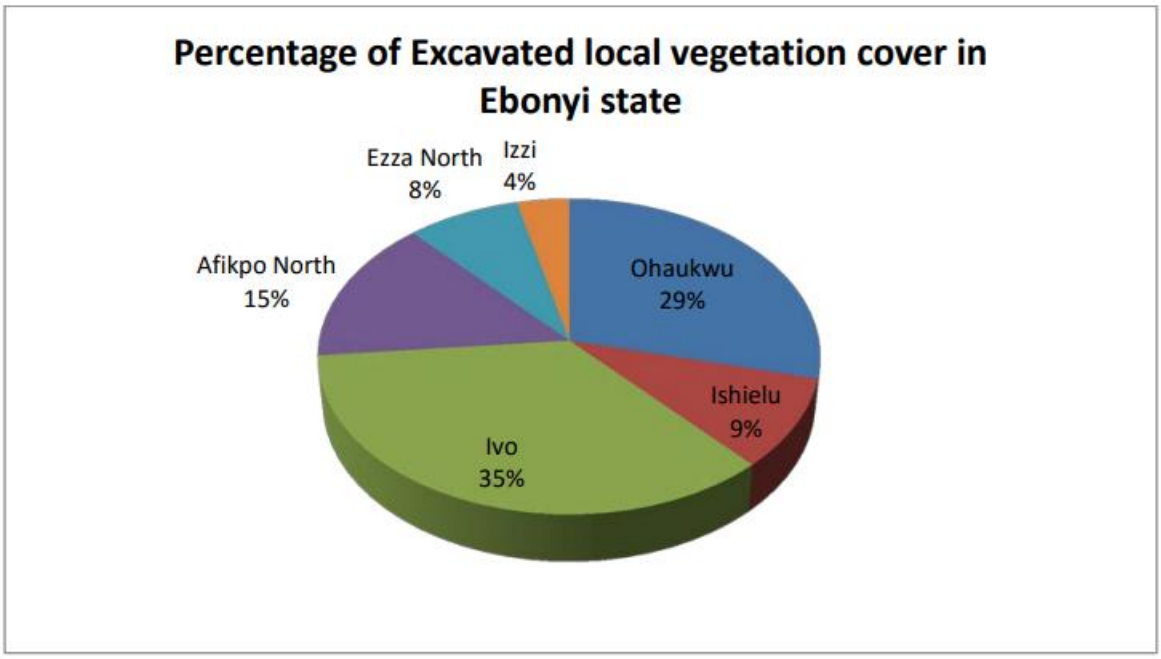

Fig 3. Showing the Percentage of Excavated Vegetation Cover in Ebonyi State. Source: Akanwa et al .2016

Findings from the field measurements show that this has had a resultant negative effect on the arable lands and vegetation, as shown in Table 1. Considering that the residents are predominantly farmers, EBSEEDS (2004) indicated that agriculture constitutes about 90% of the State's GDP with 75% of the population engaged in farming and the State remains largely rural with an estimated 60% percent (over 1.2 million people) living in the rural areas. The loss of farmlands and soil degradation has affected agricultural production and caused a setback in the economy, income, and the primary occupation of the inhabitants. Field observations showed that in the areas where quarrying operations are active, the lands are heavily degraded. Removal of the topsoil, trees, and vegetation with heavy machines deprives the land of its nutrients and renders the land infertile for agricultural purposes. For instance, at Amaeze in the Ishiagu area, located at Ivo LGA, there were areas where the land had been covered by rocks and other debris from quarrying activities. This has not only impeded plant growth on the land but has also rendered the surface rugged, making it impossible for productive farming activities to take place.

Fig 4: Quarry with the largest effect of vegetation loss at Ishiagu, Ivo LGA. Adapted from Akanwa et al. 2016

One of the major environmental impacts of quarrying is water pollution, caused by acid mine drainage and heavy metal contamination. Eyankware et al. (2020) reported that quarrying activities in Ebonyi State have altered the geochemistry of water resources around active and abandoned mines and quarries, resulting in high concentrations of iron, manganese, copper,

lead, zinc, cadmium, chromium, nickel, and arsenic. The authors estimated that 72 percent of water resources and soil quality are declining across Ebonyi State due to quarrying activities. The contaminated water poses health risks to humans and animals who consume it or use it for irrigation.

Obasi et al. (2019) found that quarry workers and residents of quarrying communities in Abakaliki had a high prevalence of ocular problems such as conjunctivitis, cataract, glaucoma, and refractive errors due to exposure to dust and noise.

According to Kalu and Ogbonna (2019), quarrying activities in the Akpoha and Ishiagu communities of Ebonyi State have resulted in soil degradation and pollution that have affected soil fertility and crop production. The soil samples collected from the quarry sites and the nearby areas showed high levels of acidity, electrical conductivity, total hydrocarbon content, and heavy metals such as lead, zinc, copper, iron, manganese, and chromium. These parameters exceeded the permissible limits for agricultural soils and posed risks to human and animal health.

Fig 5: Community Pit at Akpeagu Amofia showing damaged landform and changed landscape. Source Photographed by Akanwa et al, 2016.

Kalu and Ogbonna (2019) found that the water samples collected from the surface water and boreholes in Akpoha and Ishiagu communities of Ebonyi State also had high levels of acidity, electrical conductivity, total dissolved solids, total suspended solids, total hydrocarbon content, and heavy metals including lead, zinc, copper, iron, manganese, chromium, nickel, cadmium, arsenic, mercury, and cobalt. These parameters exceeded the permissible drinking and irrigation limits and posed risks to aquatic life and human health.

Locals and laborers in these quarries have been interviewed at different times. These different oral interviews indicate that the quarry operators and organizations have not compensated the communities in any way, as stated in the initial memorandum of understanding. (Emetumah & Okoye 2022). The standard mining procedures and post-mining processes are stated in the Nigerians Mining and Minerals Act (2007). Reclamation and possibilities of returning the land to use are also outlined. However, these Acts are not being implemented due to inadequate institutional capacity, lack of coordination among relevant agencies, enforcement challenges and corruption within the regulatory framework can undermine the implementation of policies and Acts and the locals are left to suffer as their source of livelihood is being taken away.

4.0 Potential Reclamation Possibilities in Southeastern Nigeria and Benefits

4.1 Definition and importance of reclamation

Reclamation is the process of restoring land, water, or both, that has been altered or damaged by human activities, such as mining or industrial activities, oil and gas extraction, or landfills, to a useful and productive state. Reclamation aims to return the land to a productive state that supports ecological, agricultural, recreational, or other human activities. Reclamation often involves activities such as soil stabilization, remediation of contaminated soils and water bodies, soil improvement, erosion control, and planting vegetation to create a functional and productive landscape. (Naeth et al., 2020, Yeldell and Squires, 2016).

Reclamation efforts are very important in the mining industry, oil and gas industries, and even agriculture. Usually, when mines come to the end of their lifecycle, reclamation is carried

out to ensure Post Mining Land use. This mitigates the destructive effects caused by mining and ensures the ecosystem is returned to a sustainable state.

Yeldell and Squires (2016) stated that successful reclamation involves physically stabilizing the terrain, landscaping, restoring topsoil, and utilizing the land for a productive purpose. At a minimum, the reclamation of mine sites necessitates physically stabilizing tailings dams and waste rock piles.

4.2 Examination of different reclamation techniques, approaches, and Benefits

Land reclamation is vital in mitigating the environmental impacts of mining and quarrying activities in Southeastern Nigeria. Based on the terrain and geological characteristics of Southeastern Nigeria, some of these reclamation techniques discussed below can be employed to restore the disturbed land to its original condition and promote sustainable development in the region. (Naeth et al.,2021, Yeldell and Squires, 2016, Joseph, 2021)

a. Grading: Grading is a land reclamation technique involving reshaping the land to its original contours after mining or quarrying activities. By modifying the topography of the reclaimed area, grading restores drainage patterns, prevents erosion, and creates a more natural-looking landscape. The process begins with the removal of excess soil or fill material, followed by the redistribution and leveling of the remaining soil to achieve desired contours.

Through careful manipulation of the land, grading restores the landscape's natural appearance, minimizing the visual impact of mining or quarrying. It creates a harmonious environment that blends with the surrounding natural features, enhancing the aesthetic value of the reclaimed area. Additionally, grading improves soil conditions and stability by encouraging compaction, enhancing soil structure, and promoting better water infiltration and retention. By directing water flow and reducing runoff and sedimentation, grading helps prevent soil erosion. Moreover, grading facilitates vegetation establishment by creating favorable microtopography and drainage conditions. This enables the growth of native plant species, which further stabilizes the soil, reduces erosion, and restores ecosystem functions.

The success of grading depends on factors such as professional expertise, accurate planning, and alignment with the overall land reclamation goals. Monitoring and maintenance are

essential to evaluate grading effectiveness, address issues, and ensure long-term success. By recreating the original landforms and optimizing drainage patterns, grading significantly contributes to the success of land reclamation efforts. Through careful planning, implementation, and ongoing management, grading is crucial in transforming previously disturbed lands into functional and visually appealing landscapes that harmonize with the natural surroundings

b. Topsoil replacement: Topsoil replacement is a highly effective technique in land reclamation that plays a vital role in restoring ecosystem functions and establishing sustainable vegetation communities. This technique involves removing topsoil before mining or quarrying operations begin, which is then carefully stored for later use. By preserving the topsoil, which contains essential nutrients, beneficial microorganisms, and organic matter, the natural vegetation and soil structure can be successfully restored after the mining or quarrying activities are complete.

The process of topsoil replacement starts with the careful removal of the top layer of soil using specialized equipment. The depth of topsoil removal depends on site-specific conditions and the extent of land disturbance. Proper handling and storage of the topsoil are crucial to maintain its integrity and viability during this phase. Once the mining or quarrying activities have concluded, the stored topsoil is reintroduced to the site. It is evenly spread over the disturbed area to replicate the natural soil profile. This reintroduction of topsoil recreates the original soil composition and structure, providing a fertile substrate for vegetation re-establishment.

The benefits of topsoil replacement in land reclamation are significant. Reintroducing the original topsoil also reintroduces the natural seed bank in the stored soil, facilitating the germination and growth of native plant species. This promotes the re-establishment of a diverse and resilient ecosystem. The presence of organic matter in the topsoil enhances soil fertility, nutrient cycling, and water-holding capacity. It improves soil structure, porosity, and moisture retention, reducing erosion risks and supporting vegetation establishment and overall land stability.

c. Revegetation: Revegetation is a crucial method used in land reclamation to restore vegetation cover and promote ecological recovery in areas impacted by mining or quarrying

activities. It involves deliberately planting vegetation or reseeding native plant species on the reclaimed land to establish a diverse and resilient plant community. Native plants are preferred because they are adapted to local conditions, require less maintenance, and support the re-establishment of the original ecosystem. The planted vegetation helps stabilize the soil, prevent erosion, provide wildlife habitat, and contribute to the ecological balance.

The revegetation process begins with carefully assessing the site's ecological conditions to determine suitable plant species that can thrive in the restored ecosystem. Native plant species are preferred due to their adaptation to the local climate, soil conditions, and interactions with other organisms. They have evolved with the environment and are more effective at recovering from disturbances, preserving biodiversity, and maintaining ecosystem integrity.

Revegetation can be achieved through various methods, such as direct seeding or transplanting seedlings. Direct seeding involves scattering seeds over the reclaimed area while transplanting involves planting seedlings grown in nurseries directly into the site. Factors such as seed quality, viability, planting techniques, and post-planting care are important considerations to enhance the success of revegetation efforts.

Revegetation serves multiple purposes in land reclamation. It stabilizes the soil, acts as a physical barrier against erosion, improves soil quality, filters the air, and enhances carbon sequestration processes. The established vegetation also provides habitat and food sources for wildlife, contributing to the restoration of biodiversity. Monitoring and adaptive management are crucial to assess vegetation establishment, make necessary adjustments, and ensure long-term success.

d. Water management: Water management is a crucial technique in land reclamation that aims to effectively manage water resources, prevent erosion, control sedimentation, and establish a sustainable hydrological system. Techniques such as sediment ponds, wetlands, and vegetated swales manage stormwater runoff and support ecological recovery.

One key aspect of water management is the implementation of sediment ponds or basins. These ponds capture runoff water, allowing sediments to settle before discharge. Carefully

engineered with features like sediment traps and vegetation, sediment ponds maximize sediment removal efficiency, reducing downstream pollution risks.

Wetlands play a significant role in water management during land reclamation. Constructed wetlands or restored natural wetland areas retain and treat stormwater runoff, acting as natural filters. They remove pollutants through sedimentation, filtration, and biological uptake while providing a habitat for diverse species and enhancing ecological functions.

Vegetated swales, shallow channels with vegetation, collect and slow down stormwater runoff, promoting sediment settling and infiltration. They prevent erosion by reducing runoff velocity and supporting water absorption into the soil. Vegetated swales also contribute to vegetation growth and enhance the aesthetic appeal of the reclaimed landscape.

Proper planning and design of drainage systems are vital for effective water management. Drainage channels, ditches, and culverts are strategically designed to collect and redirect water away from sensitive areas, minimizing excess water accumulation and reducing erosion risk and waterlogging. Regular monitoring and maintenance ensure the efficiency of water management strategies, enabling timely corrective measures and contributing to the restoration of ecosystems.

5.0 Conclusion

This project provides a comprehensive study of the environmental impacts of quarrying in southeastern Nigeria, focusing on water resources, soil quality, air quality, and wildlife. The objectives were to describe quarrying activities, evaluate direct and indirect environmental impacts, analyze a case study, examine reclamation techniques, assess their feasibility and suitability, and evaluate the potential benefits to the environment and local communities. Through a combination of literature review, case study analysis, and the evaluation of global reclamation strategies, this project has contributed to existing knowledge in particular to emerging economies, such as Nigeria. The findings and recommendations of this study aim to improve quarrying practices and restore degraded lands in southeastern Nigeria, ultimately benefiting the stakeholders involved, including the local citizens, miners, and government. This project provides a valuable resource for sustainable regional quarrying and ecosystem

restoration by addressing the environmental consequences and proposing innovative reclamation techniques. These processes have proven effective in various parts of the world and can also be applied to the Case of Southeastern Nigeria with effective planning, implementation, and monitoring.

By adopting a combination of appropriate techniques, there is hope for mitigating the impacts of quarrying activities and facilitating the restoration of the environment in southeastern Nigeria. Moving forward, it is imperative to prioritize the implementation of these findings to ensure the long-term well-being of the region and its communities.

6.0 Recommendations

To minimize the environmental impacts of quarrying in southeastern Nigeria, some measures that can be taken are:

- Environmental management policy: Government agencies overseeing mining operations should revise and enforce environmental management policy to ensure quarry operators comply with environmental standards and regulations. This can help to prevent or mitigate environmental damage and ensure accountability by implementing better site management practices, monitoring environmental changes during quarrying, and employing effective mitigation measures.

- Rehabilitation and restoration of degraded land: Quarry operators should reclaim and restore land degraded by quarrying activities. This involves filling up pits, leveling dumps, planting trees, grasses, and crops, and restoring water sources. Rehabilitation and restoration can help improve the land's ecological value and functionality.

- Adoption of best practices and technologies: Quarry operators should adopt best practices and technologies that reduce the environmental impacts of quarrying activities. This can include using less invasive extraction methods, minimizing waste generation, recycling materials, using renewable energy sources, controlling dust emissions, reducing noise levels, and monitoring environmental parameters.

- There is also a need for community engagement and public awareness campaigns to foster a better understanding of the environmental consequences of quarrying. This will help them

hold the mine operators accountable and enforce the outlined measures for mitigation and rehabilitation.

7.0 Limitation faced.

The study's findings depended on the availability and quality of data related to quarrying activities and their impacts on the region. Limited access to comprehensive and reliable data may have restricted the scope and accuracy of the assessment. Acknowledging these limitations helps to contextualize the study's findings and provides opportunities for further research and refinement of the assessment process. It is essential to address these limitations in future studies to ensure a more comprehensive and robust understanding of the impacts of quarrying in southeastern Nigeria.

REFERENCES

Adekoya, J.A, Olatunji, O.A. & Oluwole, A.F. (2013). Effect of quarrying activity on biodiversity: Case study of Ogbere site, Ogun State Nigeria. African Journal of Environmental Science and Technology 7(11): 883-892.

Aigbedion I., & Iyayi S.E., 2007. Environmental effect of mineral exploitation in Nigeria. International Journal of Physical Sciences 2(2): 033-038.

Ajibade, O. M., Olisa, O. G., Oladipupo, S. D., Adegoke, C. B., & Adebayo, O. H. (2022). Health impact assessment of quarrying in some parts of southwestern Nigeria. Arabian Journal of Geosciences, 15(8)https://10.1007/s12517-021-08391-7

Akanwa, A. O., Onwuemesi, F. E., Chukwurah, G. O. & Officha, M. C.(2016). Effects of Open Cast Quarrying Technique on Vegetation Cover and the Environment in South-Eastern Nigeria. https://www.researchgate.net/journal/American-Scientific-Research-Journal-for-Engineering-Technology-and-Sciences-2313-4410

Akanwa, A.O., Mba, C. H. & Jibrum, U. U. (2017). Effects of Quarrying Activities on Local Vegetation Cover in Ebonyi State, Nigeria. http://www.ijsrm.humanjournals.com Vol.:6, Issue:2

Akanwa A.O., Nwachukwu M.A., Alinnor J.I., 2010. Assessment of Environmental Impacts of Quarry Operation in Ogun State, Nigeria. International Journal of Engineering Science Invention 9(6): 59-65.

Alberta Environment. (2002). *Glossary of Reclamation and Remediation Terms Used in Alberta* (7th ed.). Retrieved from https://open.alberta.ca/dataset/c9fa40a2-b672-441f-9350-39419b1df905/resource/856641d8-e0be-4f0a-996d-8683c25d5928/download/glossaryrecremediationterms7edition-2002.pdfAmerican Geosciences Institute (n.d.). Can we mitigate environmental impacts from mining? https://www.americangeosciences.org/critical-issues/faq/can-we-mitigate-environmental-impacts-mining

Ayodele, A., & University of Ibadan (2010). Effect of quarrying activity on biodiversity: Case study of Ogbere site, Ogun State Nigeria. African Journal of Environmental Science and Technology, 4(11), 740-750. https://academicjournals.org/journal/AJEST/article-full-text-pdf/0F6E4F420016

Baah-Ennumh T.Y., Ndur S., and Amegbey N., (2019). The Impact of Quarrying on the Environment: A Case Study of Ghana. Journal of Environment and Earth Science 9(8): 1-10.

Baah-Ennumh , T. Y., Yeboah, A.S., Akularemi, A.J. (2019). Contextualizing the effects of stone quarrying: insights from the Wenchi municipality in Ghana. GeoJournal. https://doi.org/10.1007/s10708-019- 10080-8

Beerling, D. J., Kantzas, E. P., Lomas, M. R., Wade, P., Eufrasio, R. M., Renforth, P., … & Leake, J. R. (2021). Potential for large-scale CO2 removal via enhanced rock weathering with croplands. Nature, 583(7815), 242-248. https://doi.org/10.1038/s41586-020-2448-9

Brayshaw A.C. (2015) Quarry reclamation in England: A review of techniques. Journal of Environmental Management, 146, 124-133. https://doi.org/10.1016/j.jenvman.2014.07.020

Britannica, T. Editors of Encyclopaedia (2017, November 2). land reclamation. Encyclopedia Britannica. https://www.britannica.com/science/land-reclamation

Chima, G.N., Nwaugo, V.O. and 1Ezekwe, I.C. (2010). Impacts of rock quarrying on Akwukwuo tributary of the Ivo River in Ishiagu Ebonyi State, Nigeria. Journal of Applied and Environmental Sciences 2010 Vol. 6, No. 2. pp. 68-73

Darwish, T., Khater, C., Jomaa, I., Stehouwer, R., Shaban, A., & Hamzé, M. (2011). Environmental impact of quarries on natural resources in Lebanon. Land Degradation & Development, 22(3), 345-358. https://10.1002/ldr.1011

Emetumah, F. C., & Okoye, C. O. (2022). Miners' experiences and perceptions of environmental and safety regulations: Statistical evidence from Ebonyi State, Nigeria. Journal of Cleaner Production, 341, 130862. https://doi.org/10.1016/j.jclepro.2020.130862

Eyankware, M. O., Nwankwoala, H. O., & Ukaegbu, V. U. (2020). Impact of past mining activities on water resources around active and abandoned mines and quarries in

Ebonyi State, SE Nigeria- A mini review. Hydro Science & Marine Engineering, 2(1), 1-11.

Eyankware, M. O., Nwankwo, N. P. & Ogwah, C. (2020). Impact of Past Mining Activities on Water Resources Around Active and Abandoned Mines and Quarries in Ebonyi State, South-Eastern Nigeria - A Mini Review. Hydro Science & Marine Engineering | Volume 02 | Issue 02 | October 2020

Gann, G.D., McDonald, T., Walder, B., Aronson, J., Nelson, C.R., Jonson, J., Hallett, J.G., Eisenberg, C., Guariguata, M.R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K. & Dixon, K.W. (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology*, *27*(S1), S1-S46. https://doi.org/10.1111/rec.13035

Green, J. A., Pavlish, J. A., Merritt, R. G., & Leete, J. L. (2005). Some Gravels and Gravel-pits in Hampshire and Dorset. Elsevier BV. https://10.1016/s0016-7878(47)80004-5

Hassan, I. A. (2022). Assessment of the Socio-Economic and Health Impact of Quarrying on the Inhabitants of Kenta Logemo Village in Odeda Local Government Area, Ogun State, Nigeria. Environment and Natural Resources Research, 12(1), 29. https://10.5539/enrr.v12n1p29

https://www.earthmagazine.org/article/reclaiming-albertas-oil-sands-mines/

Hobbs, N. T., Twombly, S., & Schimel, D. S. (2006). Deepening Ecological Insights Using Contemporary Statistics. Ecological Applications, 16(1), 3-4. https://10.1890/05-0791

Joseph, A. A. (2021). The Need for Sustainable Mining: A Case Study of Uranium Mine Reclamation in Canada (Master's thesis, University of British Columbia). https://lfs-mlws-2020.sites.olt.ubc.ca/files/2021/10/Joseph-2021-The-Need-for-Sustainable-Mining.pdf

Kalu, I. E., & Ogbonna, N. J. (2021). Investigation of environmental effect of stone quarrying activities on soil and water in Akpoha and Ishiagu communities of Ebonyi state, Nigeria. International Journal of Construction Management, 21(12), 1185-1199. https://10.1080/15623599.2019.1604115

Kalu I.E., & Ogbonna N.J., (2019). Investigation of environmental effect of stone quarrying activities on soil and water in Akpoha and Ishiagu communities of Ebonyi state, Nigeria. International Journal of Construction Management 21(12): 1185-1199.

Kalu, I. E., Ogbonna, N. J., Sparkes, M., & Institute of Fusion Energy (2019). Korean nuclear fusion reactor achieves 100 million°C for 30 seconds. *International Journal of Construction Management*, *21*(12), 1185-1199. https://doi.org/10.1080/15623599.2019.1604115

Karmakar, H. N., & Das, P. K. (1991). Review of: "Biofuels and nanocatalysts: A Data Mining study". Qeios Ltd. https://10.32388/fyjsga

Knapik, L., Green, J. E., Wylie, C., Van Egmond, T. D., Paterson, L. R., Jones, I., & Alberta Environment and Sustainable Resource Development (1991). A user guide to pit and quarry reclamation in Alberta. https://era.library.ualberta.ca/items/7df34e6f-c64e-49e8-998d-403067e0ff55

Kovács-Hostyánszki, A., Espíndola, A., Vanbergen, A. J., Settele, J., Kremen, C., & Dicks, L. V. (2017). Ecological intensification to mitigate impacts of conventional intensive land use on pollinators and pollination. Ecology Letters, 20(5), 673-689. https://doi.org/10.1111/ele.12762

Lad, R.J., & Samant J.S., (2014). Environmental and social impacts of stone quarrying-a case study of Kolhapur District. International Research Journal of Environment Sciences 3(3): 81-86.

Lameed, G. A., & Adetoro, A. O. (2004). Biodiversity assessment of high rain forest under human activities: a case study of Erinle Forest in Ogun State, Nigeria. Journal of Environmental Extension, 4(1), 740. https://10.4314/jext.v4i1.2732

Lameed, G.A. & Ayodele, A.O. (2010). Environmental impact assessment of quarrying activities in Oba-Ile, Ondo State, Nigeria. Journal of Environment and Earth Science 1(1): 1-9.

Lawal, M. (2002). Constraints to Small-Scale Mining in Nigeria: Policies and Strategies for Development. In CEPMLP Annual Review—The Dundee Yearbook of International Natural Resources and Energy Law and Policy (p. 17). Centre for Energy Petroleum Minerals Law and Policy, University of Dundee.
https://www.dundee.ac.uk/cepmlp

Melodi, M. M. (2017). Assessment of Environmental Impacts of Quarry Operation in Ogun State, Nigeria. FUOYE Journal of Engineering and Technology, 2(2) https://10.46792/fuoyejet.v2i2.141

Naeth, M. A., Rutherford, P. M., & Jobson, A. M. (2021). Environment and social impacts of stone quarrying: South Western Ethiopia. *Digging into Canadian Soils*, *16*, 1-24. https://openpress.usask.ca/soilscience/chapter/soil-reclamation-and-remediation-of-disturbed-lands/

Naeth, M. A., Rutherford, P. M., & Jobson, A. M. (2020). Soil Reclamation and Remediation of Disturbed Lands. In A. Bedard-Haughn (Ed.), Digging into Canadian Soils: An Introduction to Soil Science (1st ed.). University of Saskatchewan. https://openpress.usask.ca/soilscience/chapter/soil-reclamation-and-remediation-of-disturbed-lands/

National Bureau of Statistics : Nigerian Mining and Quarrying Sector (January, 2015) Summary Report 2010 – 2012.

National Population Commission (2006). Nigeria Population Census Report. NPC, Abuja. Nigeria.

National Bureau of Statistics. (2020). Mining and quarrying statistics. https://nigerianstat.gov.ng/elibrary?queries[search]=mining%20and%20quarrying%20statistics

Natural Stone Council (2009). Quarry site best practices. https://naturalstonecouncil.org/best-practices/quarry-site-best-practices/

Nartey V.K., Nanor J.N., & Klake R.K., (2012). Effects of Quarry Activities on some Selected Communities in the Lower Manya Krobo District of the Eastern Region of Ghana. Atmospheric and Climate Sciences 2(3): 362-372.

Nwachukwu M.A., Ukaegbu V.U., & Ukpai S.N., (2010). Contamination of water sources by potentially toxic elements around agricultural and quarry land uses of Oban Massif and environs southeastern Nigeria. Journal of Applied Sciences Research 6(8): 1040-1048.

Obasi, R. A., Akudinobi, B. E., & Onwuka, S. U. (2018). Estimation of carbon dioxide emissions from coal mining in Enugu area of Nigeria using carbon emission factor equation. Journal of Environmental Science and Engineering A, 7(1), 1-9.

Obasi, R. A., Nwosu, S. N., Eze, B. I., & Okoye, O. (2019). Major ocular problems found among quarry workers and residents of quarrying communities in Abakaliki Southeastern Nigeria. Journal of Ophthalmology & Eye Care, 4(1), 1-6.

Ocheli, A., Ogbe, O.B. & Aigbadon, G.O. Geology and geotechnical investigations of part of the Anambra Basin, Southeastern Nigeria: implication for gully erosion hazards. *Environ Syst Res* **10**, 23 (2021). https://doi.org/10.1186/s40068-021-00228-2

Oguntoke O., Aboaba F.O.,& Oludare H.O., (2009). Air quality assessment in the vicinity of quarry site. Malaysian Journal of Scientific Research 2(1): 37-43.

Okafor F.O., (2010). Environmental impact assessment of coal mining at Enugu, Nigeria. Impact Assessment and Project Appraisal 28(4): 299-309.

Okafor F.O., (2016). Environmental impact assessment of limestone quarrying in limestone deposit areas. Journal of Environment Pollution and Human Health 4(1): 5-11.

Okafor, O. C., & Njoku, C. (2021). Water Quality as Affected by Quarry Activities in Ebonyi State, Nigeria. Research Square Platform LLC. https://10.21203/rs.3.rs-1183204/v1

Omosanya, K.O. & Ajibade, O.M. (2011). Environmental Impact of Quarrying on Otere Village, Odeda, Southwestern Nigeria. Ozean Journal of Applied Sciences 4(1), 2011. ISSN 1943-2429

Ozcan, O., Musaoglu, N., & Seker, D. Z. (2012). Environmental impact analysis of quarrying activities established on and near a river bed by using remotely sensed data. Fresenius Environmental Bulletin, 21(11), 3147-3153.

Ozoko, D. C., Nwankwoala, H. O., & Ukaegbu, V. U. (2021). Temporal variations of heavy metals in sediment soil and dust particulates across the rock quarrying districts of the Oban Massif southeastern Nigeria. International Journal Of Geology And Mining, 7(1), 1-12.

Peter, C. (2018). Stone Quarrying Impact on Air Soil Water in Ebonyi State, Nigeria. Journal of Pollution Effects & Control, 6(2), 225. https://doi.org/10.4172/2375-4397.1000225

Sikakwe, G. U., Anam, G., & Ilaumo, B. U. (2021). Risk assessment of potentially toxic elements in stream sediments around granite quarries, barite mines, and cultivation areas, Southeastern Nigeria. Environmental Monitoring and Assessment, 193(11), 709. https://10.1007/s10661-021-09496-y

Sha, Z., Bai, Y., Li, R., Lan, H., Zhang, X., Li, J., … & Xie, Y. (2022). The global carbon sink potential of terrestrial vegetation can be increased substantially by optimal land management. Communications Earth & Environment, 3(1), 1-11. https://doi.org/10.1038/s43247-021-00333-1

Statista. (2022). Share of GDP by mining and quarrying sector in Nigeria 2021. https://www.statista.com/statistics/1276929/nigeria-share-of-gdp-by-mining-and-quarrying-sector/

Taye, E. N. A., & Brown-Wood, R. (2016). Impacts of quarry activities on water resources and effects on biodiversity; the Odonata assessment. Journal of Pollution Effects & Control, 4(4), 1000169. https://doi.org/10.4172/2375-4397.1000169

Wang, Y., Wilson, J. E., Brayshaw, D., & Lavkulich, L. M. (2017). Effects of Aggregate Extraction on Water Storage in the Pepin Creek Watershed, British Columbia, Canada. Natural Resources, 8(7), 461-477. https://doi.org/10.4236/nr.2017.8703

"Why Quarrying has become a major environmental concern" Accessed online at https://www.geeksforgeeks.org/why-quarrying-has-become-a-major-environmental-concern/ in March 2023.

"What is quarrying and why is it important? - Quarry." Quarry. N.p., 19 Mar. 2020. Accessed on 30 June 2023 at https://www.quarrymagazine.com/2020/03/19/what-is-quarrying-and-why-is-it-important/

Yeldell, A., & Squires, V.R. (2016). Restoration, Reclamation, Remediation and Rehabilitation of mining sites: Which path do we take through the regulatory maze? In V.R. Squires (Ed.), *Ecological Restoration: Global Challenges, Social Aspects and Environmental Benefits* (Ch. 3). Nova Science.