



NIGERIAN SOCIETY OF MINING ENGINEERS

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INTERNATIONAL CONFERENCE**

BOOK OF PROCEEDINGS

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T H E M E :

**Sustainable Mining in Nigeria:
Prospects and Challenges**

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ABUJA 2022 BOOK OF PROCEEDINGS

Content

Paper	Title	Page
1	Mining in Nigeria: Prospects and Challenges Goni M. Sheikh	1 - 4
2	Financing Mineral Project in Nigeria Hajiya Fatima Shinkafi	5 - 6
3	Regulatory Mechanism and Compliance in Nigeria's Mineral Industry Rasheed Bawa	7 - 10
4	Partnership and Collaboration for Extension Services for Artisanal and Small-Scale Miners in Nigeria Lawal Umar Mayere	11 - 14
5	Assessment of Socio-Economic Impact of Artisanal Granite Quarrying at Karji Community in Kaduna Metropolis, North-Western Nigeria L.K. Salati & P. Ishaya	15 - 22
6	Environmental Effect of Stone Quarrying – Case study of Zeberced Ltd, Turunku, Igabi Local Government Area, Kaduna State Lydia B. Orunmade, & A.D. Bida	23 - 27
7	Comparative Analysis of Rock Fragmentation in Granite Quarry using Kuz-Ram Model and Split-Desktop Software I. K. Augustine	28 - 34
8	Mq135 GMCD for Detecting Underground Mine Gases O.E. Adebayo, O.M. Salawu & E.O.A. Damisa	35 - 41
9	A Review of Some Mining Legislation in Nigeria: Origin, Effects, Limitations and Possible Reform Akinluyi Olamide Victor	42 - 46
10	Appraisal of Process Route for the Preparation of Kibya Silica Sand for Glass Production I. Isa, U. Aminu & A.A. Abubakar	47 - 50
11	Characterization of Deru Silver-Gold Ore, Bauchi State Isa, I & E.O Ajaka.	51 - 56
12	Economic Assessment of Artisanal Gold Mining in Uke Community, Nasarawa State, North-Central Nigeria L.K. Salati & Z.M. Umah	57 - 67
13	Geochemical and Economic Potential of Calcite Deposit from Owa Kajola, Ifelodun LGA, Kwara State, North Central, Nigeria Agbalajobi, S.A., Obaro, R.I., Jethro, M. A., & Oyathelemi E.O.	68 - 72
14	An Appraisal of Reclamation Method of Mined Out Area: Case Study of Bua Cement Quarry Plc, Sokoto, North Western Nigeria S. Omale & A. D. Bida	73 - 78
15	A Review of the Causes, Effects and Controls of Pipe Sticking in Hole Cleaning Adebayo Samuel Ayomide	79 - 82
16	Tackling Security Challenges in the Mines: A Case of Illegal Mining and Banditry in Northern Nigeria L. K. Salati & H. Haruna	83 - 88
17	Computer Software and Its Application in Mineral Exploration and Mining Yekeen Salau Agunleti	89 - 94
18	Activation of Faya Clay Using Different Sodium Compounds N. P. Dodo, J.P. Dodo & U.A. Hussaina	95 - 97
19	Environmental Footprints of Sand Mining in Nigerian Coastal Regions Ogunjimi Ayodeji Emmanuel	98 - 102



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**Nigerian Society of Mining
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11th - 14th October

**Communique of
Abuja 2022
International Conference**

**The Communique of the Nigerian Society of Mining Engineers (NSME)
at 21st Annual General Meeting (AGM)/International Conference
held at Barcelona Hotel, Abuja**

The 21st Annual General Meeting/International Conference of the Nigerian Society of Mining Engineers (NSME) held at Barcelona Hotel, Abuja with the theme: **Sustainable Mining in Nigeria: Prospects and Challenges**.

The Conference drew participants from Government, Academia, and mining industry, engaged in brainstorming sessions dissecting the theme and came up with the following as resolutions.

1. The Society noted with great concern the abundant mineral resources that have remained insignificantly exploited. NSME enjoins Government to take deliberate and pragmatic steps to encourage harnessing these resources.
2. A major challenge confronting sustainable mining in Nigeria is largely inadequate funding. It is a known fact that mining is capital intensive.

Government attempted injecting some funds through soft loans but brick wall bureaucracies stalled full implementation. Government can do well to debottleneck the brick walls allowing operators to access the facilities with ease.

3. Insecurity has consistently threatened

sustainable mining in Nigeria with series of kidnapping invasions at mines fields.

NSME is advocating that the security architecture be further strengthened to check and control insurgency, banditry and kidnappings which activities have almost grounded legal mining operations in the country.

Synergy with community policing emphasized to ensure safe environment for investors ote sustainable mining will be a mirage.

4. NSME enjoins Government to create and sustain enabling environment to encourage foreign and local investors in the mineral sector.
5. NSME has always advocated for collaboration with Government by professionalizing the practice of mining in line with world best practices. Illegal mining activities have thrived in the Nigerian minefields overtime and at same time usurping the functions of our professionals.

NSME is making a clarion call Government to employ cognate laws protecting professionalism in the mining sector.

Engr. Prof. B. S. Jatau. FNSME
President (NSME)

Engr. A. U. Ojile, FNSME
General Secretary



Mining in Nigeria: Prospects and Challenges

Engr. Goni M. Sheikh, FNSME

Introduction

Nigeria is blessed with abundant mineral resources such as precious metals (gold), silver metallic minerals (cassiterite, tantalite, iron ores, columbite, lead/zinc sulphides, chromite, copper ores, molybdenite, manganese, wolframite, bismuthinite),

industrial minerals and dimension stones (clays, barytes, gypsum, feldspar, limestone/marble, kaolin, talc, mica, diatomite, silica sand, phosphate, soda ash) gemstones (amethyst, aquamarine, tourmaline, garnet, zircon, sapphire) and fossil fuels (coal, tarsands, bitumen, uranium).

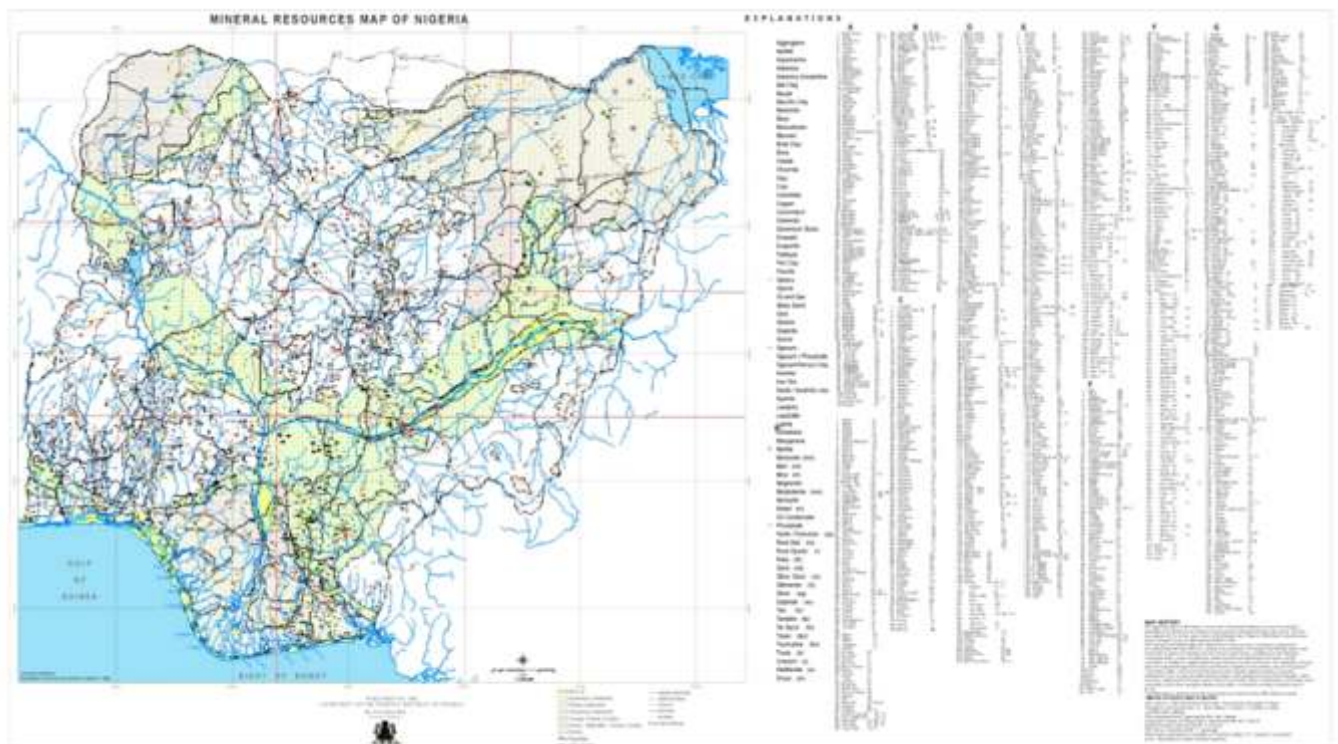


Figure 1: Mineral Resources Map of Nigeria

Nigeria had a rich history of mining. She is globally known for cassiterite, columbite and tantalite production; 6th largest producer of cassiterite. World's leading producer of Columbite at a time. Also, coal deposits were exploited in the past as a local energy source (30MW Oji River Power Station). Widespread gold production with over 3 million ounces of gold produced in the early 40s. A substantial wolframite and lead/zinc sulphides production was also experience at a time. Exploitation of these resources contributed significantly to the economy up to 10% in the 70s. Mineral resources became a major foreign exchange earner for the nation, source of raw

materials for local industries and major employer of labour: Many towns and cities developed as a result of mining.

However, discovery of oil in commercial quantities led to the neglect of the mining sector; the civil war (1966-70) that led to exodus of mining expatriates and dislocation of Nigerian miners.; collapse of the international tin price in the mid-80s; depleted surface alluvial deposits, especially tin ore; indigenization decree of the 70s and inadequate funding and inefficient state operations; all contributed the collapse of mining sector in Nigeria. This led to mines abandoned and taken over of the minefield by largely migrant illegal miners. Moreover,

complete devastation of the environment by mining activities by this illegal miners, lack of records to aid planning. Huge revenue loss and loss of life and spread of diseases and social vices has become the sad story of mining in the country.

The oil sector alone generates more than 80% of Nigeria's export earnings making Nigeria to become mono-economy. The oil sector could only employ about 6% of the workforce. and has volatile due price fluctuation: the drop-in price at a time. Also, high rate of vandalism and oil theft has made necessary to diversify the economy for sustainable growth. There is need to develop the mining sector optimally in order to improve our foreign earnings as a nation. To revitalize the mining sector, a number of reforms were carried out aimed and sanitizing the minesfield, generating quality geoscience data and attracting investment into the sector

Development of a national minerals and metals policy to give clear direction of the future activity of the Industry, transformed government's role from owner-operator to regulator-administrator and freed mineral title areas. This will pave way for private sector which the engine of growth; to lead development. Government has to restructure the ministry for enhanced performance and better administration and regulation of the sector

Enacted the 2007 Minerals and Mining Act to provide incentives for private sector participation and improved legal and regulatory framework. These regulations and guidelines were developed in 2011. Introduction of community development agreements and environmental protection and rehabilitation measures ensure that community participant in the mining business. State Mineral Resources and Environmental Management Committees (MIREMCO) to ensure participation of States and Local Governments in community engagement and conflict resolution amongst others. Fiscal incentives such as tax holiday (3 to 5 Years), low royalty (3 – 5%), tax relief period, exemptions from custom duty in respect of approved machinery for mining operations, full capitalization of exploration and pre-development expenses; provision to carry losses forward etc were introduced to woo in investors to mining business. Also, granting licenses on objective criteria based on first-come first-served basis was introduced.

With the establishment of Mining Cadastre Office (MCO) in order to granting exclusivity of rights and ensuring security of tenure; the following were

mandate given to MCO:

- Transferability of mineral titles
- Non- discretion (same rule for all)
- Transparent
- Eliminating overlap of mineral titles
- Use of time limits for granting titles

Furthermore, MCO Carried out significant transformation since its establishment such as aligned MCO to the NMMA and its regulations; upgraded to achieve automation of online application and operationalising 6 Zonal offices; fully computerised Cadastre System; impending launch of eMC Plus (e-records and archiving) and significant increase in transition from exploration licences to leases!

Strengthening institutions will help in repositioning the mining industries. Reorganizing the NGSA into a parastatal to facilitate provision of quality geoscience data and information to investors for economic diversification: geological mapping, geochemical mapping geophysical mapping, mapping of mineral targets, development of mineral database, geodata archiving, enhanced data generation through the National Integrated Mineral Exploration Project(NIMEP), Nigerian Institute of Mining and Geosciences and geosciences data generation for specific minerals: carbonates, phosphate, bitumen, magnesite.

Government has to privatize and deregulate mining sector, hence, government divested from mining activity and divestment in Nigerian Mining Corporation and Coal Corporation; Bitumen Project. The aim was to award Bitumen Blocks through bidding process and open up mineral titles space. Curbing illegal mining, government has to formalize informal operations through Mining Cooperatives, encourage registration of Mineral Buying Centres, provision of extension services: training, technical support, health and safety. Promotion and marketing of investment opportunities will make the industry attractive to investors. This can carry out using international and local mineral investment promotion activities: NDABA, PDAC, ADU, Mines and Money etc. Mineral sector support for economic diversification project (MINDIVER) came into existence in order to strengthening key government institutions; strengthening geological knowledge and improving information infrastructure; increasing downstream linkages; fostering domestic investment in the sector; improving environmental impact and supporting the delivery of the Governments mining sector roadmap

Current Mining Industry Situation

Contribution of Mining Industry to Gross Domestic Product (GDP) in some African countries:

Country	Botswana	DRC	Zambia	South Africa	Ghana	Nigeria
GDP (%)	35	18	18	7.3	5.5	0.3

Slow Progress

Despite the opportunities, reforms and improved geoscience data generation and dissemination, we are still not where we want to be. Mining is generally controlled by artisanal and informal operators. Progress had been made in attracting serious players who are working in a manner consistent with industry standards: gold, lead and zinc sulphides and cassiterite.

Key Challenge

1. Regulatory

Ensuring independence of the MCO as enshrined in the law (section 15 of the Act). Conflicts in the law (powers of officers, savings provisions)

2. Governance

Inadequate capacity to enforce extant laws. Inadequate resources to establish and operationalise statutory provisions of the law. Provision of extension services. Fully operationalising MIREMCO. Ministry Departments are not commercial oriented by their very nature. Need for a one stop shop Agency for licencing and operations. Overlap of functions with FME and NIWA. Interference in Governance by State and Local Governments. Multiple taxation. Poor ESG framework. Inadequate synergy with other MDAs on overarching functions and responsibilities. Inadequate Geoscience data generation and dissemination.

3. Operational

Interference by State Governments, Local Governments and community. Overbearing expectations and disruptive behaviour from communities. Field invasion. Poor industrial base to support production. Multiple and unpredictable taxation by State and Local Governments. Field sterilisation by illegal and informal miners. Inadequate access to equipment leasing facilities. Cycle of consent grant and withdrawals by various people within the same community. (Challenges posed by section 100(Notice to owner or occupier). Lack of sufficient manpower. Lack of backward integration and synergy with manufacturers and users. Insufficient geoscience data. Addressing environmental challenges and disturbances, noise, tailings disposal, waste water, acid water. Value addition challenges. Poor marketing capabilities. Lack of access to R&D facilities. Unlawful closure of

mining sites. Forcing and changing CDAs on operators. Registration and issuance of Licences. Outrageous demands during compensation and midnight economic trees planting by land owners. High cost of securing consent. Parallel creation of State Ministries of Mines and Environment. Almost complete lack of support from MIREMCO

4. Safety and Security

Kidnapping, banditry, armed robbery, vandalism has made difficult to access mining sites. Arrest and harassment of legitimate mining operators by state and local government officials has affected mining activities tremendously.

5. Inadequate funding options

Local financial institutions not set up to support mining operations due to long time required to break even. Funding challenges results in low productivity, inadequate exploration and evaluation

6. Professionalism

Some dishonest and unqualified professionals have been misleading and discouraging otherwise genuine investors. Lack of standardisation in the production of feasibility documents with approved codes similar to JORC (Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves) has affected the encouraging foreign investors. Inadequate infrastructure to mining sites such as power, roads, gas and fuel supplies. Most mining operations requires huge amount of power and water supplies and access to sites.

7. Perception

While geology and fiscal regimes are good, perception of the sector by foreign investors is crucial. Currently, investment attractiveness index is low

Recommendation

After viewing the key challenges face by mining operation in Nigeria, the following recommendations are suggested:

- Review the Minerals and Mining Act 2007 and address ambiguity and conflict between officials.
- Review those provisions of the law that have created difficulty and those that are practically impossible to implement (100,146(1), 76).

- Strengthen the Departments to facilitate full and complete implementation of the laws.
- Train and retrain staff for optimum service delivery
- Ban the export of unprocessed ores
- Fund the NGSA and other Agencies adequately to deliver timely and quality geoscience data
- Establish a strong Regulatory Agency that handle licencing and Operations
- Develop a local content policy similar to NOGICDA
- Develop a deliberate policy to focus on the production of industrial minerals
- State Mines Officers should be empowered to deliver their mandate effectively
- MIREMCO should be fully operationalised nationwide to deal with community and other issues
- Improve mines site policing through collaboration with security agencies
- Solids Mineral Development Fund should be fully funded
- Government should establish a sector specific funding institute and provide more generous incentives to hedge risks
- Government should fund the MMSD and its Agencies adequately considering the value addition to the economy
- The performance of service organisations

and Departments such as MCO and MI should not be judged on revenue generation, but rather on value creation

- Improve infrastructure support through collaboration with other MDAs
- Government should improve the general business climate through support services and reduced taxes
- Taxes should be harmonised
- Government should take deliberate steps to improve the country's Investment Attractiveness index

Conclusion

Nigeria is blessed with abundant minerals, the exploitation of solid minerals will increase the energy resources of the nation; The development of solid minerals will ensure supply of adequate raw materials to major industrial complexes like iron and steel, cement and fertilizer; thereby increasing capacity utilization. When mining sector is fully developed every part of the country will contribute to the National wealth. Government had reformed the sector to attract private capital. The opportunities to invest in the production of industrial minerals for local industries as well as metallic minerals and gemstones are very encouraging especially in the period of high cost of foreign exchange. Industry has several challenges that need to be addressed, if it is to achieve the set targets in the recently developed road map.



Financing Mineral Project in Nigeria

Hajiya Fatima Shinkafi,
Executive Secretary,
Solid Minerals Development Fund, Abuja

1.0. Introduction

Solid Minerals Development Fund (SMDF) was established by the 2007 Mining Act and inaugurated in 2013. SMDF, despite its noble intentions has struggled to take off but is gradually stabilizing. The present administration has envisioned to diversify the nation's economic dependency from the oil sector to non-oil sector. The Plan, through its Economic Recovery and Growth Plan (EGRP) launched in April 2017 targeted a 7% economic growth by year 2020

A more aggressive growth rate of 8.54% for the solid minerals sector was planned for the same period. The government's goal is for the solid minerals sector to contribute at least 3 percent of GDP by 2025—but it currently contributes less than half a percent.

The fund has five main objectives:

1. The development of human and physical capital
2. Geo-scientific data gathering, storage, and retrieval
3. The purchase of equipment by state-owned mining institutions
4. The provision of infrastructure and
5. The provision of extension services to small-scale and artisanal mining operations.

The intention of SMDF is to catalyse the growth of the minerals sector mainly by **providing access to financial resources** and training:

- Its intention is also by formalizing the status of artisanal miners.
- This activity is envisaged as a way to reach the 3-percent target.
- The first solid minerals roadmap, developed in 2015, had the objective of raising the sector's contribution to GDP to 5 percent by 2015, and 10 percent by 2020.
- Unfortunately, this target proved to be unattainable, and it was lowered to 3 percent

by 2025.

2.0. Project Plan

The Solid Minerals Development Funds (SMDF) an Agency under the Ministry of Mines and Steel Development, is Future of Financing Mining Project in Nigeria

1. The growth of Nigeria's economy is a cardinal responsibility of all Nigerians.
2. working towards Financing Mining Projects under Public Private Partnership with the full support of the Federal Government.
3. The Precious Metals, base metals and Industrial Metals were the initial target Project commodities,
4. Successfully executed is the **Presidential Artisanal Gold Development Initiatives, (PAGMI)**.

3.0. Financing Mining Project – What Is the Missing Link

There are most important factors in Project Financing: namely; a reliable Project to Finance and the financing proponent

3.1. What constitute a Project Finance?

Project Finance involves a corporate sponsor investing in and owning a single purpose, industrial asset through a legally independent entity financed with non-recourse to debt.

3.2. Basic required information to attract Mineral Project Financing:

- A reliable and verifiable geodata including analytical results from a world class laboratory
- A comprehensive market projectivity report showing the commodity is having a reliable and profitable off-taker
- Evacuation infrastructure are within economically acceptable positing
- There is convincing evidence of good and harmonious relationship with the community

4.0. CASE STUDY – Africa's landlocked mineral resources, on paper, bankable

Historically, non-existent transport infrastructure and the scarcity of risk capital and investment funds have limited exploration & mining development

Unlocking Africa's vast mineral resources – a straightforward problematic – or is it?

Who is going to finance the mining transport infrastructure needed?

For known iron ore projects alone, the financing needs are estimated to be in excess of US\$50 billion (4,000 km of new railways, new ports,

etc.).

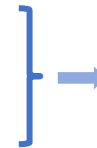
Uneven size of deposits, long distances from export location facilities strongly suggest a need for coordination between Governments and mining companies to develop affordable and bankable logistics solutions.

Multi-client/user infrastructure: a particularly relevant topic in West Africa

High Volumes

High price

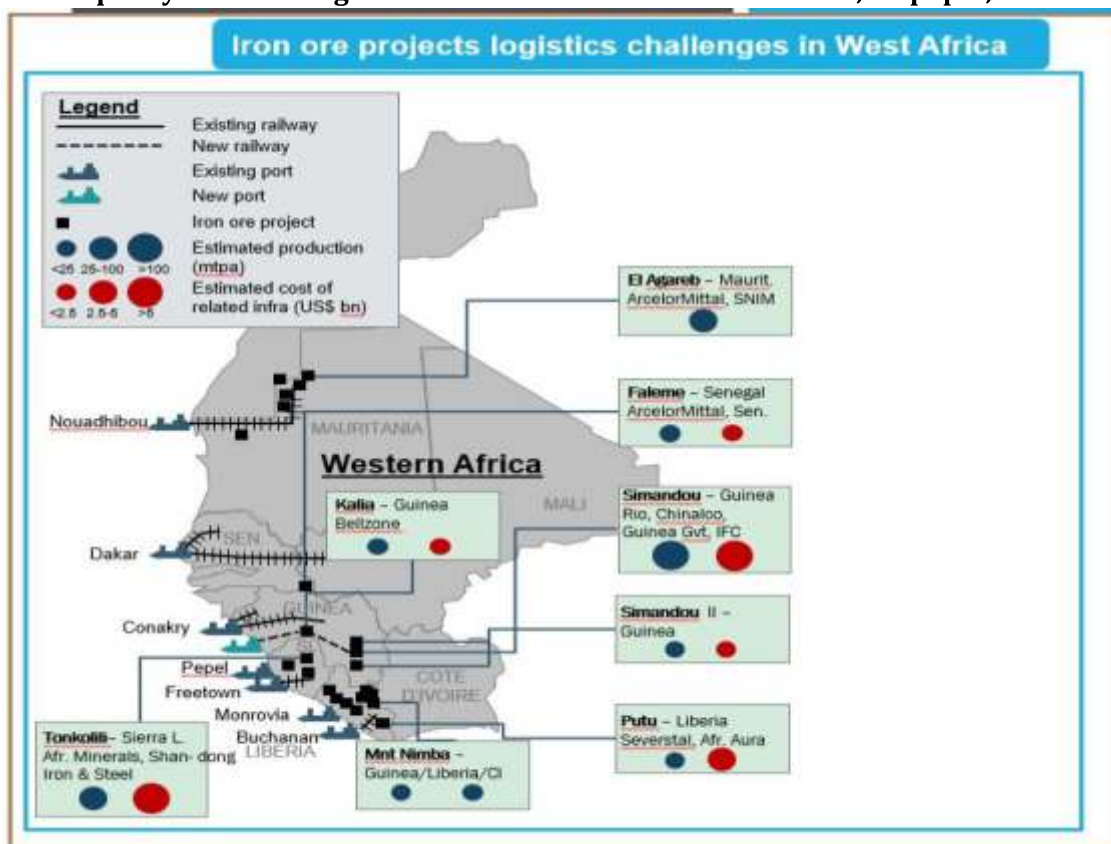
Long distances



Iron Ore / Coal:

Need for heavy rail and port infrastructure

This super cycle is making Africa's landlocked mineral resources, on paper, bankable



Conclusion and Challenges

Conclusion

High commodity prices are unlocking new opportunities. Exploiting these resources depends on having the infrastructure to export them. Government financing is simply not an option in SSA. Developing greenfield multi-user infrastructure to support mining operations through public-private partnership schemes seems to be the only credible solution to unlocking Africa's untapped mineral resources.

Challenges

Can mining companies deliver on the infrastructure?

Bankability of mining-related transport assets is difficult to achieve. There are a limited number of financing solutions available for structuring a greenfield multi-use project. Transport assets present fundamental differences with mining assets from a project finance standpoint. Sub-Saharan African countries present Sponsors with unique and often misunderstood political economy challenges.



Regulatory Mechanism and Compliance in Nigeria's Mineral Industry

Rasheed Bawa

Economic and Financial Crime Commission

Introduction

It gives me great pleasure to be at this August event organized by the Nigerian Society of Mining Engineers. I have been invited to speak on the topic "Regulatory mechanism and Compliance in Nigeria's Mineral Industry" which I believe is a topic that ought not to be only an academic exercise ending at the close of this event, but which should be canvassed at national and international platforms.

In the words of Racheal Carson, an American Marine Biologist and author of the renowned book; *Silent Springs* "The real wealth of the nation lies in the resources of the earth, soil, water, forests, minerals and wild life". An exposition of the above quote vis a vis our country Nigeria reveals that Nigeria is in possession of everything it needs to attain and retain true wealth. Indeed, every state in Nigeria including the FCT is naturally endowed with multiple deposits of minerals; from the gold rich states of Zamfara, Kebbi, Bauchi and Abia, to the gem endowed state of Kaduna to the coal, gems and ore rich states in the south, every state has at least one mineral in commercial quantities. It is however sad to note that these endowments have not translated into an economically viable industry for the nation's sustainable development. This is a sad reversal for a country which prior to the discovery of oil, developed its infrastructure, roads, rail, dams, provided free education in some of its regions, from the proceeds of minerals, agriculture and its taxes.

National development through a sustainable and viable industry is not an alien concept. All over the world, economies of nations have been built and sustained by regulated mining activities. It was reported that in 2018, the three leading mining countries worldwide, based on mineral production value (in billion U.S. dollars), where 1st China, with a total mineral production value of about \$183.8

billion, followed by Australia with \$142.9 billion and the United States of America with \$92.9 billion. It goes without saying that these countries have effectively ensured a beneficial utilization of their mineral resources.

The preceding therefore begs the question, "Can we do better? and how?". I believe that herein lies the crux of our topic; effectively regulating the Mining Industry, ensuring compliance in order to effectively harness its economic benefits for the sustainable development of Nigeria.

CURRENT REGULATORY MECHANISMS

- Federal mining activities in Nigeria is principally regulated by the Nigerian Minerals and Mining Act, 2007 which stipulates the acceptable rules, offences, fees, punishment amongst others in respect to mining industries in Nigeria.
- The Nigerian Minerals and Mining Act, 2007 vests the control and ownership of all mineral resources in, under or upon any land in Nigeria, Nigeria contiguous continental shelf and all rivers, streams and water courses throughout Nigeria, any area covered by Nigeria territorial waters or constituency and the Exclusive Economic Zone in the Federal Government of Nigeria for and on behalf of the people of Nigeria.
- The Act further prohibits any person to search for or exploit mineral resources in Nigeria or divert or impound water for the purpose of Mining except as provided for by the Nigerian Minerals and Mining Act, 2007.
- The Federal Ministry of Mines and Steel Development (MMSD) is responsible for overseeing the mining sector in Nigeria as well as the administration of the Nigerian Minerals and Mining Act, 2007.
- Furthermore, Section 8 of Miscellaneous

Offences Act (2004) criminalizes dealing in minerals without lawful authority and prescribes life imprisonment as punishment.

- It is also a regulatory requirement that prior to the commencement of mining activities, the Federal Ministry of Environment through its designated department assesses the environmental impact of the proposed mining activities and disapproves or approves by issuing the appropriate certifications.
- The Nigerian Investment Promotion Commission indirectly regulates the Mineral Industry where the players are foreigners by receipt of their application and registration of same before the commencement of business.
- If expatriates are needed to work in the industries, the Federal Ministry of Interiors and the Nigerian Immigration Service are mandated to give such approval for expatriate quota.
- Also, compliance with the provision of the Pre-shipment Inspection of Exports Act ensures that proceeds derived from the exported minerals are repatriated to Nigeria in due time.
- The Central Bank of Nigeria, Commercial Banks, Nigeria Customs Service, appointed pre-shipment agents and the Federal Ministry of Finance among others are responsible for ensuring that proceeds of exported minerals are repatriated to Nigeria.

It goes without saying that the purpose of regulation of the Minerals Industry by the Government is to ensure that there are no leakages in Government's revenue, to prevent environmental degradation, ensure creation of jobs for qualified Nigerians and foreign investments into Nigeria.

THE COMPLAINT REALITY

Despite statutory and regulatory processes listed above, the reality is that compliance by key players and stakeholders is minimal. Examples of non-compliance include the following:

- Reckless illegal mining activities causing environmental degradation, an example would be the lead poisoning which killed about 163 persons in Zamfara State, Nigeria between March and June 2010. About 111 of the victims were children.

- High number of illegal foreign expatriate working in Mineral industries where qualified Nigerians are available contrary to stipulated regulations. Often, the expatriates lack the requisite qualifications for the jobs.
- The casual nature of hiring workers in the Mining Industry is another example of non-compliance. These casual staff are paid in cash and records of their income are not made available to the respective States thereby foreclosing personal income tax due to the states from the workers' earnings.
- The Nigeria Extractive Industries Transparency Initiative (NEITI) annual solid minerals industry audit for 2018 and 2019 revealed concerning non-compliance statistics by players in the Nigerian Mining industry.

Amongst other infractions, the reports revealed that on revenues due to Federal Government in relation to royalties within the period, the Government lost about N538, 759,327.55 as shown in the table below.

Year	Issue	Government loss(N)
2018	Non-payment of Royalty by 30 companies that exported Minerals	45,318,640.50
	Under-declaration by mineral exporting companies	11,435,440.00
	Total	56,754,080.00
2019	Under-payment of royalty: There was no evidence of royalty payments by 25 companies that exported minerals in 2019	482,005,247.55
	Grand Total	538,759,327.55

The NEITI report also identified other forms of non-compliance with regulations to include:

- Unauthorized Operations,
- Issuance of Treasury Receipt of Advance Payment,

- Under Declaration of Minerals,
- Non-payment of Taxes,
- Non-Regularization of Transfer of Minerals Titles etc.

SCHEMES, TYPOLOGIES AND REMEDIES

The Economic and Financial Crimes Commission has successfully investigated several cases of fraud in the Extractive Industry. Over the years through these investigations, the Commission has been able to identify the following schemes as prevalent in the industry, ultimately costing the country significant revenues:

1. The Use of Private Mineral Buying Centres:

Private Mineral Buying Centres are centres owned and operated by private individuals or entities. The Nigerian Mineral and Mining Act, 2007 made provision for the establishment of Mineral Buying Centres which would procure mineral proceeds recovered under a licensed Small-Scale Mining lease only. Some operators of these centres manipulate the system in the following ways:

i. Lack of due diligence in the process leading to the registration: Section 95 of Nigerian Minerals and Mining Act, 2007 stipulate that “proceeds recovered under the Small-Scale Mining Lease shall be sold to a licensed Mineral Procurement Centre, hereinafter referred to as Mineral Buying Centre”. However, in reality, it is found that Private Mineral Buying Centres that do not have identified holder of Small-Scale Mining Lease are registered to commence business. The Statutory Department registers the Private Mineral Buying Centre without relevant details of their supposed source(s) of purchase of mineral proceeds.

Remedy: This can be checked by having the statutory department carry out due diligence on the Small-Scale Mining Lease holder(s) the Private Mineral Buying Centre intends to procure minerals from and conducting an interview with the owner(s) of the Small Scale Lease privately. Also, the owner(s) should be required to provide a sworn affidavit in respect to same before the private mineral buying centre is registered.

ii. Procurement of Minerals from illegal Miners. These fraudulently registered private Mineral Buying Centres' major source of mineral purchase is from illegal and unauthorized miners. To enable them to export the minerals, the Private Mineral Buying

Centre will after purchase of minerals from the illegal miners file the statutory returns to the statutory department and pay royalty which enables them to export minerals derived from illegal mining. The statutory department fails to verify the source of mineral purchases filled by Private Mineral Buying Centre to confirm if they are from a licensed Small-Scale lease before receiving the payment of royalties.

Remedy: This can be prevented by having the statutory department crosscheck records of minerals produced from the Small-Scale Lease against that of the private mineral buying centre prior to accepting records of fillings by the Private Mineral Buying Centre

iii. Payment of Royalties on illegally sourced minerals: This is usually done to legitimize the mineral proceeds of illegal mining in order to make it eligible for exportation.

Remedy: Royalties should not be received from minerals purchased by the private mineral buying centres from illegal miners rather such products should be seized by the statutory department.

iv. Under-declaration of purchased mineral resources: Sometimes the Private Mineral Buying Centres file mineral purchase returns to the statutory department which indicate lesser quantities than the actual minerals purchased. This enables them to pay less revenue to government and also disguise their purchases from the illegal sources which are then comingled with the legal ones for export.

Remedy: This can be solved by physical verification before the royalties are received.

v. The Use of Nigerians' Certificates/Certifications without the consent of the owner: To circumvent the requirement of having a qualified person such as a geologist or related experts to run relevant tests on the mineral to be procured, some fraudulent foreign players advertise for the said job and receive documentation of Nigerians who are qualified for the job. However, without employing these individuals, they use their certification to secure the registration of the private mineral buying centre and later employ the services of an expatriate who is not qualified for the job. This is a clear case of obtaining the registration by false pretenses

Remedy: This malpractice can be checked by the statutory department through interviewing the person whose certification is presented as qualified

to run the place physically and requiring an affidavit sworn to that effect before registration of the private mineral buying centre.

vi. Dealing in Minerals not approved by the Private Centres: Some of the Private Mineral Buying Centres use the centre to deal in minerals that they are not authorized to deal in. They further commingle the minerals with the authorized minerals and export it.

Remedy: The statutory department should carry out random scientific tests on the minerals meant for export at the point of export to ascertain the actual minerals meant for export.

2. The Use of Various Corporate Companies owned by the same shareholders/Management:

This scheme entails players incorporating various companies of interest to enable them evade taxes due to government and also obtain multiple licenses to avoid compliance with stipulated regulations.

a) Non-Payment of Taxes: Section 28 of Nigerian Minerals and Mining Act, 2007 grants tax relief for a company granted mineral title for a period of three years. It has been discovered that some fraudulent companies enjoy the tax relief for three years and transfer the mineral right to another company fully owned by them so as to continue enjoying the tax relief.

Remedy: The scheme can be stopped by ensuring that the owners of the companies in which the Titles are transferred to are not related parties by conducting interview with the directors of the companies separately. Also, evidence of payments or any consideration for the transfer should be documented and verified and all the statutory payments such as Value Added Tax paid on the consideration.

b) The Use of Multiple Licenses: Players in the Nigerian Solid mineral industries use various companies that belong to them to obtain various licenses so as not to comply with regulations. For example, A player that used his company 'A' to obtain Small Scale Mining Lease, Company 'B' to register as a Private Mineral Buying Centre and company 'C' to obtain the Licence to purchase mineral can easily choose not to comply with the regulation. The combination makes it more difficult for the statutory agencies to ascertain if the players are involved in illegal mining.

Remedy: Affidavits should be required for the players

to disclose all licenses, permits and any other form of authorization linked to them when they apply to be considered for any license, permit among others. Also, a central data base should be created detailing players in the mineral industry to serve as reference

III. Use of Vulnerable Nigerians as Proxy Directors by Foreign Players:

In a bid to circumvent the provisions of the regulations in respect to foreign interest in the Nigerian Mineral Industry, some foreign players that have interest in other sectors of the Nigeria economy while venturing into the mining sector, use their staff as directors of the corporate entity to drive their interest.

The said proxy directors sometimes are not aware of the actions of the owners and they are usually paid meagre amounts for their roles.

Remedy: The requirement of registration should include full disclosure on the relationship between the directors, shareholder and the promoters of the corporate entity that is seeking registration. Also, where the disclosure reveals that the directors are employees of the promoters, they should be interviewed to determine that they are not being exploited by their employer.

Conclusion

Nigeria has a credible legal framework to guard against loss of revenue and other economic benefit to Nigerians through fraud and illegal mining activities. However, like all other enacted and domesticated laws, non-enforcement and non-compliance to the provisions of regulations and laws has weakened its effect.

It is therefore expedient that Nigeria aggressively sanitizes the Mineral Resources Sector in order to enjoy the ultimate beneficial ownership of these resources thereby funding the nation's development like in the time past. This should be done through equipping and building the capacity of the relevant regulatory bodies in order to detect and prevent infractions of laid down laws by greedy individuals. It is a duty that we must willingly undertake for the benefit of the future generations. I will leave you with the thought-provoking words of the Vice President; Professor Yemi Osabanjo during a one-day visit to Zamafara State in July, 2017 where he said *"Our diversity as a people united is also our potential to transform our large deposits of mineral resources and use same for national development"*.



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Partnership and Collaboration for Extension Services for Artisanal and Small-Scale Miners in Nigeria

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"MINING POLICY OF BENEFICATION" A GAME-CHANGER FOR MINERS AND NVESTORS TO
CREATE MASS JOBS AND WEALTH - ARC. OLAMILEKAN ADEGBITE MINISTER OF MINES AND
STEEL DEVELOPMENT

1.0 Introduction

The paper intends to x-ray implementation of the Extension Services provided by the ASM department at the Ministry of Mines and Steel Development in order to find the successes, challenges as well as to propose a way forward in tune with the reality of our time. Questions like, is there any partnership and collaboration in the implementation of the EXTENSION SERVICES? If yes in what form? If no, is there any need for it? Is there any provision in the laws?



It is evidently clear that the participants in Artisanal and small-scale mining are mostly indigenous in nature. Also, the small-scale mining titles has the highest percentage upon all the types of mining titles based on the statistics of 2021 investors of minerals titles obtained from the mining cadastral office as shown below:

From the above, it is pertinent for the government to design a special programme in order to assist the title holders under this category. For years, I have been writing papers on Solid Mineral Development most of them published on national dailies after submitting to relevant agencies. I decided to share those relevant to this topic for the benefit of this August gathering and record purposes.

2.1. Revenue from Solid Minerals in Nigeria Mirage or Reality?

The paper was written in response to Mr. Presidents" declaration to the effect that attention will be focused on Agriculture and Solid Minerals in order to diversify the economy.

The paper aims to recommend improve means and ways in order to achieve the desired result. Some of the recommendations are as follows:

(a) Identify some valuable mineral deposits across the nation and do the exploration and feasibility study before issuing grant to serious companies. The idea is that the government will have a good idea of the amount of deposit in order to provide check against any attempt to short-change it. The cost of the exploration and the feasibility study to be borne by the allottee to serve as a revolving fund. This will provide a solution to the problem of lack of capacity earlier mentioned. Also the process will ensure sustainability.

(b) Enough time of study must be given to formulate proper policy taking into consideration the main problems areas in the mining sector Viz, competent agency, exploration, infrastructure, access to funds and marketing.

(c) Establishment of solid mineral development bank or a special desk at the central bank. This will provide for a loan scheme that will be investor friendly, to design a special loan to carter for the various stages of mining cycle, making funding more accessible to the miners with a low interest rate and repayment terms more reflective to the realities in the mining sector.

(d) Exploration Agencies (Geological Surveys and National Steel Raw Materials Exploration Agency) have acquired expertise in mineral exploration; as such should be empowered with modern equipment and instruments to undertake the

exploration and feasibility study as well as training ground for our young mining engineers.

2.2. Development of Solid Sector – A Balancing Factor

A committee known as MINING IMPLEMENTATION STRATEGY TEAM (MIST) was formed. Seven types of minerals were identified to be developed into major mining activity. The minerals are gold, Bitumen, Limestone, Coal, Barite, Lead and Zinc.

It is recommendations that:

- (i) The selection of the mineral types to be developed into major mining activities should cut across all the states in the federation. This will ensure the contributions of all the states into the National Economy.
- (ii) In the past, the main stay of the economy are Agriculture and Solid Minerals; as such, we recommend the judicious use of the 3% of the federation account set aside for the development of Natural Resources in the solid mineral development because of the potentials therein.
- (iii) Recommend a deliberate effort through publicity campaign to attract local investors to key-in into the mining sector value chain.

2.3. Small Scale and Artisanal Miners Intervention Fund – The Plight of Small and Artisanal Miners.

A sensitization workshop for miners for the purpose of awareness campaign on the N2.5b intervention domicile at the Bank of Industry (BOI) was carried out and the following are the recommendations:

- (i) Full implementation of the extension services to be part of the loan requirement.
- (ii) The beneficiaries for the loan must benefit from the extension services for more comfort to the bank.
- (iii) The services of the mining engineers must be involved in the appraisal of the loan proposal because of the peculiar nature of the mining business.

3.0. Provision of the Law

The relevant sections of the mining Act (2007) are sections 34, 35 and 91 for this discussion.

(A) Sections 34 & 35 – solid mineral development fund and solid mineral development, board provides that:

- i. There is hereby established a fund to be known as the solid minerals development fund.
- ii. The fund shall be utilized for the following:
 - a) Development of both human and physical

capacity in the sector.

- b) Funding for geo-scientific data gathering, storage and retrieval to meet the needs for private sector led mining industry.
- c) Equip the mining institutions to enable them perform their statutory functions.
- d) Funding for the extension services to small scale and artisanal mining operators pursuant to section 91 of this Act. And
- e) Provision of infrastructure in mines land.

The solid minerals development funds as provided in section 35(1) is to be managed by Solid Mineral Development Board and shall be a body corporate with perpetual succession and a common seal and may sue and be sued in its corporate name.

(B) Section 91 – Extension Services

The Government through the ministry shall provide the following extension services to duly registered and performing mining co-operatives of small scale and artisanal miners:

- a. Prospecting and exploration services shall be provided for mining co-operatives and artisanal to determine the geological setting, structure and nature of occurrence quantity and quality of minerals being mined.
- b. Provided mineral testing standards and the determination of minerals grades;
- c. Provide proven mineral reserve evaluation including feasibility reports;
- d. Assist small scale miners on mine design and planning suitable for the deposit;
- e. Teach adequate skills in mining to small scale and artisanal miners and regularly introduce them to new mining technology;
- f. Provision of teaching equipment and plant for hire on an arrangement with manufacturers of leasing companies and proper linkage and guarantees provided;
- g. Introduce appropriate mineral processing technology skills in order to meet market demands and optimize profit.
- h. Provision of environmental impact assessment report and detailed guidelines on waste and tailing disposal;
- i. Introduction of health and safety procedure in the mines, provision of water and health facilities to large mining camps;
- j. Holding regular workshops to update miners knowledge on legal, marketing, business skills and infrastructural support, facilitate mineral testing and the determination of mineral grades; and
- k. Facilitate mineral testing and the determination of mineral grades.

The law has provided a solid foundation for the solid minerals development as mentioned under section 34-38 and 91 of the mining Act (2007).

Therefore, the backbone of successful development of this sector lies in the full implementation of the extension services. The ministry of mines and steel development, through the Artisan and small-scale mining department implements the extension services to registered co-operatives societies and artisanal miners. They are doing their best within the limited resources available.

The cancer that bedeviled the implementation of the extension services are lack of funding and capacity building for personnel handling the issue. The disease manifest itself in two fold viz; the lack of adherence to the provision of extent laws, for example all funds for the development of this sector should be accessed through the solid minerals development fund as stated in section 38 of the Act (2007), herein presented for ease of reference; the fund shall consist of:

- (a) Any sums appropriated for solid minerals development under the revenue act or any other federal law;
- (b) Any sums appropriated for solid minerals development under the Small and Medium Industries Equity Investment Scheme (SMIEIS).
- (c) Any funds received as grants, donations, foreign loans, bonds and long-term swaps;
- (d) Any sums appropriated to it by the Federal Government Budgetary allocation. The board should confirm the true situation.

We recommend a study of Agricultural extension services in order to design more appropriate approach for the implementation.

The Agricultural extension services succeeded with the support of the World Bank and the Central Bank of Nigeria.

The approach adapted in the sector is to encourage farmers to form co-operative societies and then group them into clusters for a particular crop e.g. maize clusters, rice clusters etc. The clusters are given all the necessary support including road infrastructure in order to succeed. The central bank grant loans to these clusters of co-operative

societies; while the bank becomes the off-taker of their products, the result of which we have seen rice and maize pyramids in Abuja and Kaduna respectively.

The dream is to have similar arrangement in the mining sector under specially designed programme to reflect the peculiar nature of the sector. Imagine clusters of KAOLIN, Amethyst, sapphire, tin etc. for the purpose of adding value for local and international market in line with the Federal Government approved mining policy for beneficiation.

4.0. Way Forward

The declaration by Mr. President to focus attention on Agriculture and solid minerals for economic diversification aims to achieve the followings:

- (a) Increase organized legal mining activities in order to provide more employment most especially to our teaming youth.
- (b) Increase revenue generation from the sectors.
- (c) Increase their contribution to the GDP.

The added advantage of focusing attention on the two sectors is the reduction of the menace of rural/urban migration and can only be achieved through provision of infrastructure social amenities, job creation and security.

As stated earlier in this paper, the sure way of achieving diversification agenda is to pursue a programme of well-organized mining activities by means of forming small scale and artisanal miners cooperative societies into clusters where proper extension services will be provided under special partnership and collaboration arrangement.

There is no doubt that full implementation of the extension services as provided under section 91 has a huge cost implication which government done may not be able to bear most especially in the current economic situation. Thus, one of the ways forward is to consider collaboration and partnership between governments at various levels and the private sector on one hand, and partnership between stakeholders in the private sector to cover the entire value chain in the mining industry.

It is equally important to consider special awareness campaign to our local investors to key-in in this sector so that our minerals are used locally to enhance our economy to create jobs and create wealth for our people.

Incidentally, collaboration has been in practiced for a long time in the industry most especially with artisanal miners in the field. It works in the following manner: Labourers in the field are sponsored by the prospect off-taker called "sponsor." They give money, food items and required implements to the labourers on one condition that the person sponsored undertake to sell whatever he gets to the sponsor. The amount expended is not part of the sell bargain and if nothing is gotten out of the operation, the labourers are not required to refund. The labourers on the field are highly disciplined as they have strong leadership that intervenes in cases of default.

If individuals can be "Sponsors," why can't agencies like CBN and Solid Mineral Development Fund Board be "sponsors." Agencies that are corporate bodies with perpetual succession and a common seal and may sue and can be sued in its corporate name can design suitable programme within their laws to cater for this sector. Section 36(b) of the Act under functions and powers of the Board provides that, "Advise the minister as to changes required to improve the operation of the fund".

Conclusion

- Let all stakeholders for the formation of proper guidelines for the full implementation of the

EXTENSION SERVICES see to it.

- Partnership and collaboration are vital tools for a successful and sustainable approach. Also, innovations are great tools for growth as it enhances changes and improvements to current system.
- The new mines policy may not succeed if artisanal and small-scale miners are not carried along and this can be done by forming them into clusters where facilities and infrastructures are provided at a suitable arrangement. This will automatically eliminate or drastically reduce the menace of illegal mining in the country.
- In order to invest in developing our people and create a strong culture of constant learning, it should be a condition that mining engineers are involved in each cluster. This will also ensure compliance with applicable laws, rules and regulations related to safety, security and environment protection.
- Finally, there should be more funding to the Ministry of Mines and Steel Development and the Solid Minerals Development Fund Board to accommodate the new arrangement on sustainable basis.



Assessment of Socio-Economic Impact of Artisanal Granite Quarrying at Karji Community in Kaduna Metropolis, North-Western Nigeria

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Abstract

This study examines the socio-economic impact of artisanal granite quarrying at Karji community in Kaduna metropolis. Its objectives include identifying the socio-economic benefits and demerits of artisanal granite quarrying on workers livelihood. Primary data collected through field studies, administered questionnaires and oral interview, and secondary data sourced from literature review were used for the socio-economic assessment. The study revealed that artisanal granite quarrying workers in the community do not have access to loan facilities, training, medical attention, sponsorship of children's education, basic amenities and housing. Artisanal granite quarrying has been identified as the only source of reliable livelihood in the area but this remains meagre in the midst of numerous socio-economic challenges facing the workers. It was also revealed that 32% of the community residents earn roughly between ₦1,000 to ₦1,500 or less per day which is approximately ₦42,000 per month, accounting for a percentage of people whose household derive income from artisanal granite quarrying in the area. The negative socio-economic impacts from artisanal granite quarrying activities in the community are indicated as follows: drug use (45%), robbery (50%) and accidents (50%). Hence, artisanal granite quarrying provides significant economic benefits to workers but this is rarely felt by residents in the community. The workers' vulnerability to accidents due to non-use of personal protective equipment have been identified as potential threats. It is therefore recommended that the community should be supported by the government concerning the highlighted areas of need.

Keywords: Artisanal granite quarrying; socio-economic impact; quarry workers; livelihood.

1 Introduction

Quarrying is the process of removing rock, sand, gravel or other minerals from the ground in order to use them to produce materials for construction or other uses. The term quarry is often associated with a place where natural stone is extracted to produce building stone or dimension stones. Quarrying activities have led to development of infrastructure, created employment opportunities, growth of towns and contributed to the establishment of various Industries. Quarrying has also help in generating wealth for those involved. Aggregate products from quarries are mainly used in constructions works like buildings and road constructions, dimension stone monuments, decorative building slabs, floor tiles and other miscellaneous uses (Galetakis and Soutana, 2016).

Quarrying has been identified as one of the land use activities obtained by extraction of non-fuel and non-metal minerals from rock (Ukpong, 2012). Institutions in different parts of the world have tried to carry out researches in order to identify how quarry activity has impacted the environment. A report by the World Bank working group on

environment sustainability reveals that occupations such as lumbering, mining, quarrying, and sandblasting degrade the environmental and worsen the plight of the poor (IEG, World Bank, 2008). It is believed that quarry workers are underpaid considering the amount of labour they put in to the job. Akanimo (2015) opined that economic impacts of quarry operations on workers are synonymous with negative effects and positive benefits. According to Afeni and Adeogun (2015), negative impacts of increased quarrying activities in a community could include pressure on local housing, marketing and increase in community conflict and crime. Omosanya and Ajibade (2011) also argued that quarrying negatively affects the environment in a variety of ways during exploration and blasting, transportation and disposal of waste rocks. The primary source of noise during stone quarrying is from earth-moving and, processing equipment, and blasting (Stephen, 2014). Stehouwer *et al.* (2006) also added that quarrying activities exert tremendous pressure on limited soil and water resources, thus increasing the rate of erosion processes and subsequent damage of existing arable lands.

However, the creation of supporting social infrastructure including schools, hospital and others may transform a previously remote area. Investment in transport facilities may also improve accessibility to other centers of economic activities, further enhancing its prospect for development. In an effort to ensure sustainable development, laws and policies are often in place to limit over-exploitation of the resources. Quarrying activities generate employment and contribute to a country's Gross National Product (GNP), both through production for the local market and for export trade (National Council of Bhutan, 2013). According to Bewiadzi *et al.* (2018) and Melodi and Ogunyemi (2019), stone quarrying generates considerable employment opportunities as it is a relatively labour intensive and under-mechanized industry.

The artisanal and small-scale (ASM) sector in Nigeria provides a rural livelihood to thousands of rural families dispersed throughout the country. Because the vast majorities of miners work casually, seasonally or are migrant workers from other parts of the country, it is impossible to determine the exact or actual number of workers in the ASM sector. Asante *et al.* (2014) believe that artisanal granite quarrying is capable of creating additional job opportunities and generate additional incomes, while Bewiadzi *et al.* (2018) allude to the fact that over 500 million people in developing countries engage in occupations such as small-scale surface mining and quarrying for survival. Rock quarrying is, however, not any different from other informal activities as it engages all groups: men, women, and children. Birabwa (2006) revealed that rock quarrying involved mostly men who comprised 62 percent while the women were 38 percent. The ratio of women to men is related to the intensive activities involved in rock quarrying. Artisanal and small-scale rock quarrying also involves significant numbers of children an issue that received international attention in the 1990s following press reports on child labor in coal mines in Colombia (MMSD, 2002). Figure 1 shows artisanal granite quarrying workers in a typical site.



Fig. 1: Artisanal Granite Quarrying Workers in a Site

Birabwa (2006) identified poverty as a major causative factor in the rock workers engagement in quarrying activities. Most of the workers related poverty to lack of money to buy food, clothing, to obtain shelter or to pay for their children's education. They therefore had to engage in quarrying activities, so as to meet these basic needs. To these workers, Birabwa (2006) asserts that poverty is also associated with lack of adequate education. The rock quarry workers justified their low education status with their presence at the quarry. They also said that the nature of their work and the tools they used did not require formal education. What they needed was physical strength to extract, lift and crush rock boulders in order to earn a living. The ability to labour in this case is an asset that the poor use to realize livelihood outcomes.



Fig. 2: Chisels used for Stone Extraction by Artisans

In view of the highlighted issues concerning granite quarrying, this study, therefore, attempts to examine the socio-economic impact of artisanal granite quarrying at Karji village in Kaduna Metropolis, Kaduna State, North-western Nigeria. The study is aimed at specifically examining the socio-economic benefits and demerits of granite stone quarrying engagement on workers livelihood; appraising the existing situation and practice of quarrying processes and identifying the necessary mitigation measures to curb its negative impact.

2 Materials and Methods Used

2.1 Description of the Study Area

Kaduna Metropolis comprises Kaduna North, Kaduna South, parts of Igabi and Chikun Local Governments Areas. The area lies between 10° 26'N and 10° 36'N latitudes, 7° 23'E and 7° 35'E longitude. The granite quarrying site is located off Ibrahim Yakowa express road. It is about 11 kilometres away from Kaduna Refining and Petrochemical Company (see Figure 3). The quarry has a good access road and comprises the granite outcrop being exploited by the artisanal quarry workers.



Fig. 3 Access Roads Leading to the Granite Quarrying Site

2.2 Climate, Vegetation and Relief

The climatic condition of Kaduna metropolis is divided into two: rainy season and dry season, each of about six months respectively. The rainy seasons is distinguished by the availability of rainfall, the wet months start in April and end in October (Omonijo, 2014). At this period, extreme rains especially in the months of August and September do occur in between and whenever they occur, they usually cause serious destruction.

A study of rainfall trend and variation characteristics across Kaduna State using eleven selected stations in the Southern, Central and Northern parts of the State for a period of 50 years (1966-2015) was carried out and the climatic condition of the study revealed that certain part of Kaduna State (the study area inclusive), has the highest total rainfall, yet there was not any significant trend in the five decadal periods that were analyzed (Abaje and Oladipo, 2019). From the early 1970s to the late 1990s the rainfall was below the long-term mean. The rainfall of the remaining years nearly approximates the long-term mean (Ati *et al.*, 2009). Figure 4 shows the satellite imagery of the area.



Fig. 4 Satellite Imagery of the Study Area



Fig. 5: Map Showing Various Locations in Kaduna Metropolis
(Source: Geo Dept. NDA Kaduna, 2013)

2.3 Brief Geology of the Area

The entire land area is underlain by Precambrian basement complex rocks of migmatite-gneiss complex, Meta sedimentary/Meta volcanic (mostly schist, quartzites, and amphibolites), Pan African granitoids and Cal – alkaline granites and volcanic of Jurassic age. Figure 6 shows the geological map of Kaduna metropolis adapted from Geological and Mineralogical Map of Kaduna State. The migmatite – gneiss complex constitutes the largest group of rocks in Kaduna area. The soil type found in Kaduna metropolis is tropical ferruginous developed soil on sandy parent material. Salawu and Sadiq (2020) described the soil of the Ribadu cantonment as tropical ferruginous that is mainly litho-soil developed on sandy material.

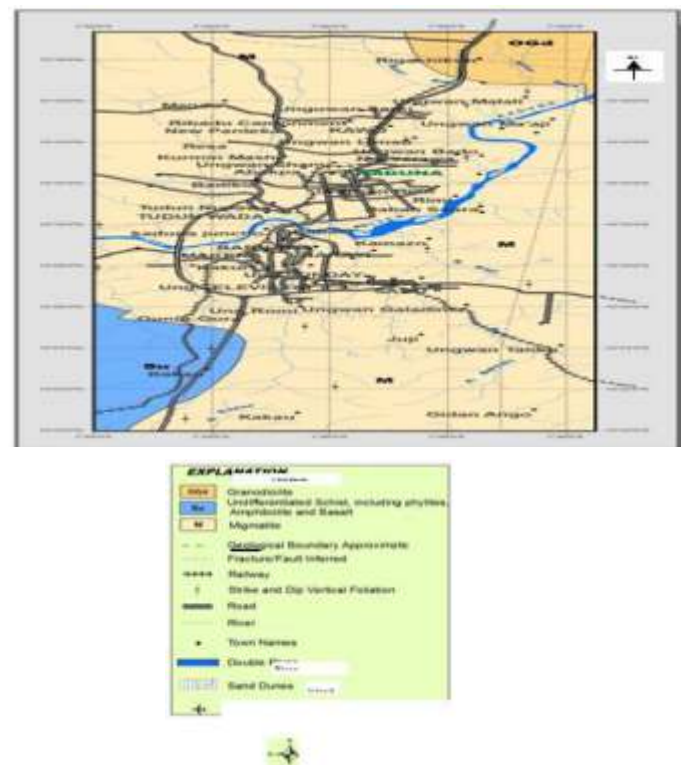


Fig. 6: Geological Map of Kaduna Metropolis
(adapted from geological and mineralogical map of Kaduna State. (Source: Geological Survey Department of Nigeria, 2004)



Fig. 7: Exposure of the Granite Quarrying Outcrop Showing its Relief

3 Field Data and Data Collection

Field studies carried out in this study involves the administration of questionnaires and conduct of oral interview for the collection of information on AGM from respondents in the area. Collection of primary data, complimented by researchers' observations on AGM's economy and structure in the area, and secondary data sourced from literature also form part of field studies and data collection. The coordinates of the location were taken and recorded with the aid of global positioning system (GPS). The processed, interpreted and analyzed data were then subjected to Microsoft Excel for further economic analysis and projections for general discussions.

The indices of socio-economic assessment employed in this study were largely drawn from critical study of Karji community's lifestyle, culture and income level. This study employed the approach adopted by Melodi and Ogunyemi (2019) in their study involving socio-economic impact of granite quarrying and the findings seem to follow the same pattern. Data collection patterns in the study were also found to have similar features with those of Afeni and Adeogun (2015) as well as those of Turyahabwe *et al.* (2021) in terms of interrelationship between the artisanal quarry workers and other community residents. Hence, socio-economic assessment of artisanal granite quarrying impacts in Karji community in Kaduna metropolis represents an evaluation of purely informal activities which require varied socio-economic approaches due to the nature of people and working tools involved.

4 Results and Discussion

All data collected from the use of questionnaires at the quarry were analyzed and used to show the distribution of socio-economic benefits of artisanal granite stone quarrying at Karji community in Kaduna metropolis. From the results of questionnaire administration and as shown in Tables 1, 2 and 3, it is implied that majority of the respondents are of younger age which indicates that they are more productive and work with more zeal to earn more from the artisanal quarrying activities. Result from Table 2 also implies that out of the 50 respondents at the quarry, a large percentage of are from Babban Saura, a neighbouring community in Kaduna metropolis, which indicates that the quarry has provided job opportunity for the youths of the nearby community and within the vicinity. Table 3 implies that more of the respondents are single and a few percentages of them are married which indicates more commitment and little distraction for the respondents. The results from Table 4 just as in latter tables show that there are less dependents on the

respondents and fewer responsibilities for them to handle.

As shown in Table 5, it is implied that the educational level of the respondents indicates less knowledge on artisanal quarrying activities which eventually leads to low productivity and inefficiency. It also implies that more training needs to be provided for them in order to improve the performance and productivity of the respondents. From Table 6, it is also implied that most of the workers earn slightly above the approved National minimum wage of ₦30,000 per month which implies that the venture is sustainable for most of the respondents. Hence, most of them can provide basic necessities for their family members, although this is not sufficient to solve their entire problems. As implied in Table 7 concerning the socio-economic benefits of the respondents, lack of access to basic social amenities, inability of the children to be educated due to financial difficulty and other social impediments have hindered the artisanal quarrying workers in the community from raising their standard of living to an enviable level. The implications of this are enormous in that income generated by artisanal and small miners is vital for revenue and Gross Domestic Product (GDP) of the State and country in general. The provision of some of these socio-economic benefits would increase interest and perception of the people and artisanal quarrying activities. From Table 8, it is implied that some of the social effects of artisanal quarrying activities on the lives of the respondents include accidents, drug use, robbery to mention a few at the quarry. These portray the activities in bad light and reduce the quest for people to get into them, especially with accidents which could be fatal. As shown in Table 9, it is implied that the production rate is quite low but with mechanization of the activity, there would be improved productivity and more income for the artisans. From Table 10, it can be deduced that with mechanization of the artisanal quarrying activities, more aggregate sizes of granite can be produced thereby increasing the income from sales of the products. Also, from Tables 11 and 12, it is obvious that the tools used by the artisans cannot yield or produce the expected revenue to provide some of the benefits required by the respondents. Therefore, there is need to upgrade their activities and tools for higher productivity and income, among other benefits. Finally, as implied in Table 13, it is clear that access to loans and grants by the artisans in form of equipment and incentives, the quarry can produce more to meet the demands for stone products by construction industries. This would translate to larger contribution to the national

economy. All the deductions made in Tables 1 to 13 are also true for Figures 1, 2, 3 as the socio-economic assessments made are in agreement with them.

Table 1: Ages of Workers Engaged in Artisanal Granite Quarrying at Karji.

Ages	Frequency out of 50 respondents	% Frequency out of 50 respondents
Less than 20 years	21	42
21-30 years	16	32
31-50 years	12	24
Above 50 years	1	2
Total	50	100

Table 2: Places of Origin of Workers Engaged in Artisanal Granite Quarrying at Karji

Places of origin	Frequency out of 50 respondents	% Frequency out of 50 respondents
Kastina state	6	12
Baban saura Kaduna state	24	48
Kano state	1	2
Rigachickun Kaduna state	1	2
Ungwan dosa Kaduna state	2	4
Kawo Kaduna state	1	2
Kafanchan Kaduna	2	4
Malali Kaduna state	2	4
Tudun wada Kaduna state	3	6
Zaria Kaduna state	8	16
Total	50	100

Table 3: Marital Status of workers in the Community

Marital status	Frequency out of 50 respondents	% frequency out of respondents
Married	19	38
Single	31	62
Divorce	-	-
Total	50	100

Table 4: Number of Children and Dependents of Respondents

	Number of children	Number of dependents	% frequency out of 19 respondents	% frequency out of 50 respondents
Less than 5	12	23	24	46
Above 5	7	6	14	12
None	-	21	-	42
Total	19	50	38	100

Table 5: Educational Level of the Workers Engaged in Artisanal Granite Quarrying at Karji

Educational level	Frequency out of 50 respondents	% Frequency out of 50 respondents
Arabic knowledge	16	32
Primary	15	30
JSSCE	9	18
SSCE	8	16
Tertiary	2	4
Total	50	100

Table 6: Income Category of the Quarry Workers

Income category	Frequency out of 50 respondents	% frequency out of 50 respondents
₦500-1000	16	32
₦1000-1500	5	10
₦1500-2000	9	18
₦2000-2500	9	18
₦2500-3000	5	10
₦3000-3500	6	12
Total	50	100

Table 7: Frequency of Workers Economic Benefits

Economic benefits	Yes (%)	No (%)	% frequency out of 50 respondents
Access to loan facilities	-	50	100
Sponsorship of children's education	-	50	100
Access to medical facilities	-	50	100
Provision of basic infrastructure	-	50	100
Improved standard of living	50	-	100
Training programs	-	50	100
Welfare packages	-	50	100

Table 8: Frequency of Respondents' Social Benefits and Demerits

Positive and negative impact	Yes (%)	No (%)
Drug use	45	5
Prostitution	-	50
Alcoholism	24	36
Increased robbery	50	-
Child labor	50	-
Job creation	50	-
Accidents	50	-

Table 9: The Total Production Rate for Year 2021

Month	Production (tonnes)
January	2,400
February	1,980
March	1,840
April	1,845
May	1,500
June	1,480
July	800
August	200
September	350
October	300
November	480
December	600
Total	13,775

Table 10: Different Aggregate Sizes Produced.

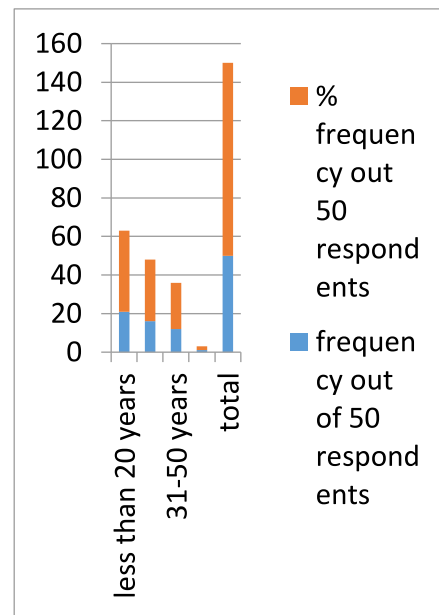
Equipment	Quantity
Big Hammer	25
Shovel	20
Small Hammer	45
Firewood	3-5 trucks
Protective hose	50
Pumping machine	5

Table 11: Equipment and Materials Requirement

Aggregate sizes(inches)	Aggregate sizes(mm)
3/8 inch	32 – 70mm
3/4 inch	19 – 25mm
Boulders	>256mm

Table 12: Quantity and Cost of Equipment and Materials

Equipment	Rate (₦)	Quantity	Total Cost (₦)
Pumping machine	45,000	10	450,000
Big Hammer	8,000	25	200,000
Shovel	800	20	16,000
Small Hammer	1,500	45	67,500
Firewood	8,000	5	40,000
Total			₦773,000

**Figure 1** Frequency Distribution of Various Ages of Workers**Table 13** Monthly Operational Cost for Year 2021 in Monetary Value

Months	Cost of firewood (₦)	Cost of fuel (₦)	Cost of equipment depreciation (₦)	Cost of Maintenance (₦)	Salary/ Royalties (₦)	Total (₦)
Jan	160,000	87,000	59,000	20,000	150,000	476,000
Feb	160,000	-	59,000	21,000	150,000	390,000
March	160,000	-	59,000	22,000	150,000	391,000
April	160,000	-	59,000	23,000	150,000	392,000
May	160,000	100,000	59,000	19,000	130,000	468,000
June	160,000	168,000	59,000	17,000	108,000	512,000
July	200,000	165,000	59,000	18,000	100,000	542,000
Aug	240,000	170,000	59,000	16,000	90,000	575,000
Sept	240,000	170,000	59,000	15,000	80,000	564,000
Oct	240,000	170,000	59,000	13,000	110,000	592,000
Nov	220,000	145,000	59,000	20,000	140,000	584,000
Dec	200,000	140,000	59,000	22,000	150,000	571,000
					Total	5,757,000

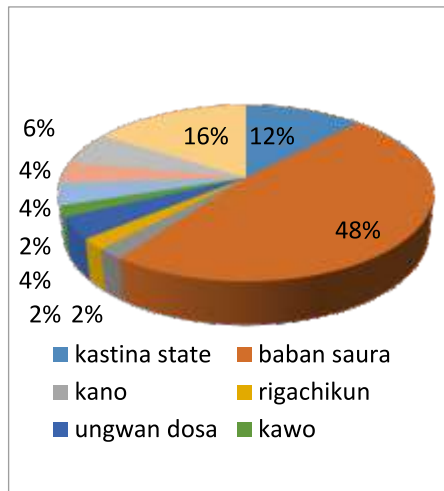


Figure 2 Percentage Frequency Distribution of Various Places of Origin

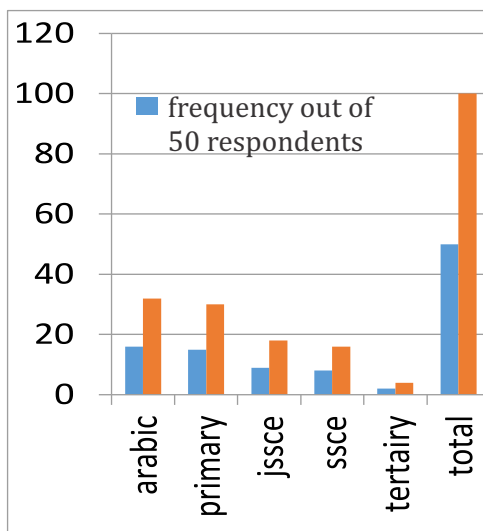


Figure 3 Frequency Distribution of various Educational Levels of Workers

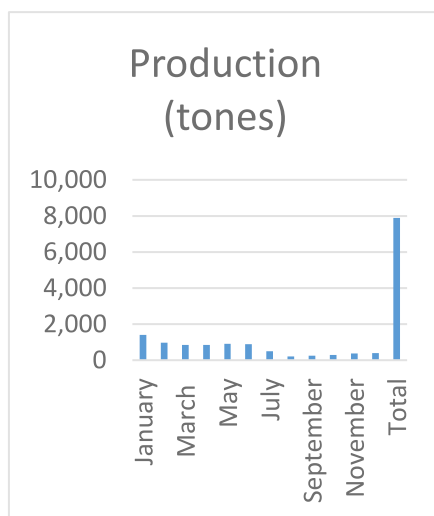


Figure 4 Total Production for the Quarry for a Year

4 Conclusions and Recommendations

A study on the assessment of socio-economic impact of artisanal granite quarrying at Karji community in Kaduna metropolis, North-Western Nigeria, has been carried out and from the results of the study, the following conclusions were made:

- Artisanal granite stone quarrying provides a number of significant socio-economic benefits to the quarry workers including job creation, improved standard of living of the workers;
- There are, however, little or no access to loan facilities, sponsorship of children's education, access to medical facilities, provision to basic infrastructure and housing; and
- Negative socio-economic impacts of artisanal quarrying engagement also lead to prevalent drug use, alcoholism, robbery and accidents among the quarry workers.

The following recommendations are thereby made from the findings of this study:

- Access to loans and grants should be made available to workers by the government in order to improve their operation.
- Technical training programmes should be organized to boost the capacity of the quarry workers
- Due to challenge of flooding of the pit and other dangers associated with artisanal quarrying activities, adequate sensitization should be organized for the residents of the community to improve their occupational safety.

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**Environmental Effect of Stone Quarrying – Case study of Zeberced Ltd,
Turunku, Igabi Local Government Area, Kaduna State**

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Abstract

Rapid growth of construction activity to meet the modern day requirements of increasing population and housing and infrastructure development needs of the society has immensely boosted the demand for building materials in Nigeria. Stone quarrying continues to play major role in this process. This research assessed quarry activities which cause environmental degradation conflicts at Zeberced Quarry Limited, Turunku in Igabi local government area of Kaduna State. Data were generated from field observation and structured interview, which were analysed using statistical tools. The major environmental problems related to quarrying revealed during this study include, landscape alteration, hill cutting affecting local biodiversity, dust pollution, noise pollution and incident of fly rocks. It is, therefore, recommended that the company should optimize its blasting parameters to address the risk of flyrocks and blasting-related accidents.

Keywords: Dust and noise pollution; Landscape alteration; Fly rocks; Biodiversity.

1.0 Introduction

Stone quarrying is the extraction of stones from natural rock beds primarily for the construction of roads and buildings (Punmia, Jain & Jain, 2013). It is carried out using different methods depending on the mineral composition, chemical, and physical constituents of rock. Stone quarrying is done almost on the ground level, which is a contrast to a mine that is carried out deeply below the earth's surface (Punmia, Jain & Jain, 2013). Quarrying methods include quarrying with channeling, explosives, and equipment and tools (Kumar, 2014). Stone quarrying is commonly done through excavation. The major environmental effects are destruction of vegetation, disruption of animal habitats, diversion and blockage of natural drainage systems, soil erosion and river situation, noise and vibration and dust pollution (Maponga and Munyanduri, 1998). According to Stehouwer *et al.* (2006), quarrying activities exert tremendous pressure on limited soil and water resources, thus increasing the rate of erosion processes and subsequent damage of existing arable lands.

Generally, a quarry is a type of open-pit mine in which dimension stone, rock, construction aggregate, riprap, sand, gravel, or slate is excavated from the

ground. The operation of quarries is regulated in some jurisdictions to reduce their environmental impact. Thus, quarrying entails the process of removing rock, sand, gravel or other minerals from the ground in order to use them to produce materials for construction or other uses. So, a quarry is any such working on the surface of the earth where minerals are extracted. Quarries are also known by other names around the world: 'surface mine', 'pit', 'and open pit' or 'opencast mine'. Within the UK, the largest quantity of mineral extracted by quarrying is used for construction and known as "aggregates". (Raymond, 2014). In most cases, stones are won using through any of the following techniques (Ternay, 2004):

- i. Digging – This method is used when the quarry consists of small & soft pieces of stones.
- ii. Heating – This method is used when the natural rock bed is horizontal and small in thickness.
- iii. Wedging – This method is used when the hard rock consists of natural fissure. When natural fissures are absent then artificial fissures are prepared by drilling holes.
- iv. Blasting – This is the breaking of rock masses using explosives to obtain the fragments and separate rock materials for further processing.

According to the Natural Environment Research Council, quarrying has played a significant role in boosting local economies for several years (NERC, 2017). The continued global population growth has propelled an increase in stone quarrying to fulfill the building and construction needs (Lad & Samant, 2014). As a result, several points of stone at Western Kentucky, which is the largest stone quarrying in the United States, generates annual sales of between \$190 and \$250 million. The report indicates that crushed stones contribute significantly to Kentucky's economy in many ways, including highway construction.

Zeberced Quarry is located at Turunku, Igabi Local government area of Kaduna State (Fig. 1.1). Zeberced limited have begun producing crushed stones in 2009 by processing the granite quarry located in Kubwa near Abuja, found within a terrain of 3.168.344,24 m². In 2018, the company had signed a material supply agreement for the highway project of Abuja-Kano Road, owned by Julius Berger Plc. It has made an investment of Quarry and Asphalt facility up to ten Million USD within the hinterland of Zaria, Kaduna State. (John 2003). Igabi town is approximately 34 km driving distance to the center of Zaria. The current local government's headquarter is Turunku with a number of towns such as Jaji, Kabubuwa, Girku, Amaza, Rihogi, Wasana, Kudandan, Rigachukun, and Rigasa making up the LGA. The estimated population of Igabi LGA is 189,055 inhabitants with the most populous tribes in the area being Hausa, Fulani and Gwari. Notable landmarks in Igabi LGA include the Turunku hills.



Fig. 1.1: Satellite Imagery of Zeberced Quarry
(www.zeberced.com)

1.1 Geology of the Study Area

The entire Kaduna State is underlain by a basement complex of igneous and metamorphic rocks of

mainly Jurassic to pre-Cambrian ages. The basement complex rocks are essentially granites, gneisses, migmatites, schists and quartzites (Benett, 1979). The geology of Kaduna North is predominantly metamorphic rocks of the Nigerian basement complex consisting of biotite gneisses and older granites (Anon, 2003).

The topographical relief is relatively flat, having an elevation of between 600 and 650 metres in large areas of each local governments. It is over 650 metres above mean sea level (a.m.s.l) in some places, and below 500 metres in places that slope downward towards the Kaduna River as shown in Fig. 1.2.

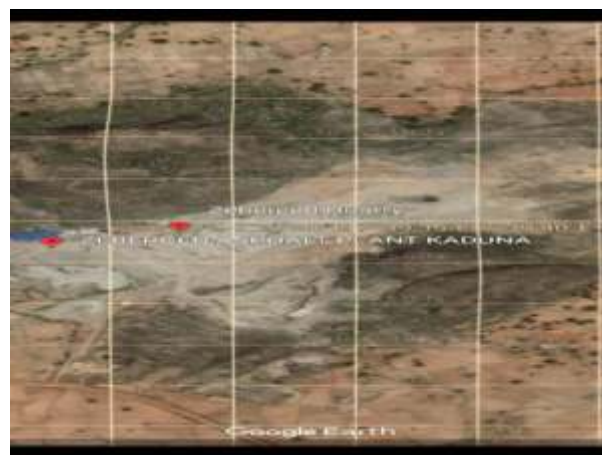


Fig. 1.2: Map of Kaduna State showing Zeberced Quarry (Source: Google Earth, 2021)

1.3 Environmental Impacts of Quarry Operations at Zeberced Limited Quarry

The environmental effects are the resultant effects that come with the activity of quarry mining or any other mining activity. They may be positive or negative impact to the environment. In some cases, development has taken the front seat and the implications of the development process are not considered. Development requires the utilization of available resources but it does not check the effects of resource utilization to the environment (Oyaigheviven, 1998). The reason why there have been many environmental problems associated with resource extraction as in the case of quarrying, is that most quarrying activities lack environmental considerations in the planning and building of the major project.

According to Ayodele and Lameed (2010), projects are usually sited for and embarked upon to satisfy

the social and economic needs of the company without the need and aspiration of the people that are directly concerned at the nearest neighboring communities as well as the impact on the primary environment. In open cast mining and quarrying environment, vast area of land usually exists, leaving behind stagnant ponds or open pits. The major environmental and social impact problems related to quarrying revealed during this study includes.

2.0 Materials and Methods Used

The research methodology was discussed under the following:

- (i) Field observation;
- (ii) Verbal interview and observations;
- (iii) Use of digital Camera;
- (iv) Google Earth; and
- (v) Data Analyses using Microsoft
- (vi) Excel.

A visit to the study area was undertaken in order to obtain information about the environment and social issues related to quarry operations. The nature of terrain and notable features were equally captured. This was followed by verbal and group interview, which was carried out covering staff and the management of Zeberced limited company. Consequently, all responses received were analysed using Microsoft Excel. Highlights of interview include:

- a) the effects of quarry activities on the workers of Zeberced limited quarry;
- b) the health impact of granite quarrying on the site workers;
- c) the social fulfilment of Community Development Agreement (CDA) and other amenities provided by Zeberced limited and
- d) the level of compliance with Nigerian extent laws on quarry operations.

3.0 Results and Discussion

3.1 Verbal Interview

Interview was conducted with some of the quarry workers at Zeberced limited quarry which involved verbal communication with the quarry staff, driller, and head of blast unit. Information sourced and data collected from the interview includes diameter of blast holes, sub-drill and

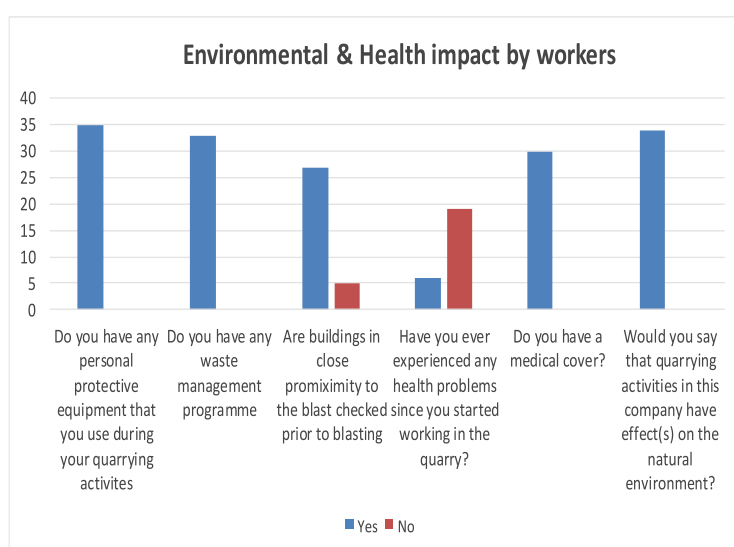
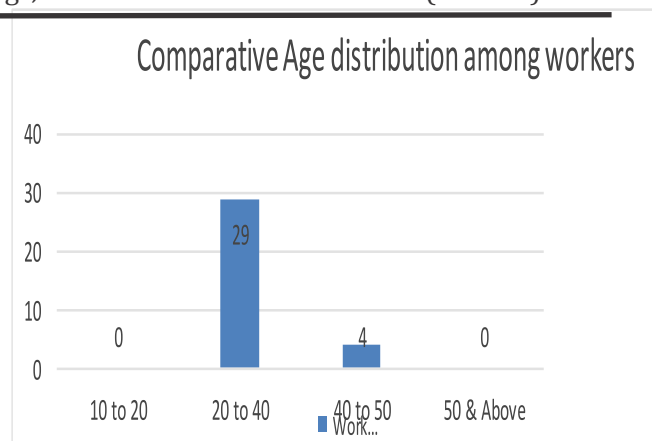


Fig. 3.2: Responses on Environmental & Health Impacts by Quarry Workers

3.2 Noise and vibration

Noise is generated during drilling, blasting and crushing activities and its also an effect of quarrying to the environment and human health. About 33% of the quarry workers when asked responded that noise is one of the major problems they are facing and they also complain of the ground vibration that comes with the noise during blasting. Due to the vibration that occurs during blasting, it causes cracks on the ground as shown in Fig 3.3.



Fig. 3.3: Cracks due to vibration from blasting (at Zeberced quarry limited)

3.3 Flyrock Effect

These are rock fragment that fly into the air during blasting (Fig. 3.4). Since the trajectory, size and speed of flyrock are difficult or impossible to anticipate, flyrock can create a tremendous danger for workers on site. In order to prevent injury from fly rocks, staff and the community members are advice to stay indoors till the blasting is completed.



Fig. 3.4: Fly Rock at Zeberced limited quarry at a distance of 1km from where the blasting took place

4 Landform and Vegetation Cover

According to the information obtained from local elder during interview, destruction to the landscape, lost in vegetation cover, alteration of water courses etc. became prominent after the commencement of stone quarrying in the study area. Similarly, field observation also observed some of the occurrences of landslides and soil erosion along quarrying site. The soils and stone are vulnerable to swept down the slope during heavy

rains. This was as a result of large holes left after stone quarrying. The land is left bare and huge landmasses were wasted hanging dangerous from high land. The high cliffs which were left are mostly moved and others heaped in the quarry. In support of the present study (Mouflis, 2008); finding indicated that quarry activity result in the permanent alteration of original land form and the destruction of original vegetation cover.

3.5 Air Pollution

Air pollution was aggravated because of the fact that the roads in the area were plain earth and dusty coupled with the constant passage of the heavy trucks; the earth becomes loose and dust particles are always seen suspended in the air especially when there is a lot of wind blowing. When strong winds blow over the quarry sites and with the movement of trucks, a lot of dust is lifted in the air and causes a lot of nuisance around the area (Allen, 2018).

3.6 Noise Pollution

Noise means any undesirable sound that is intrinsically objectionable or that may cause adverse effects on human health or the environment. Noise is generated by all opencast mining operations from different fixed, mobile and impulsive sources, thus becoming an integral part of the mining environment. It is a common environmental factor as generated by the heavy earthmoving machineries and poses a major health risk to the mine workers. The noise occurring during extraction works that take place in mine pits is important when considering labor health and job performance as the highest disease and illness rates in mining continue to be mine worker's permanent or temporary hearing loss (Triparty, 1999).

3.7 Health related effects

Health can be defined as a state of complete physical, mental and social wellbeing of an individual, and not merely the absence of disease and infirmity (World Health Organization, 2005). Respondents from the study area show some health related issues such as physical body damage, coughs and colds, and stress.

4.0 Conclusions and Recommendations

4.1 Conclusions

Based on the findings, the following conclusions are made:

- (i) It is evident that Zeberced limited quarrying activities has impacted on the quarry workers, ranging from dust to noise pollution and vibration which led to some cracks on the ground.
- (ii) Production of flying rocks is prominent during quarry activities.
- (iii) Several boulders are produced which affect quality of fragmentation.

4.2 Recommendations

In view of the foregoing, the following recommendations are made:

- (i) Zeberced quarry limited should provide advance notification of blasting to nearby residents through written notices or by using warning sirens, or other locally-agreed arrangements.
- (ii) Compliance monitoring visits by Mines Environment Compliance (MEC) department to quarry sites should be done routinely so as to minimize the negative effects of blasting operations on human health and the quarry workers.
- (iii) The company should optimize its blasting parameters to address the risk of flying rocks.
- (iv) There is need for the company to ensure that personnel should be acquainted with best environmental management practice as set out in Environmental Protection Agency (EPA) guidelines.

Acknowledgments

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Comparative Analysis of Rock Fragmentation in Granite Quarry using Kuz-Ram Model and Split-Desktop Software

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Abstract

The efficiency of blasting operation is quantified by evaluating the fragment size distribution of muckpile produced during blasting. This study involved field data collection at ENL Quarry, which was analyzed to evaluate the rock fragmentation through images of blasted material also known as muckpiles. The study evaluates and compares the particle size distribution of ENL granite aggregate quarry using Split-Desktop digital image processing software and Kuz-Ram empirical model. Five muckpiles of blasted rocks with the same blast design were analyzed. The results of the fragment size distribution obtained from the Split-Desktop vary from that of Kuz-Ram model due to the variation in the structural features of the rocks. However, the size distributions of both models follow a similar trend. The research findings showed that the variations between the models can be attributed to differences in discontinuity characteristics that the models assumed to be uniformly distributed within the rock mass. Thus, the model is good for preliminary evaluation of blast design.

Keywords: particle size distribution, split-desktop, Kuz-ram, muckpile, quarry.

1 Introduction

Effective fragmentation of rocks is an important factor in the determination of the economic viability of the rock/mineral excavation (Lawal, 2021). The geomechanical features of rocks depend on the geology that form them, some geotechnical parameters that are intrinsic of each mass and its tectonic history (Hudson and Cosgrove, 1997).

Fragmentation degree plays an important role in control and reduction of loading, transportation and crushing costs (Siddiqui *et al.*, 2009; Akande and Lawal, 2013). A well fragmented rock requires less energy during loading and crushing with little or no cost in secondary blasting. Among the various models proposed by researchers, the Kuz-Ram model, which was proposed by Cunningham, is very popular and extensively used for predicting rock fragmentation size distribution by blasting (Cunningham, 1983; Cunningham, 1987). Despite its popularity, extensive usage and ability to predict the coarse fragments accurately, it can also give an unrealistic prediction of the amount of fines generated during blasting (Ouchterlony, 2005; Ouchterlony, 2016).

The ANN method which is found to be more accurate among the Machine learning (ML) methods for predicting rock fragmentation sizes is a black-box

approach. This makes its practical implementation difficult (Lawal and Idris, 2019; Onifade *et al.*, 2019; Lawal, 2020; Lawal *et al.*, 2021). Empirical model is still commonly applied to determine rock fragment size and distribution (Lawal, 2021; Idowu *et al.*, 2021).

The choice of a method for analysis of blast fragmentation depends largely on the essence of such analysis (Shehu *et al.*, 2020; Lawal and Kwon, 2020; Idowu *et al.*, 2021). The operation of the image analysis software involves the analysis of the digital images obtained through a smart high precision digital camera (Sanchidrian *et al.*, 2009; Bobo, 2010). The Split Desktop image analysis software is a user-friendly software with improved accuracy; no limitation on the sample sizes that can be analyzed and does not interrupt the production process (Tavakol and Hosseini, 2017). Thus, the aim of this research is to use the image analysis software to analyze the rock fragmentation of ENL quarry, Ibadan, Oyo State, Nigeria and compare the results with that of Kuz-Ram model.

1.1 Description of the study area

The study area is a fully operational granite quarry located at Akinyele Local Government, Ibadan, Oyo State, Nigeria. Figure 1 shows the geological map of

ENL quarry in Ibadan, Oyo State as extracted from the geological map of Nigeria. ENL quarry is located geographically between the latitude $7^{\circ} 30' 0''$ N to $7^{\circ} 40' 0''$ N and longitude $3^{\circ} 50' 0''$ E to $4^{\circ} 00' 0''$ E at 302 m above the sea level. Figure 2 shows the quarry site after the blasting operation.

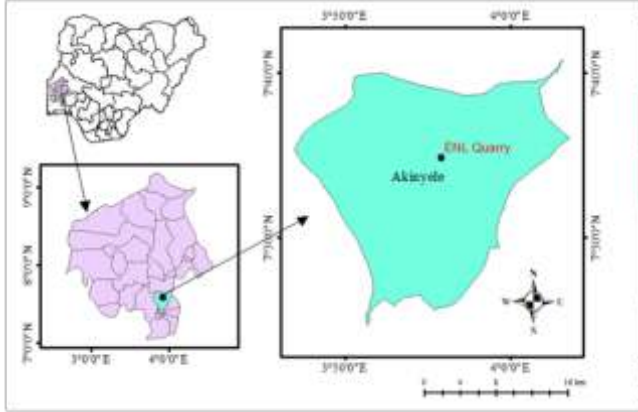


Figure 1 Map of the study area



Figure 2 ENL quarry site after blasting

2 Materials and Methods Used

This research studied five different blast operations of ENL Quarry and results of their fragmentations were examined and evaluated by the Split Desktop image analysis and Kuz-Ram empirical model. The Kuz-Ram model has three key equations; the Kuznetsov's equation, Rosin-Rammler equation and the uniformity index as shown in Eqs. (1) – (3) respectively (Shehu *et al.*, 2020).

$$X_{50} = A \times P_f^{-0.8} \times Q^{\frac{1}{6}} \times \left[\frac{115}{RWS} \right]^{\frac{19}{30}} \quad (1)$$

where;

X_{50} is the mean particle size of muckpile (cm); A is the rock factor; P_f is the powder factor (kg/m^3); Q is the

mass of explosive in the blast hole (kg); and RWS is the weight strength of explosive relative to ANFO.

Table 1 shows the recommended values of rock factor (A) for different rock mass condition. For this study, 10 was selected as value of A (Hustrulid, 1999). The Rosin-Rammler distribution (Rosin and Rammler, 1933) was used to evaluate the proportion of muckpile passing through a specific screen size as given in Eq. (2).

Table 1: Rock factor based on structural conditions

Rock mass condition	Rock factor A
Very soft	3
Soft	5
Medium soft	7
Rigid	10
Rigid and homogeneous	13

(Hustrulid, 1999)

$$R(X) = 1 - e^{-\left(\frac{X}{X_c}\right)^n} \quad (2)$$

where $R(X)$ is the % passing through a screen opening of size X ; X is screen size (cm); X_c is the characteristic size (cm); and n is the uniformity index.

Eq.3 shows the uniformity index (n) which was calculated by employing the effects of blast geometry (Akande and Lawal, 2013).

$$n = \left[2.2 - \frac{14B}{d} \right] \left[\frac{1}{2} + \frac{S}{2B} \right]^{0.5} \left[1 - \frac{w}{B} \right] \left[\frac{L}{H} \right] P \quad (3)$$

where n is the uniformity index of the Kuz-Ram model, B is burden (m), S is spacing (m), d is the hole diameter (mm), w is the standard deviation of drilling precision (m), L is the charge length (m), H is the bench height (m), and P is the factor of staggered drilling pattern.

The uniformity exponent of the Rosin-Rammler distribution is estimated as a function of the blast design parameters. The characteristic size X_c of the Rosin-Rammler distribution (Eq. 2) was obtained using Eq. (4).

$$X_c = \frac{X_{50}}{(0.693)^{\frac{1}{n}}} \quad (4)$$

3 Results and Discussion

3.1 Results

In this research, a total number of five blasted muckpiles were studied and analyzed. The blast design parameters for the five blast operations are shown in Table 2 with the burden of 2.2 m and spacing of blast holes of 2.2 m. Figure 3 shows the

particle size distribution analyses of the muckpile obtained from the five different blasts, named A to E using Split-Desktop image analysis. The results of the Split-Desktop processing of the blasted rock

fragments are recorded in all the five blasts. The Split-Desktop analyses show closely related particle size distribution for the five blasts with two uniformity indexes of 1.512 and 1.535.

Table 2 Blast design parameters

S/N	Parameter	Value
1	Burden (m)	2.2
2	Spacing (m)	2.2
3	Bench height (m)	5.5
4	Hole diameter (mm)	65
5	Stemming (m)	1
6	Sub-drill (m)	0.2
7	Powder factor (kg/tons)	0.2
8	Quantity of Explosive per meter	ANFO = 3.75 kg
9	Explosive type	Ammonium nitrate and Bulk emulsion
10	Delay time/interval	20ms

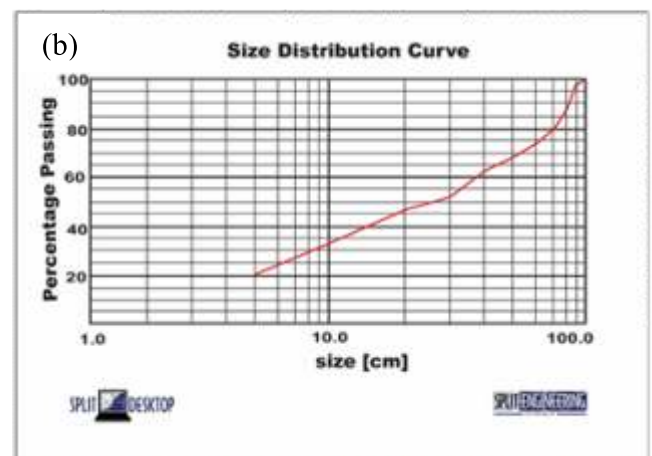
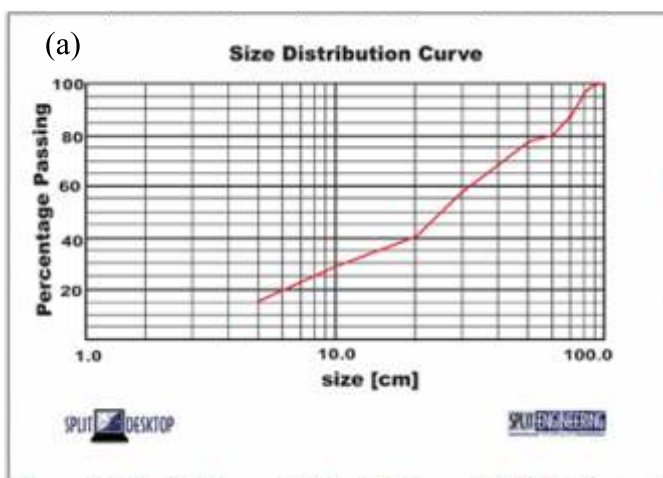
The % passing of particles from the Split-Desktop image analysis for the five blast operations are shown in Table 3, the average values of F_{50} , F_{80} and F_{90} are 73.16cm, 93.66 cm and 98.80 cm respectively. The size distribution curve of the blast design obtained from the Kuz-Ram model is shown in Figure 4 (a).

Figure 4 (b) compare the Kuz-Ram curve with the five

results obtained from Split-Desktop. The results of the fragment size distribution obtained from the Kuz-Ram model deviate from that of the Split-Desktop despite showing similar trend due to the variation in the structural characteristics of the rocks. The Kuz-Ram model shows that all the fragments of the muckpile are less than 100 cm benchmark.

Table 3 Values obtained from image analysis of the blasted rocks

Muck pile	F ₁₀	F ₂₀	F ₃₀	F ₄₀	F ₅₀	F ₆₀	F ₇₀	F ₈₀	F ₉₀
A	28.4	40.3	58.7	69.2	77.5	80.6	87.4	97.3	100
B	33.1	46.8	51.2	62.6	68.9	74.2	80.3	88.6	98.4
C	47.2	50.8	60.2	67.9	71.5	79.0	88.3	96.2	99.9
D	29.2	38.9	56.3	70.8	75.1	81.0	85.7	93.2	98.1
E	38.9	42.6	58.2	65.7	72.8	77.2	89.4	93.0	97.6



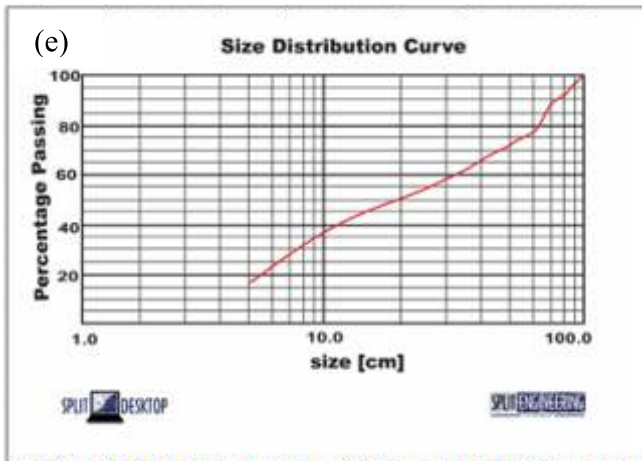
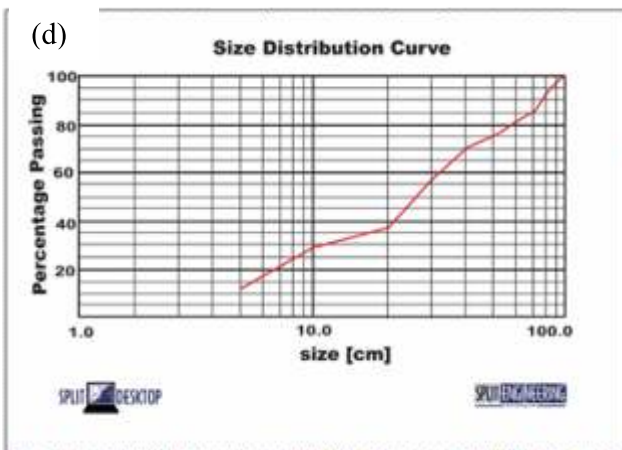
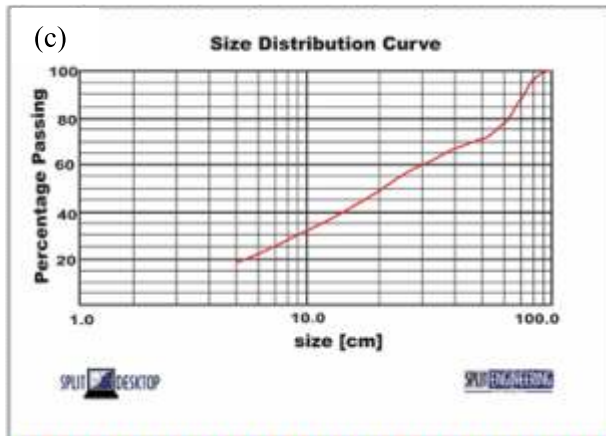


Figure 3 Cumulative Grain Size Curves of Image Analysis of Blasts A-E. **Figure 3** Cumulative Grain Size Curves of Image Analysis of Blasts A-E.

The percentage passing obtained from the Kuz-Ram model analyses of the blasted rock is shown in Table 4.

Table 4 Results of the Kuz-Ram model

Size (cm)	F ₁₀	F ₂₀	F ₃₀	F ₄₀	F ₅₀	F ₆₀	F ₇₀	F ₈₀	F ₉₀
% Passing	6.04	16.28	27.96	39.76	50.85	60.93	69.60	76.82	82.65

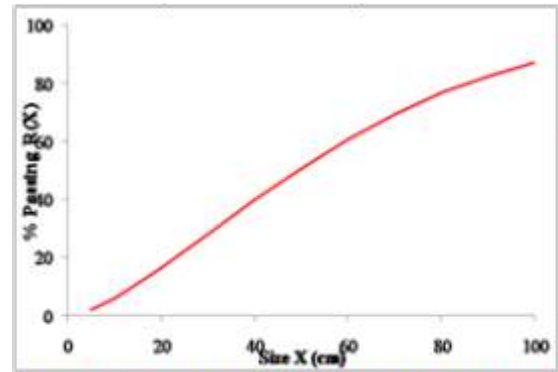


Figure 4a Kuz-Ram curve at ENL.

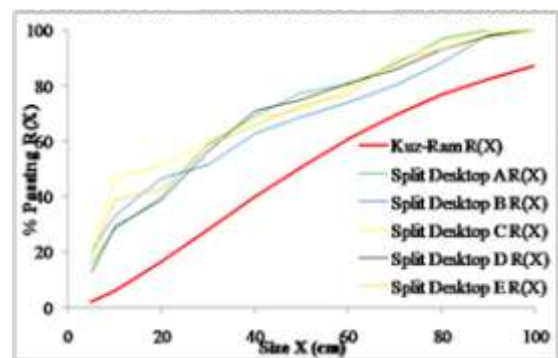


Figure 4b The varied size distribution curves for blasts A-E away from the Kuz-Ram curve at ENL.

According to Lawal (2021), the percentage error of the image analysis can be calculated by Equation 5;

$$\% \text{Error} = \frac{|I_A - \text{Kuz-Ram}|}{I_A} \times 100\% \quad (5)$$

where, I_A is the value obtained from the image analysis, Kuz - Ram is the value obtained by Kuz-Ram model.

Table 5 shows the error analysis of the Split-Desktop and Kuz-Ram models for the five blasts.

By comparing the results obtained from the Split-Desktop with that of the Kuz-Ram model, the error analysis was also carried out to further ascertain the variations between the two models. It can be seen as presented in Table 6 that the overall average error

between the Split-Desktop and Kuz-Ram model for F_{50} , F_{80} and F_{90} are 30.38%, 17.89% and 16.34% respectively. Table 6 shows the characterization features of the analyses.

Figure 5 shows that the five independent results from

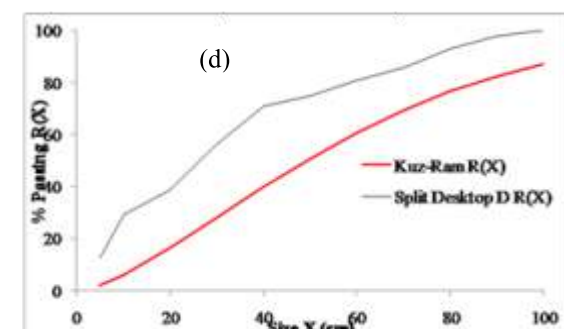
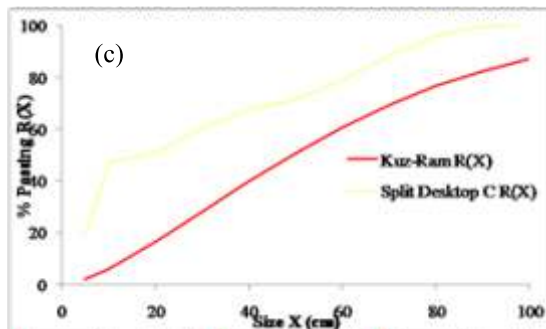
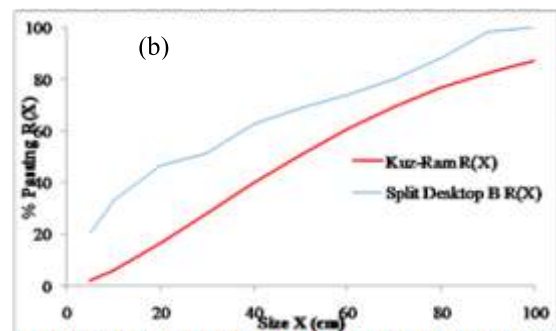
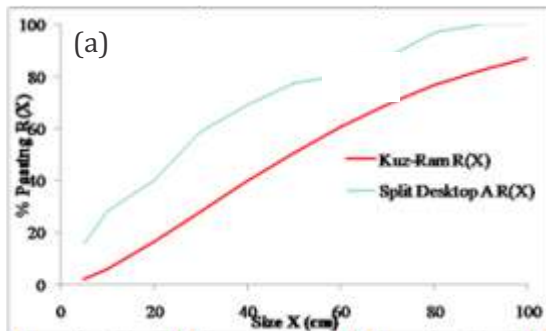
the Split-Desktop model are very close and thus reflects the same design method. The small variations from the results can be attributed to variation in rock mass structural features (Gheibie *et al.*, 2009; Akbari *et al.*, 2015).

Table 5 Error analysis of Split-Desktop and Kuz-Ram models for the muckpiles.

Fragment Size (cm)	% Error of Blast A	% Error of Blast B	% Error of Blast C	% Error of Blast D	% Error of Blast E	Average % Error of Blast
F_{90}	17.35	16.01	17.27	15.75	15.32	16.34
F_{80}	21.05	13.29	20.14	17.57	17.40	17.89
F_{70}	20.37	13.32	21.18	18.79	22.15	19.16
F_{60}	24.40	17.88	22.87	24.78	21.07	22.20
F_{50}	34.39	26.20	28.88	32.29	30.15	30.38
F_{40}	42.54	36.48	41.44	43.84	39.48	40.76
F_{30}	52.37	45.39	53.55	50.34	51.96	50.72
F_{20}	59.60	65.21	67.95	58.15	61.78	62.54
F_{10}	78.73	81.75	87.20	79.31	84.47	82.29

Table 6 Characterization features of the analyses.

	X_{50} (cm)	X_c (cm)	n
Kuz-Ram	49.2	62.68	1.512
Split-Desktop of blast A	27.5	35.03	1.512
Split Desktop of blast B	25.3	32.23	1.512
Split Desktop of blast C	20.1	25.52	1.535
Split Desktop of blast D	26.8	34.03	1.535
Split Desktop of blast D	19.7	25.02	1.535



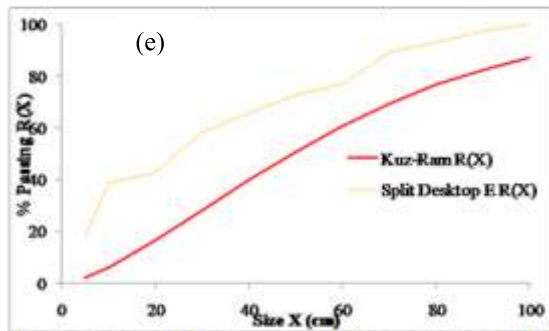


Figure 5 Kuz-Ram versus Split-Desktop Size Distribution Curves for Blast A-E

Table 6: Fragmentation Indicators for the blasted rock

S/N	Blast Events	X_{kr} (cm)	X_{bm} (cm)	FI
1	Blast A	49.2	27.5	1.789
2	Blast B	49.2	25.3	1.945
3	Blast C	49.2	20.1	2.448
4	Blast D	49.2	26.8	1.836
5	Blast E	49.2	19.7	2.497

3.2 Discussion

This study performed the particle size distribution analysis of blast-induced fragmentation of ENL granite quarry using Split-Desktop digital image analysis software and compared its results with that of the Kuz-Ram empirical model. From the analysis of five different blasts studied, it was observed that the rock mass characteristics are very important to the performance of blasting operation. The results of the Split-Desktop show close relationship with one another. Apart from reduction in transportation, handling and crushing costs, a more detailed study of rock mass will reduce the cycle time when these operations are enhanced and hence, increase the productivity. The minor differences can be linked to human errors and heterogeneity of structural geological features of the rock mass. The average values of F_{50} , F_{80} and F_{90} obtained from the Split-Desktop image analysis were 73.16 cm, 93.66cm and 98.80cm respectively. The results of Split-Desktop show that different rock masses subjected to similar blast design will usually produce varied degrees of fragmentation as a result of inherent resistances of the rock masses to blasting operation. These average values of F_{50} , F_{80} and F_{90} percentage passing of the muckpiles are considered suitable for the quarry operation as a result of the values closeness to the allowable value of 100 cm of the crusher. The particle size distribution predicted from the Kuz-Ram model shows significant variations from that of the Split-Desktop and thus, do not reflect the true values obtained in the five blast events. The Kuz-Ram model overestimates the coarseness of the fragmentation

According to Shehu *et al.* (2020), fragmentation indicator (FI) for assessing the quality of blast fragmentation is as expressed in Eq. (6).

$$FI = \frac{X_{kr}}{X_{bm}} \quad (6)$$

where; FI is fragmentation indicator, X_{kr} is expected ideal mean size of the blasted material from Kuz-Ram model (cm) and X_{bm} is mean size of blasted muck pile from particle distribution analysis (cm). Table 6 presents the fragmentation indication for the muckpiles.

and the mean fragment size predicted is larger than the correct values in the five blast events studied. These variations can be attributed to differences in discontinuity characteristics that the model assumed to be uniformly distributed within a rock mass. This is also evident from the average percentage errors obtained between the models for F_{50} , F_{80} and F_{90} as 30.38%, 17.89% and 16.34% respectively.

4 Conclusion

The study reveals that the results of the fragment size distribution obtained from the Split-Desktop vary from that of Kuz-Ram model due to the variation in the structural features of the rocks. Hence, the image processing analysis plays a fundamental role in assessing the relationship between the blasted muckpiles and the mathematical modeling of rock.

Acknowledgement

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Mq135 GMCD for Detecting Underground Mine Gases

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Abstract

Air quality in an underground mine environment can be influenced by mine-related gases depending on their concentrations, which may be hazardous to underground workers' health in both the short and long-terms. Such gases include methane (CH_4), carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), nitrogen (N_2), oxides of nitrogen (NO_x), hydrogen sulphide (H_2S) and radon (Rn). The accumulation of these dangerous gases must therefore be stopped by detection in order to provide a thorough and secure environment for underground mine workers. Therefore, MQ135 GMCD device has been developed to measure the level of gas concentration in any underground mine using an Arduino Nano and MQ135 gas sensor. The MQ135 GMCD also uses internet of things (IoT) technology to collect gas data, which can be accessed from a distance using a mobile app and WI-FI connectivity. It sends data to ThingSpeak Server once every 10 seconds. The ventilation section of the mine services workshop of the Department of Mineral and Petroleum Resources Engineering, Kaduna Polytechnic was used for the device's trial run. The results showed the concentration of four gases, including CO (4 ppm), CO_2 (2.8 ppm), H_2 (4.3 ppm), and CH_4 (0.48 ppm).

Keywords: Gas Monitoring and Control Device (GMCD), Arduino Nano, MQ135, and Internet of Things (IoT).

1 Introduction

To guarantee that the mine atmosphere offers a safe environment free from levels of dangerous gases and with the productivity of miners in mind, the concentrations of underground mine gases are detected and measured. On a moisture-free basis, the volume composition of the air entering a subterranean environment is around 78% nitrogen, 21% oxygen, and 1% other gases. However, that composition varies as the air travels through the system of subterranean holes due to a variety of variables. As a result of contamination by mine gases, it is typically found that return air from subterranean exhaust shafts has a low oxygen concentration. Impurities are produced by human exhalation, blasting, subsurface fires, lighting, bacterial activity and gases released from rock layers. Additionally, it has dampness and rock and coal dust. The following gases connected with underground mines, depending on their concentrations, may be harmful to the health of underground miners both immediately and over time: Nitrogen (N_2), Oxides of Nitrogen (NO_x), Hydrogen Sulfide (H_2S), Radon,

Hydrogen (H_2), Carbon Monoxide (CO), Carbon Dioxide (CO_2), and Oxides of Nitrogen (NO_x) and Radon (Rn). Because of this, it is essential to avoid the buildup of these dangerous gases underground and to back up prevention with detection. It should be noted that while the most frequent subsurface gases have been stated, it is more common for a number of gaseous contaminants to emerge together as gas mixes. Technology advancements have made it necessary to upgrade the detection of underground mine gases for increased effectiveness, dependability, and precision.

The concentrations of four gases (CH_4 , CO_2 , CO , and H_2) were measured in this work using a gas sensor (MQ135), which includes real-time sensing and decision-making, Internet of Things (IoT) (Ashton, 2009), and a server called ThingSpeak (an extension of MathLab).

2 Materials and Methods Used

2.1 Working Principle

The principle of the MQ135 GMCD device is likened to the electrochemical method of detecting gas (i.e. the change in electrical current is proportional to the concentration of gas in the sample/mineral). This

work consists of a tin dioxide (SnO_2): a perspective layer inside aluminum oxide micro-tubes (measuring electrodes) and a heating element inside a tubular casing. The end face of the sensor is enclosed by a stainless-steel net and the backside holds the connection terminals. The gases present in the environment are oxidized into acetic acid passing through the heating element. While the gases cascade on the tin dioxide sensing layer, the resistance decreases. By using the external load resistance, the resistance variation is converted into a suitable voltage variation. Once the gas detector senses gas in the environment, it sends the voltage variation reading through the Wi-Fi module via API key (Application Programming Interface) to ThingSpeak (a server on the web) through a router; the server is a database that reads all the gas voltage variation generated from the detector, interprets and represent the result as graphical model or spreadsheet data and stores them into different fields on the server as parts per million (ppm) or percentage (%). Other platforms can access and read data from the Server, like the Android OS (operating system) which in this case was used to read the generated data on a mobile app that displays the level of each gas in real-time, along with the GPS coordinate of the environment.

2.2 Materials

Software components:

(i) ThingSpeak Server (ii) Massachusetts Institute of Technology Application (MIT App) Inventor (iii) Arduino Integrated Development

Environment (IDE).

Hardware components:

(i) Arduino Nano (ii) Esp8662 WIFI module (iii) MQ-135 Air Quality and Gas Sensor MQ-4 Gas Sensor (v) Buck Converter (vi) Buzzer (vi) RGB Led display.

2.21 The ThingSpeak Web Server

"ThingSpeak" is an open-source Internet of Things (IoT) software and API (Application Programming Interface) for storing and downloading information from physical objects using the HTTP protocol over the Internet or through a Local Area Network, according to its creators. ThingSpeak helps the development of applications for sensor recording, location tracking and a social network of items with status updates. ThingSpeak was initially launched as a platform to aid IoT apps by ioBridge in 2010. ThingSpeak has incorporated help from MathWorks' MATLAB mathematical computation tools, allowing users of ThingSpeak to evaluate and display downloaded information using Matlab without needing Mathworks to buy a Matlab certificate. Mathworks, Inc. has a close relationship with ThingSpeak. In addition, all the ThingSpeak information is merged into the MathworksMatlab documentation platform and even allows verified Mathworks user accounts on the ThingSpeak website as legitimate login credentials. The terms of service and privacy policy of ThingSpeak.com are between the agreeing user and Mathworks, Inc. ("IoT Analytics - ThingSpeak Internet of Things," 2016).

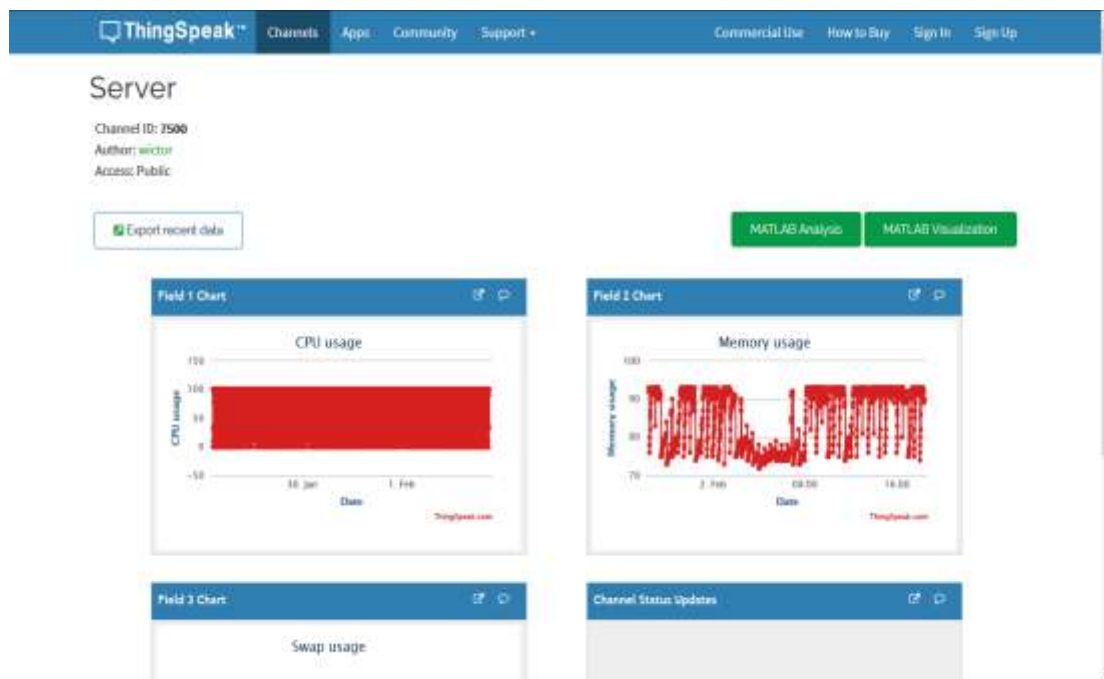


Figure 1: ThingSpeak Web Server Interface

2.2.2. MIT App Inventor

MIT Software Inventor is a user-friendly, visual programming platform that enables everyone, including children, to create completely functioning applications for smart phones and tablets. The MIT App Inventor project aims to democratize software development by enabling everyone, particularly young people, to transition from technology consumption to technology production. Professor

Hal Abelson leads a small group of CSAIL workers and students who form the backbone of a worldwide inventor movement. This core team is responsible for maintaining the free online software creation environment, which has over 6 million registered users, as well as leading educational outreach around MIT App Inventor and doing studies on its impacts (Hal, 2019).

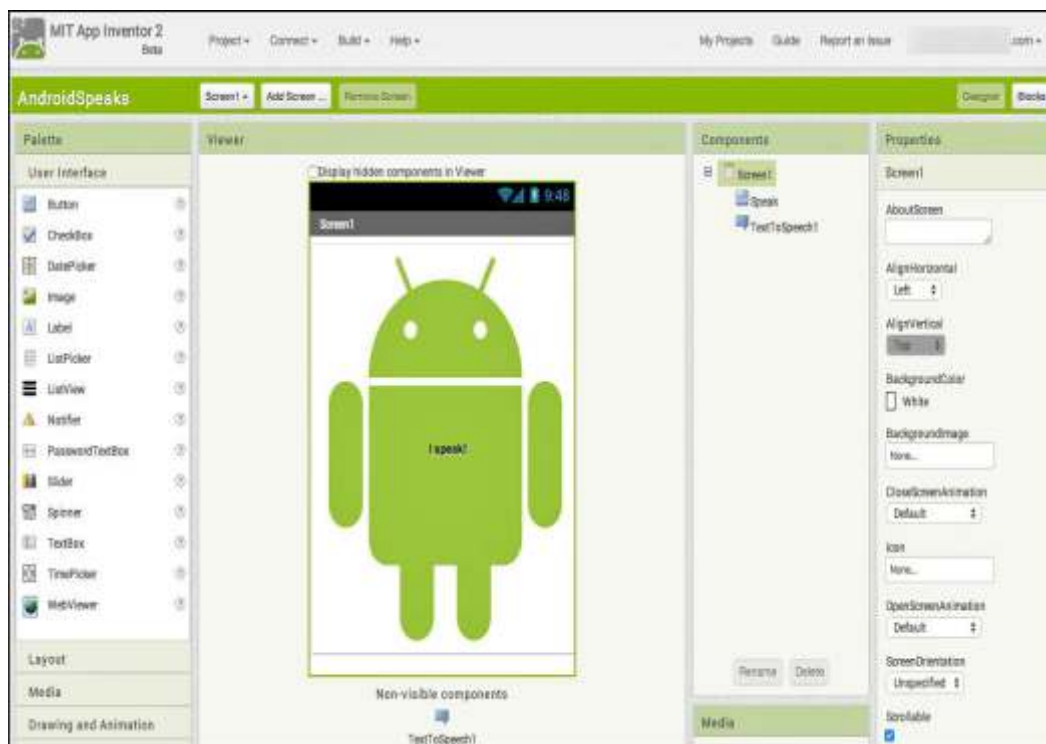


Figure 2: MIT App Inventor Environment

2.2.3 The Arduino Nano Microcontroller

Arduino is an open-source hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices. Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ('shields') or breadboards (for prototyping) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs. The microcontrollers can be programmed using the C and C++ programming languages, using a standard API which is also known as the Arduino language, inspired by the Processing language and used with a

modified version of the Processing IDE

2.2.4 The ESP8266 Wi-Fi Module

The **ESP8266** is a very user friendly and low-cost device used to provide internet connectivity to a microcontroller-based project. The unit can function both as a hotspot and a transmitter, so it can quickly capture and upload information to the cloud, making it easy to use the Internet of Things. Using the Arduino IDE, the ESP8266 module can be programmed for use..

2.2.5 MQ-135 Air Quality and Gas Sensor

The **MQ-135 gas sensor** can detect gasses like LPG, Alcohol, Propane, Hydrogen, CO, CO₂, Ammonia, Methane, Toluene and Acetone. Using an MQ sensor to detect a gas is very easy. You can either use the digital pin or the analog pin to accomplish this. Simply power the module with 5V and you should notice the power LED on the module to glow and

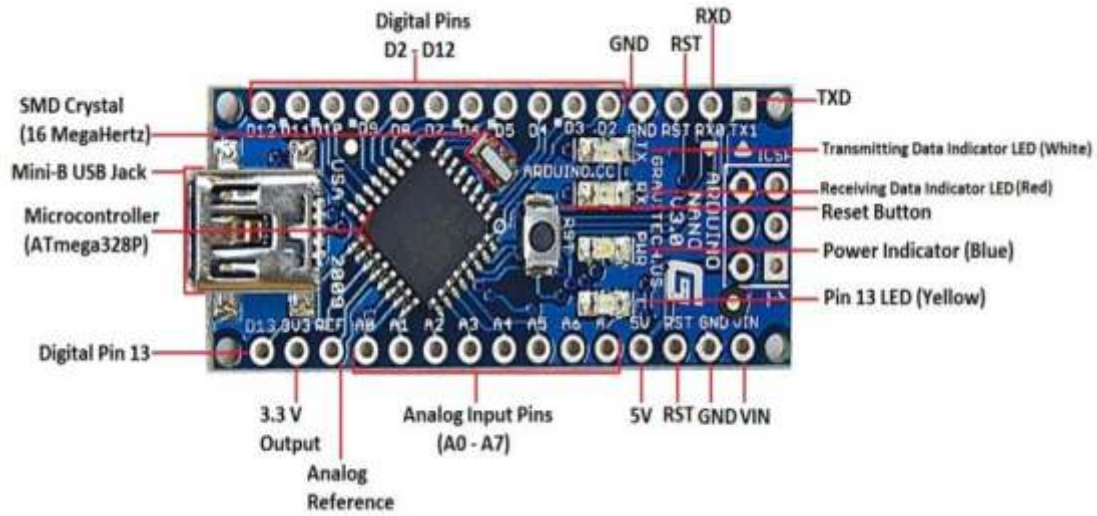


Figure 3: Arduino Microcontroller

when no gas it detected the output LED will remain turned off meaning the digital output pin will be 0V. Each time the sensor gets introduced to either of the

gases mentioned above at a specific concentration the digital pin will go high (5V) else will remain low (0V).

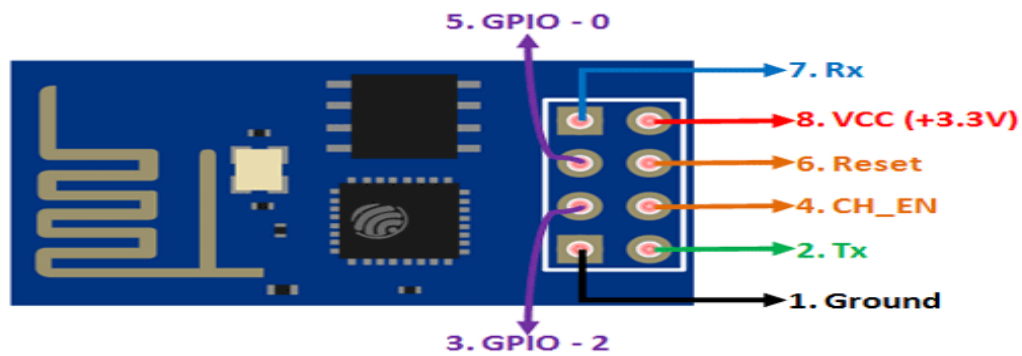


Figure 4: ESP8226 Wi-Fi Module

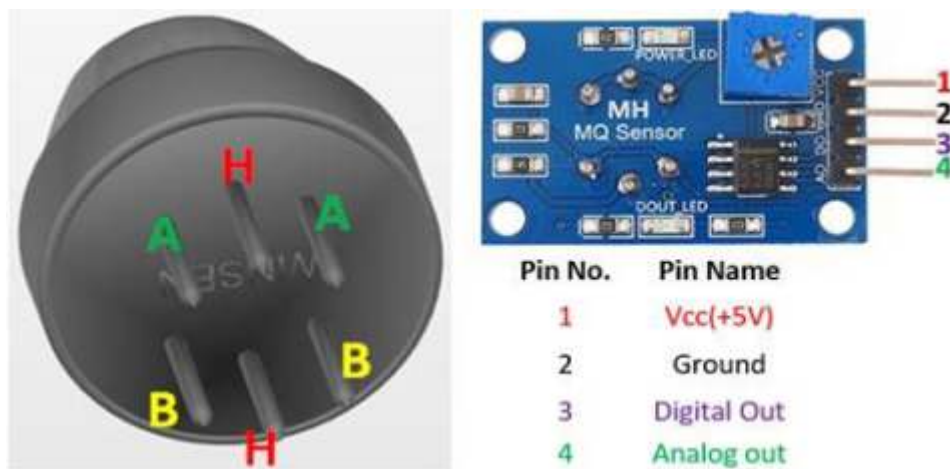
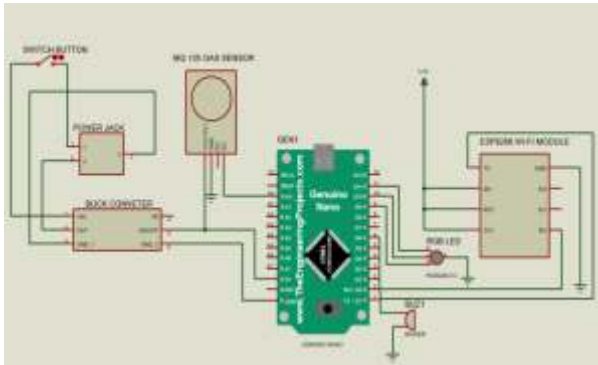
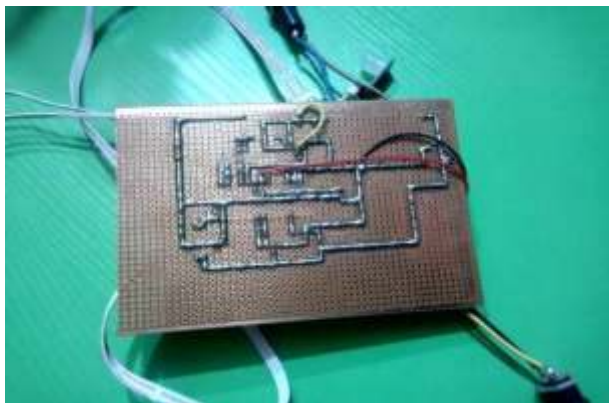
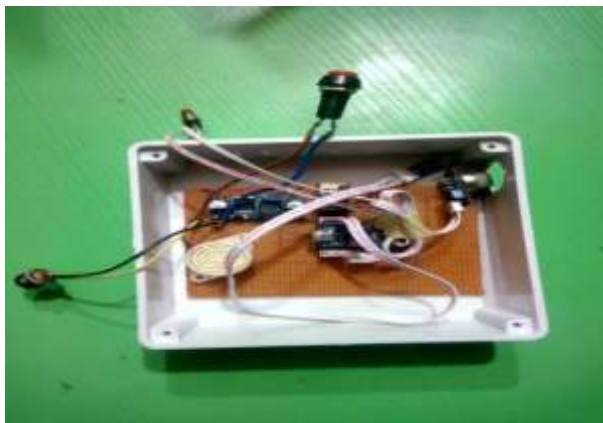


Figure 5: MQ135 Air Quality and Gas Sensor Module

Table 1: MQ135 Gas Sensor and its different Components

S/N	List of Gas the Device can Detect	Sensor Range for Each Gas (PPM)	Threshold Limit Value (PPM)
1	Methane	0 to 1012.7	1000
2	Hydrogen	0 to 300000	5
3	Carbon dioxide	0 to 110.47	30000
4	Carbon monoxide	0 to 605.18	200
5	Alcohol gas	0 to 600000	400

2.2.6 The Electrical Circuit

**Figure 6: Complete Circuit Design of the Device****Figure 7a: Soldered circuit****Figure 7b: Soldered Circuit PCB box**

3 Results and Discussion

3.1 Data Presentation

The figures shown below gives an idea of how the logging was stored on the ThingSpeak server. Each field stored each parameter needed to be viewed remotely form the mobile application. The first set of data obtained was taken at the department of Mineral and Petroleum Resources in the equipment laboratory for a period of 1hr. The result(s) are displayed below in form of a graphical model (Figs. 4.1 to 4.3).

**Figure 8: Graphical model showing Methane gas feed (0.48 ppm)****Figure 4.2: Graphical Model showing Hydrogen gas feed (4.3 ppm)**



Figure 4.3: Graphical Model showing Carbon Monoxide gas feed (4ppm)



Figure 4.4: Graphical Model showing Carbon Dioxide gas feed (2.8 ppm)

3.2 Discussion

Cost of bill for MQ135 GMCD for detecting gases in underground mines

S/N	ITEM	NO OF ITEM	PRICE (₦)
1	Arduino Nano	1	10,000
2	Patress Box	1	1,500
3	LED Display Bulb	1	1,000
4	ESP 8226 Wifi Sensor	1	5,000
5	MQ135 Sensor	1	4,000
6	Buck Converter	1	5,000
7	Fero Board	1	500
8	Resistor	5	1,000
9	Buzzer	1	500
10	Power Jack DC	1	500
11	5V DC Adapter	1	1,200
12	Switch Button	1	100
13	Hot Glue Stick	5	750
14	Jumpers/wire connectors	1 pack	500
15	Glue Gun	1	3,500
16	Miscellaneous	-	5950
	TOTAL	23	40,000

4 Conclusions

The gas monitoring and control device (GMCD) was tested at the ventilation section of the mine services workshop of the Department of Mineral and Petroleum Resources Engineering, Kaduna Polytechnic and gave the concentration of the following gases; CO (4 ppm), CO₂ (2.8 ppm), H₂ (4.3 ppm) and CH₄ (0.48 ppm). Since the sum of the series did not exceed unity, then the threshold limit value of the mixture is deemed not to have been exceeded.

4.1 Recommendations

From the aforementioned, the following recommendations are made:

- There is need to include more sensors to detect the presence of more harmful gasses such as MQ4, MQ6 and DSM501A sensor.
- The device can be upgraded to monitor multiple gases in different locations of mines.
- Incorporate solar PV to power the system so that it is always ON.
- This device can be used by small scale mining firms as well as in lotto mining to minimize mortality and long term accumulated health complications.

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**A Review of Some Mining Legislation in Nigeria: Origin, Effects,
Limitations and Possible Reform**

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Abstract

Since an earlier period, mining contributed significantly to the industrialization and development of Nigeria's economy. Organised mining of tantalite, columbite, bitumen and ores had commenced since 1903. Rapid development occurred in the mining industry during this period and led to the enactment of the Minerals Ordinance in 1946 quickly followed by the Coal Ordinance of 1950. This development was relatively short-lived though due to the discovery of oil in the Niger-Delta region of Nigeria in 1958, the civil war in the 1960s and the subsequent indigenisation policies of the Federal Government in the 1970s, there was a sharp decline in mining investments and projects in Nigeria as most foreign direct investments preferred the burgeoning oil and gas sector, which till date has remained the mainstay of the Nigerian economy, casting a large shadow on the exploitation of solid minerals scene hence its underdevelopment. This paper will give an overview of the role which some of the legal and regulatory framework which have just recently been introduced have played so far in bringing the mining sector back on track. The paper discussed particularly how the Minerals and Mining act, 2007 and the Minerals and Mining regulations, 2011 have affected the scene, relative changes to what was, limitations to be considered and recommendations on some possible solutions.

Keywords: Mining, Economy, DeveloPMENT, Minerals, Niger-Delta, Policies, Act, Regulation.

1 Introduction

Exploitation of solid minerals played a staggering role in the industrialization and early development of the Nigerian economy, right up until the late 1950s when the scope shifted majorly after the discovery of oil in the Niger-Delta region of the country which definitely seemed a game changer at the time.

The oil & gas industry blossomed over time, before the various oil shocks in the 1980s, 1990s and more recently have culminated in oscillating oil prices that have affected the Nigerian economy and necessitated the diversification of this economy. Now as it stands, despite the vast amounts of mineral deposits, the mining sector remains unharnessed and presently contributes less than 1% to the nation's GDP. This, of course, has not always been the case in the 1950's and 60's when mining contributed significantly to the growth and development of Nigeria. This contribution was unfortunately truncated by the indigenization policies of the 1970's which led to decades of stagnation and neglect of the sector with virtually all Transnational Mining Companies (TMC's) operating in the country withdrawing both their technical and financial resources. Now, at the centre of the newly elected administration of

President Muhammadu Buhari's agenda is the government's quest to transform the solid minerals sector in Nigeria through the attraction of foreign direct investments. To this end, the government has urged the review of the sector's policy and the legal and regulatory framework governing same with a view to also curtail illegal mining (Alakolaro & Akande, 2015; Advocat Law, 2015; ASTES, 2020).

The Mining Industry is now a global industry with many countries competing for exploration investment funds. The fierce international competition suggests that mining companies and their investment funds would only go to those countries where the enabling environment would allow the private sector to flourish without hindrance (Biobaku et al, 2008). One of the most critical factors to consider is the legal and regulatory framework of the country where the investment is sought. It determines how profitable it will be, which is why this study is required.

The purpose of this article is to review some of the legal and regulatory policies currently relevant to the mining sector in Nigeria. To achieve the following step will be take to:

- Highlight policies governing the mining sector.
- Evaluate the effects and influence of these policies in place on favorability of private sector investments.
- Discuss the policies and recommend means for better implementations to favor investments.

This paper spans across the various legislative and regulatory policies effective in the mining sector but focuses particularly on the Minerals and Mining Act, 2007.

2 The Legislative and Regulatory Framework

The National Assembly is saddled with the responsibility of passing laws relating to mining and other sectors of the economy. The principal legislation regulating the mining industry in Nigeria is the Minerals and Mining Act, 2007 (the Act) and the Mineral and Mining Regulations, 2011 (the Regulations). By virtue of the provisions of the Act and Regulations, the Minister of Mines and Steel Development (the Minister) is charged with the responsibility of ensuring the orderly and sustainable development of Nigeria's mineral resources and creating an enabling environment for both local and foreign investors in the mining sector. Other departments in the Ministry of Mines and Steel Development (MMSD) established by the Act to see to the regulation of the mining industry are the Mines Inspectorate Department (MID), the Mines Environmental Compliance Department (MECD) and the Mining Cadastre Office (MCO). Equally important are the complimentary legislation that impact operations in the mining industry and these include the Environmental Impact Assessment Act, Land Use Act, Explosives Act, Foreign Exchange (Monitoring and Miscellaneous Provisions) Act, Companies and Allied Matters Act, Labour Act, Employees Compensation Act, Immigration Act, Nuclear Safety and Radiation Protection Act, Mines and Quarries (Control of Building etc.) Act, Company Income Tax Act, Schedule to the Taxes and Levies (Approved List for Collection) Act (Amendment) Order 2015, and National Environmental Standards, Regulations Enforcement Agency (Establishment) Act. These legislative instruments are administered by various government agencies or departments including but not limited to the Federal Ministry of the Environment, Federal and State Inland Revenue Services, the Nigeria Nuclear Regulatory Agency and the Ministries of Land and the Environment. All of the legislative instruments listed above address various aspects of mining operations in Nigeria. (Alakolaro & Akande, 2015; ASTES, 2020).

2.1 Major Provisions of The Act

Prior to the passage of the Act, the sector was largely neglected and unregulated. The various public mining institutions had overlapping jurisdictions making application for mining titles cumbersome and unnecessarily expensive. The weakness of these mining institutions meant a dearth of accurate geological data and statistics in identifying mining prospects and the lack of any fiscal incentives was a turn off for any foreign investor. The Act and the regulations have since introduced a better regulated sector and provided an attractive investment climate for investors seeking to invest in the mining sector. We now have a transparent licensing regime with titles issued on a first come first serve basis and with the introduction of a Mining Cadastre Office we have up to date data and information on the available mining titles (Advocaat law, 2015).

2.1.1 Regulatory Bodies

In terms of regulatory responsibilities, our mining laws and regulations create various offices and prescribe their roles and responsibilities. These are as follows:

- The Ministry of Solid Minerals:** The Minister of Mine and Steel Development is vested with the overall administration of the mining industry. He oversees the sustainable development of minerals resources through the creation of an enabling environment for private investors.
- The Mining Cadastre Office (MCO):** The MCO was established for the purposes of administering mineral titles and maintaining cadastral registers. Other functions of the MCO include but are not limited to: considering applications for mineral titles and permits; issuing, suspending and revoking mineral titles; receiving and disposing of applications for renewal, extension of areas of, transfer and relinquishment of mineral titles; maintaining a chronological record of all applications in respect of mineral titles; and maintaining a priority book and general registry book.
- Mines Inspectorate Department (MID):** The MID has the sole duty of supervising all reconnaissance, exploration and mining operations for the purposes of ensuring that they comply with the provisions of the Act. Other functions of the MID include: supervising and enforcing compliance by mining title holders with all mining regulations relating to health and safety, conducting investigations and inspections necessary to ensure that all conditions relating to

grant of mineral titles as well as the requirements of the Act are complied with, and review programs for controlling mining operations for recommendation to the Minister.

iv. Mines Environmental Compliance Department (MECD): The MECD has various responsibilities which include monitoring and enforcing compliance with all environmental requirements imposed by the Act and the Regulations, periodical audit of all environmental requirements provided by the Act, the Regulations and any other law for the purposes of making recommendations on same to the Minister, and review of all plans, studies and reports on the mining environment prepared by holders of mineral titles.

v. Artisanal and Small-Scale Mining Department (ASSMD): The ASSMD has the responsibility of assisting, and supporting small scale and artisanal mining operations in the country. Other functions of the ASSMD include provision of extension services to small-scale and artisanal mining title holders, and assisting artisanal and small-scale miners to access the Solid Mineral Development Fund established by the Act (Advocaat law, 2015).

2.1.2 Mining Rights and Titles

According to the Minerals and mining act, 2007, it is important to note that though ownership of minerals in, under and or upon any land in the Federal Republic of Nigeria vests in the Federal Government, title in the mineral resources passes to the person who lawfully wins and recovers same in accordance with the provisions of the Act. Thus a foreign investor may, in accordance with the Act, acquire mining rights through an application to the MCO. These rights are usually granted on a priority basis but exploration licenses and mining leases may also be granted through a competitive bidding process for brownfield mining assets. A mining title can be granted to an applicant who is an individual, a company or a mining co-operative.

The following are the different mining titles that a private party may acquire for the exploration and exploitation of mineral resources in Nigeria:

i. Reconnaissance Permit: This permit allows, on a non-exclusive basis, reconnaissance activities on all land within Nigeria that is available for mining operations. The permit is issued and valid for a period of 1 (One) year and may be renewed upon satisfactory application for renewal of same. This permit does not cover land which is already the subject of a mining exploration license, small scale mining lease, mining lease quarry lease, or water use permit.

ii. Exploration License: The Exploration license permits the holder to exclusively conduct exploration activities on a land area not exceeding 200 square kilometers and which is not subject to an existing exploration license, mining lease or small scale mining lease. The license is granted for a 3 year term and is renewable for two consecutive periods of 2 years each subject to the title holder having fulfilled his minimum work obligation commitment and other relevant requirements of the Act. The holder of an Exploration license has the exclusive right to apply for and be granted, subject to the provisions of the Act, one or more Small Scale Mining Lease, Mining Lease, or Quarry Lease in respect of any part of the Exploration license area.

iii. Mining Lease: The mining lease confers on the holder, amongst other rights, the exclusive occupation and use of the licence area for the purposes of exploring and exploiting mineral resources. The duration of a mining lease is usually for the term applied for by the applicant but not exceeding 25 (Twenty-Five) years in the first instance and may be renewed for another 25 (Twenty-Five) year period subject to satisfactory compliance with the minimum work obligations and any commitments which may be specified by the MMSD. Mining lease is granted over an area of land not exceeding 50 square kilometers and the lease holder is not permitted to commence work in the area until after it has submitted to the MECD all environmental impact assessment studies and mitigation plans required under applicable environmental laws and has procured MECD's approval for same, concluded a Community Development Agreement approved by the MECD with relevant communities, and has paid all necessary compensation as required by the Act. A holder of a mining lease has the right to export and sell minerals won subject to other requirements for such export and sale.

iv. Small Scale Mining Lease: The small scale mining lease allows the holder of the lease to conduct artisanal mining operations which does not include the extensive and continued use of explosives, toxic chemicals or agents on an area of land not less than 5 acres but not exceeding 3 square kilometers. The holder of a small scale mining lease is not allowed to employ more than 50 workers in a typical work day and not allowed to have underground workings more than 7 meters below surface nor galleries extending more than 10 meters from a shaft.

Small scale mining lease is granted for a period of 5 (Five) years and may be renewed for further terms of 5 years and there is no limitation to the number of renewal.

- v. **Quarry Lease:** A quarry lease is granted for the quarrying of all quarriable minerals such as asbestos, china clay, gypsum, marble, limestone, sand, stone and gravel as may be specified in the lease. The quarry lease is granted in respect of an area not exceeding 5 square kilometers for a period of 5 years which may be renewed for further terms each of 5 years and there is no limitation to the number of renewal.
- vi. **Water Use Permit:** This is a right granted to a mining title holder to obtain water for use in mining exploration and exploitation. The permit is granted for the period for which the relevant mining title is granted.(Advocaat law, 2015)

2.1.3 Fiscal Incentives and Tax Laws

It is of paramount importance to any mining investor are the fiscal regime and tax incentives of the host country. Under Nigerian mining laws, a mining project is entitled to enjoy various tax advantages, incentives and benefits some of which are as follows:

- i. In determining total profits, a license holder is entitled to deduct from his assessable profits Capital allowance of 95% of qualifying expenditure incurred in the year in which the investment was made on all certified exploration, development and processing expenditure including feasibility studies; sample assaying costs; and infrastructure costs;
- ii. The amount of any loss incurred by a license holder shall be deducted as far as is possible from the assessable profits of the first year of assessment and thereafter in the year which the loss was incurred and in so far as it cannot be so made, then from such amounts of such assessable profits of the next year of assessment and so on up to a limit of four (4) years after which the period any unregistered loss shall lapse;
- iii. Exemption from customs and import duties on approved plants and machinery, equipment and accessories imported specifically and exclusively for mining operations;
- iv. Tax holiday for the first 3 years of operation which period may be extended for another 2 years. The Tax relief begins to accrue on the commencement of operations. This is at odds with CITA which only grants tax holiday of 3 years without any option of extension;
- v. Expatriate Quota and resident permit in respect

of expatriate quota personnel;

- vi. Personal remittance quota to expatriate personnel for the transfer of foreign currency out of Nigeria;
- vii. Free transferability of dividends or profits; payments in respect of servicing a certified foreign loan; and foreign capital in the event of sale or liquidation of mining operations in any convertible currency;
- viii. The Central Bank of Nigeria(CBN) may permit a title holder who earns foreign exchange from the sale of its minerals to retain in a foreign exchange domiciliary account a portion of his earnings for use in acquiring spare parts and other inputs required for mining operations which would otherwise not be readily available without use of such earnings;
- ix. Grant of investment allowance of 10% on qualifying plant and machinery;
- x. Tax deductible for environmental cost;
- xi. Tax deductible for pension funds for employees of mining companies;
- xii. Annual Capital Cost Indexation-unclaimed balance of capital cost shall be increased yearly by 5% for mines that start production within 5 years from the date of enactment of the Act;
- xiii. Deferment of royalty payments on any minerals for a specific period on the approval of the Federal Executive Council
- xiv. The investor may also be entitled to claim an additional rural investment allowance on its infrastructure cost. This is however dependent on the location of the company and the type of infrastructure provided(Advocaat law, 2015).

3 Effects of Implementation

3.1 What was

Before the Minerals and Mining Act, 2007 was passed, the market wasn't good and attractive enough which caused lack of investment particularly in the private sector. Most mining exploration and exploitation activities were dominated by government parastatals with very minimal results to show. The mining licensing and regulatory system was mostly opaque, un-accessible and discretionary. The system was massively handicapped and barely contributed to national income and development as it saw an almost total lack of investment from the private sector for close to 30 years, missing out on inter-continental mining investment funds that flowed into Africa in the 1990s. The policies gave broad discretionary powers to the minister over issues of mineral titles and the

government a right of pre-emption on all minerals exploited. All these resulted in no investments in the Nigerian mining sector.

3.2 What Was Required

Only a favorable mining sector structure would attract investments and this was the main problem of Nigerian mining sector as these policies in place were too unfavorable for the private sector. Investors want an internally attractive and stable mineral policy and decentralized administrative framework. A total involvement of private sector explorationists and assurance of protection of investment.

3.3 What Changed

The introduction of the Minerals and Mining Act, 2007 ushered in a comprehensive mining sector reform. It brought about a much anticipated fundamental shift in the sector from the Government as administrator/owner to independent regulatory bodies under which private sector investors are now driving forces in mining sector development. The mining sector saw a full review in its legal and fiscal framework strengthening mining institutions and even extending the view to environmental management. The act saw to non-discretionary and non-discriminatory procedures for granting mineral titles and created a stable, competitive and healthy fiscal regime for investment.

4 Conclusions and Recommendations

As it stands in the mining sector, we can say it is a lot better now compared to the implementation of previous laws such as the Minerals and Mining Act, 2007. The act both positively impacted and met positive response from both local and foreign investors as it introduced them to a new and favorable system which saw investments increase drastically, with over 2000 exploration licences issued in 2007 alone and projects kicking off across the country (Adeniji, 2007).

The now budding sector strengthened by these policies and regulations is still posed with a lot of challenges, one of which is the increase in illegal mining which do not in anyway acquires revenue to the government which in turn causes a lack of access to funds for prospective small scale and artisanal mining investors due to diversion of funds to combat the vice. Another major problem of the sector is insurgency especially in Northern Nigeria which

runs extensively across the schist belt rich in solid mineral. Lack of adequate security is a major risk to any mining project and this factor has led to drawbacks from intending investors as the state of security in these parts do not seem conducive for investment.

4.1 Recommendations

The following are recommended to further improve regulations and enactments of the laws and policies and also increase investments:

- i. Illegal mining is a menace that is currently paralysing the state of solid mineral exploitation nationwide. Education programs should be facilitated in rural mineral rich areas where ignorance is mainly probable cause. Informing them of the policies, means of acquisition of titles and education about artisanal mining will go a long way in the fight.
- ii. Increase of security in mineral rich areas should be enforced to secure environment for carrying out legal mining activities.
- iii. The government should urgently address the state of security in the northern part of Nigeria which is a very rich ore region for the assurance of safety for prospective investors.
- iv. The government should improve funding of public mining regulatory institutions so as to ensure effective monitoring and regulation of these laws.

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Appraisal of Process Route for the Preparation of Kibya Silica Sand for Glass Production

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Abstract

The suitability of Kibya silica sand for glass production was determined. The samples were collected along river in Kibya Local Government area of Kano state. The grain size analysis and the chemical analysis were carried out to determine the size distribution of each sample and elemental composition of the samples respectively. The result obtained from the silica sand processing, analysis and the melting of the sample. Kibya silica sand are predominantly made up of silica and low concentration of combine impurities such as Fe, AL, P, Ca, V, Cr, Zn, Mn, Pb, Sn, S, K, Ni, Ca etc using X-ray Fluorescence (XRF). The processing of the samples in acidified and basic solution reduces the concentration of the combine impurities thus increased the purity of the silica samples. The as-mined sample was washed in a multistage gravitational process to remove all associated chemical and non-chemical impurities. The multistage gravitational product was washed with solutions of different pH to remove any associated metal oxide impurities, especially Fe that is likely to introduce unwanted colour to the glass melting at the initial stage. Production of melt from the washed sample was done in the furnace that has heating capacity of 1,500°C. As received-silica sand sample were processed to suitable grade and used for the production of glass. The silica sand samples from Kibya were found suitable for glass production if process in acidic solution.

Keywords: Silica, glass, classification, impurities, and melt

1.0 Introduction

Glass is the only material which can be produced upon the planet earth without concern for exhausting the necessary resources. In its basic form, glass can be produced from glass sand (silica sand) and other readily available materials for various properties. Glass is a transparent material, particularly in the visible region of electromagnetic spectrum (Ramaswamy, S. 2009). The transparent and colouration properties made glasses best suitable for decorative and illumination purposes in the early days of their invention. Today glasses find applications in various fields: electrical transmission, optical instruments, laboratory glassware, domestic appliances, textiles, optical fibers, electrochemical devices, solid electrolytes, biological systems (bioactive glasses) and others (Paul, 1990).

Glass is a super cooled liquid that is viscous enough to stay rigid. Like less viscous liquids, glass has an amorphous, non-crystalline physical structure. Its properties depend on how different atoms and molecules interact within that structure. The primary components of glass are silica, lime, soda ash and alumina. However, most glass contains small amounts of many other components. Though minor in amount,

these components are important for achieving desired properties in the glass, like strength, abrasion resistance, heat resistance and color. Control of the glass manufacturing process, including the temperature of the glass melting furnace, is also important for achieving the desired properties (Catlin, 2015).

Silica sands has distinctive physical characteristics such as hardness, chemical and heat resistance as well as low price. Silica bearing rocks and minerals such as quartz, quartzite, silica sand together with other varieties of silica like agate, amethyst, jasper, flint etc. are used in a host of industries such as glass, ceramics, foundries, Ferro-alloys, abrasives, refractories, ornamentation and others. Important types of glasses made are sheet, flat, bottle, wired and figured, vacuum, laboratory, fibre, shell, flint, ophthalmic, beads and others (Doyle, 2009).

The processing of silica sand for the production of glass in Nigeria is relatively low. The sands present at the sample locations are only used for construction and building purposes. Silica sand which when processed can be used to produced glass is actively been used for constructions, building of structures and sand filling. The major problem associated with

the processing of silica sand for glass production is the removal of the impurities which coloured glass, the availability of the furnace that can withstand the heat necessary for its melting and the laboratory wares that can withstand heat during the pouring of the melt to the moulds.

By determine the chemical composition of the silica sand sample, carry out multi stage processing of the samples to make them suitable for glass production, produce glass specimen from the processed samples and analyze the suitability of the sample for glass production.

1.1 Location and Accessibility

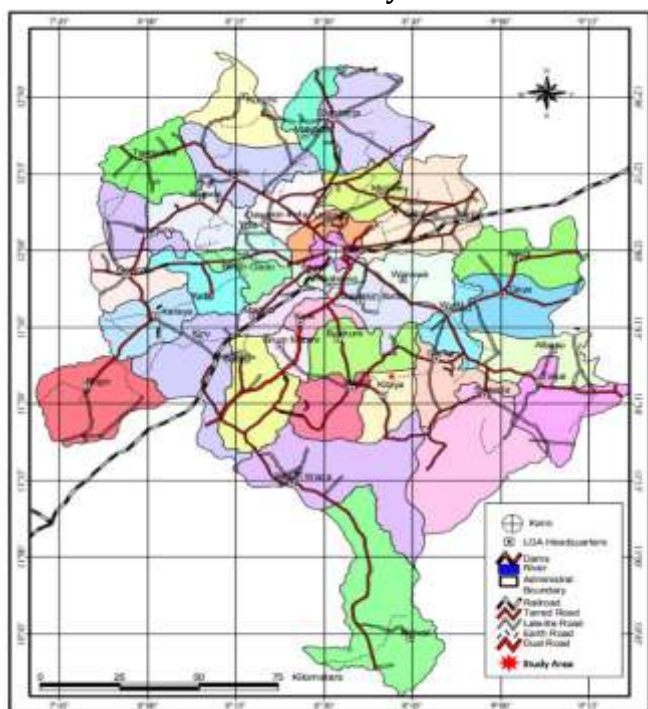


Figure 1. Map of Kano State showing the Silica Deposit at Kibiya (NGSA, 2009). The silica sand samples were collected at Kibiya River in Kibiya Local Government Area of Kano State. The GPS reading between latitudes 11°58'11"N and longitudes 9°03'0"E.

2. Materials and Methods Used

The materials that are used for of this study are; silica sand sample, Reagents (H_2SO_4 , NaOH), Na_2CO_3 , PbO , CuO and Crucible. Other materials, tools and equipment used where chosen according to the test requirements and some of this are furnace, digital weighing machine, pH meter, set of sieves and others.

2.1 Methods

1.4 Kg of each silica sand sample was prepared using coning and quartering method of sampling and labeled X, Y, and Z. The size distribution of the using a set of sieves ranges from 800microns to 75microns

was carried out.

The chemical analysis of the samples was carried out using X-ray fluorescence spectrometer.

The as-mined sample was subjected to multistage gravitational process. Standard method of instrumental analysis were adopted for determining the chemical constituents.

1.5 Kg of the sample was placed in graduated stainless-steel cyclone. Water and air were introduced into the cyclone for agitation. The solution was stirred continuously for five minutes and allowed to settle in the scrubber and moved to the classifier to remove the impurities. The solutions were further cleaned in the scrubber and moved to the final dewatering classifier where a clean silica sand was obtained. This process removed all associated non-chemicals constituents especially those with the tendency of sliming and all associated carbonaceous impurities. The final concentrate decanted and divided into four of 250 g each for further processing. 100 g was taken from one of the divided samples and pulverized for chemical analysis and the remaining was used in the glass production.

The next process stage was another washing of the washed silica samples with solutions of different pH. The aim is to remove any associated metal oxide impurities [especially Iron (III)] that are likely to induce unwanted colour to the glass melting at the initial stage. 250 g of the washed sample was taken. The pH of the solution was adjusted to 3, 5 and 10 respectively. The sample was placed in a 1000 ml beaker and a 400 ml of the acidified solution of pH 3 was added. The solution was stirred and allow to warm for 20 minutes with stirring. The solution was cooled, decanted and the acidified solution introduced again for the second time. The solution was decanted and the solvent placed in a measuring cylinder for analysis and determination of its pH. The sample was rinsed with water and transferred to the oven for drying.

Production of melt from the processed as-washed sample was done in a furnace that has heating capacity of 1500C. Ten grams (10g) of the samples was measured together with 4 g of Na_2CO_3 which acts as the flux to reduce the melting temperature. The mixtures were mixed thoroughly and placed in a well labelled crucible. The next stage in the production of the melt occurred in the furnace. The heating step was followed in this order: from the room temperature to 300°C for 30 minutes where evaporation of the moisture occurred with disintegration of carbonates and chemical reaction with the sand. It was allowed to hold for 10 minutes.

The melting temperature increases from 300°C to 600°C for 30 minutes where it was allowed to hold for another 10 minutes. At this point, melting of the sand commences.

The temperature was increased to 1000°C where fusing of the melted sands and the flux occurred and allowed to hold for 10 minutes also. The final stage of the process occurred from 1000°C to 1400°C where the silicates melted completely, disintegration of other compounds into gas and disintegration of unmelted sand. The temperature was held for 30 minutes which ensured complete and uniform melting.

The cooling of the furnace occurs in the reverse order to the melting. It moved from 1400°C to 1000°C and 1000°C to 600°C respectively in 40 minutes. The downward movement continues to 300°C and to the room temperature for 30 minutes.

3 Results and Discussion

The particle size analysis done on the sample was to achieve an ideal fraction needed for the analysis, processing and melting. The process was repeated for accuracy and to get the desire grams needed for further analysis as shown in Table 1.

The result of chemical composition analysis carried out with an EDX3600B X-ray fluorescence spectrometer on the as-mined samples and processed samples are presented in this section. Tables 2,3,4 and 5 show the constituents of the washed and chemical processed Kibiya samples. In Table 3 and 4 acidic medium, the percentage of silica increases and that of Iron decreases when compared with that of Table 2. While Table 5, basic medium, the percentage of silica and that of Iron decreases. The analysis showed that silica sand samples contains silica thus enabling its usage for glass production.

Table 1. Result of the Particle Size Analysis

Sieve Size Range (µm)	Weight Retained (g)	Percentage Weight Retained	Cumulative Weight Retained (g)	Percentage Comm. Weight Retained
800	55.60	4.34	4.34	1.52
-800 +600	55.66	4.35	8.69	3.04
-600 +425	56.00	4.37	13.06	4.57
-425 +300	75.17	5.87	18.93	6.62
-300 +150	528.48	41.27	60.20	21.06
-150 +75	261.71	20.44	80.64	28.21
-75	247.88	19.36	100.00	34.98

Table 2. Chemical Compositional Analysis of Washed Kibiya Silica Sand Sample

Element	Content (%)	Element	Content (%)
Al	1.5717	Cu	0.0509
Si	36.4001	Pb	0.0346
P	0.2491	W	0.1647
Ca	0.0892	Au	0.0347
Ti	0.1274	Rb	0.0120
V	0.0013	Nb	0.0140
Mn	0.0070	Mo	0.1520
Co	0.0024	Sn	0.1864
Fe	0.8428	Zn	0.1048
Ni	0.0602		

Table 3. Chemical Compositional Analysis of Kibiya Silica Sand Sample Processed in a Solution of pH=3.

Element	Content (%)	Element	Content (%)
Al	1.9451	Cu	0.0509
Si	42.6972	Pb	0.0346
P	0.2584	W	0.0778
Ca	0.0565	Au	0.0040
K	0.0680	Rb	0.0140
Ag	0.0057	Nb	0.0216
Mn	0.0049	Mo	0.1209
Co	0.0019	Sn	2.2178
Fe	0.4413	Sb	2.0705
Ni	0.8440	Zn	0.1157

Table 4. Chemical Compositional Analysis of Kibiya Silica Sand Sample Processed in an Acidified Solution of pH=5.

Element	Content (%)	Element	Content (%)
Al	1.6695	Cu	0.0687
Si	34.1830	Pb	0.0104
P	0.2626	W	0.1502
Ca	0.0660	Zn	0.1286
K	0.0071	S	0.1088
Ag	0.0047	Nb	0.0251
Mn	0.0460	Mo	0.1764
Co	0.0027	Sn	0.1209
Fe	0.4354	Sb	2.2271

The melting and the cooling cycle took about 6 hours to complete. The melt produced has a very faint colour. The melt showed little or no voids as result of the fine nature of the sample and the solidification that occurs in an air tight furnace figure 2.

**Figure 2. Melt Produced from Processed Silica Sand Sample**

4. Conclusions and Recommendations

Based on the results obtained from silica sand processing, analysis and the melting of the sample, it can be concluded that; The sample is predominantly made up of Silica and low concentration of combined impurities such as Fe, Al, P, Ca, V, Cr, Zn, W, Mn, Pb, Sn, S, K, Ni, Ca etc. The processing of the sample in acidified and basic solutions reduces the concentration of the combined impurities thus increasing the purity of the silica samples. As received silica sand sample was processed to a suitable grade needed as a charge towards the production of glass.

Based on the findings of this research, the following recommendations were made; The silica sand sample is suitable for glass production if it is processed in acidic solution. The processed silica sand sample must be in fine form to achieve a glass

Table 5. Chemical Compositional Analysis of Kibiya Silica Sand Sample Processed in a Basic Solution of pH=10.

Element	Content (%)	Element	Content (%)
Al	1.6197	Cu	0.0749
Si	32.6194	Pb	0.0032
P	0.2649	W	0.1311
Ca	0.0640	Au	0.0153
Ti	0.8551	Rb	0.0017
Ag	0.0043	Mo	0.1445
Mn	0.0029	Sn	2.4550
Co	0.0370	Sb	2.1856
Fe	0.7743		
Zn	0.1159		

melt from defects.

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Characterization of Deru Silver-Gold Ore, Bauchi State

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Abstract

The characterization of Deru complex ore was carried out in the course of this research work. The complex ore deposit is located in Deru village, Ningi Local Government Area, Bauchi State. Samples were taken from four pits at depths ranging from 12m to 18m. Each of the ore samples were divided into four parts and used for the various tests. A batch of each of the three samples were mixed together, crushed, and prepared through extensive coning and quartering for tests including: X-ray fluorescence (XRF), Inductively Coupled Plasma (ICP-AES), X-ray diffraction (XRD) and Scanning Electron Microscope (SEM/EDS) and mineralogical tests. The bulk density of the ore was also determined. The results of the chemical analysis revealed that the crushed sample contained 12.2g/t Au, 256g/t Ag, 29.09% Si, 40% Fe, 3.45% Pb, and 3.15% Zn on the average for XRF and 11.2g/t Au, 266g/t Ag, 34.09% Si, 45.47% Fe, 3.45% Pb, 3.15% Zn and 3.01% Al on the average for ICP-AES. Mineralogical analysis carried with SEM showed that the ore contains quartz, hematite, silver, garnet and gold in significant quantities and thus represent the major minerals. Average value obtained for bulk density is 6.73g/cm^3 and the comprehensive strength of 193.9 MPa. The SEM/EDS analysis results revealed the interlocking nature of the minerals within the ore matrix. It is observed that the minerals are separated by quartz grain boundaries which may facilitate intergranular liberation and produce high percentage of free particles during comminution. Particle size analysis revealed that the various mineral phases are evenly distributed in all the various sieve size fractions (+710 μm to -45 μm). The results obtained are compared with that of the literatures cited. Deru complex ore deposit may be another potential source of silver-gold that can be extracted after beneficiation and supplied to smelting and industries.

Keyword: Characterization, gold ore, silver ore, Deru complex ore, and bulk density.

1.0 Introduction

The enhanced concentrations of gold and silver in rocks and ores are most frequently associated with sulphides of iron, copper, and other metals (Makeeva, 2003). Until now, there has been straightforward opinion on the forms of occurrence of these elements in ore-forming sulphides. Many researchers give preference to the presence of micro- and nanophases rather than to isomorphic forms of occurrence of noble metals in the ores (Moiseenko et al., 2003). In this context, of special interest are sulphides of gold and silver, uytenbogaardtite (Ag_3AuS_2) and petrovskaitite (AgAuS), which were discovered in the 1980s and later proved to be by no means as rarely encountered as was first supposed. At

present, more than 20 gold-silver deposits and ore manifestations are known, in which uytenbogaardtite and/or petrovskaitite have been identified together with acanthite (Ag_2S) or native gold. In a number of works, especially in recent years, wide occurrence of these minerals in many deposits has been forecasted (Bradinskaya et al., 1990).

The key mineralogical attributes that are critical in the selection of an appropriate processing route include: the relative mineral abundance or modal mineralogy, the deportment of key elements, mineral association and texture, and the consequence of these on the liberation characteristics of key minerals. Different methods for recovering silver have been

of the as-mined ore, particle size studies, bulk density and the comprehensive strength of the ore were determined.

3. Results and Discussion

Table 1, equation 1 and plate 1 presented physical observation and test carried on the as mined sample. The colour of the run of mine ore is light grey and spotted dark grey, the strike of the ore were determine in a scratch test is slightly greyish, and the specific gravity was determined to be 6.73.

Figures 2 and 3 showed the chemical composition analysis carried out using an Inductively Coupled Plasma Atomic Emission Spectrometer and X-Ray Fluorescence XRF. These reveals that the run of mine ore (head sample) contains 0.0112ppm, 0.0122ppm of Au and 0.266ppm, 0.256ppm of Ag. Base on this result, it is evident that the ore meets the typical standard feed grades of 0.003ppm Au and 0.1ppm Ag require to mine gold and silver ore deposit (Earle, 2015).

Qualitative and quantitative mineralogical analyses result of Deru Complex ore as conducted with X-ray Diffraction presented in figure 4.

The scanning electron microscopic (SEM/EDX) analyses of the ore were presented in figure 5 and 6. The SEM micrograph of as-mined revealed the interlocking nature of the mineral within the crystals aggregate in the ore matrix and was observed that the minerals were separated by coarse grain boundaries that can facilitate their liberation during comminution, because the more coarse mineral particles are the easier their liberation (Wills, 2006).

The uniaxial compressive strength tests on the ore presented in Table 2 and revealed that the four rock samples the average strength value of the rock is 193.9MPa.

Table 3 and Figure 7 presented the sieve/particle size analysis and revealed that significance of size analysis in assessing the performance of grinding circuits. The product size is usually quoted in terms of one point on the cumulative undersize curve, this often being the 80% passing size. Although this does not show on the overall size distribution of the material, it does

facilitate routine control of the grinding circuit. For instance, if the target size is 80%, -90 μ m, then, for routine control, the operator needs only to screen a fraction of the mill product at one size. If it is found that, say, 50% of the sample is -90 μ m, then the product is too coarse, and control steps to remedy this can swiftly be made (Alabi, 2016).

Table1. Physical Properties of Deru Complex Ore

Properties	Diagnostic Features
Colour	The run-of-mine ore is light grey and spotted dark grey.
Texture	Fine – medium grained.
Specific Gravity	6.73
Streak	slightly grayish
Other Characteristics	Bright metallic lustre.

Table2. Comprehensive Strength Result

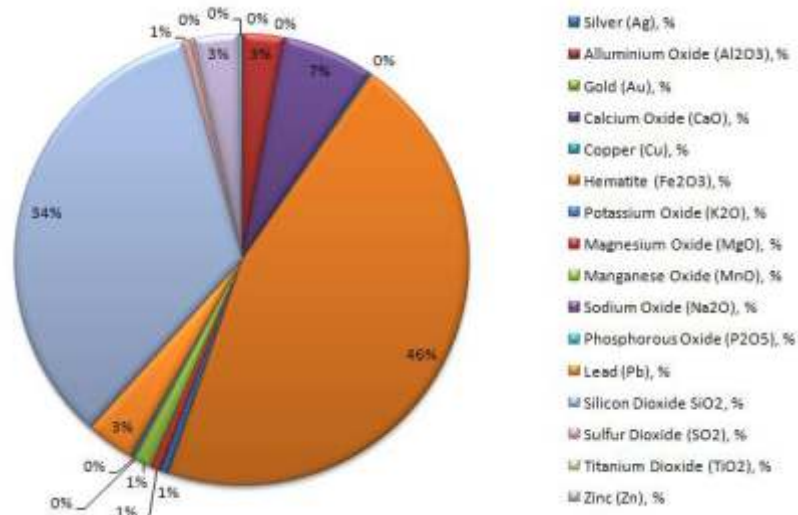
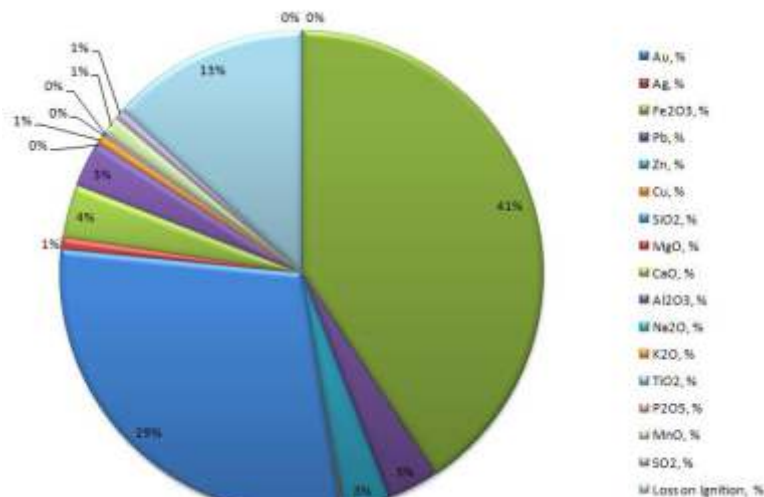
S/N	Force (kN)	Length/ Breath (cm)	Area (mm ²)	Compressive Strength (N/mm ²)
01	95.51	11.2/4.5	495	192.9
02	95.66	11.2/4.5		193.2
03	94.54	11.2/4.5		190.9
04	98.46	11.2/4.5		198.9



Plate1. Crude Sample of Deru Complex Ore

Table 4.13: Particle Size Analysis for Liberation Study

Sieve size range (μm)	Sieve fraction weight		Nominal Aperture size(μm)	Cumulative %		Au (g/t)	Ag (g/t)
	(g)	(%)		Under size	Over size		
+710	2.6	0.5	710	99.5	0.5	11	253
-710 +500	83.4	15.6	500	83.9	16.1	12.1	254
-500 +355	70.9	13.3	355	70.6	29.4	12.6	261
-355 +250	93.4	17.5	250	53.1	46.9	19	281
-250 +180	55.3	10.4	180	42.7	57.3	17	271
-180 +125	74.7	13.9	125	28.8	71.2	14	277
-125 +90	22.5	4.2	90	24.8	75.2	19.3	241
-90 +63	39.9	7.5	63	17.1	82.9	19.9	271
-63 +45	67.3	12.6	45	4.5	95.5	11	292
-45	24.1	4.5				20	312
	534.1	100					

**Figure 2. Showing the Analysis of Daru Complex Ore using ICP-AES****Figure 3. Showing the result of analysis of Deru complex ore by X-Ray Fluorescence.**

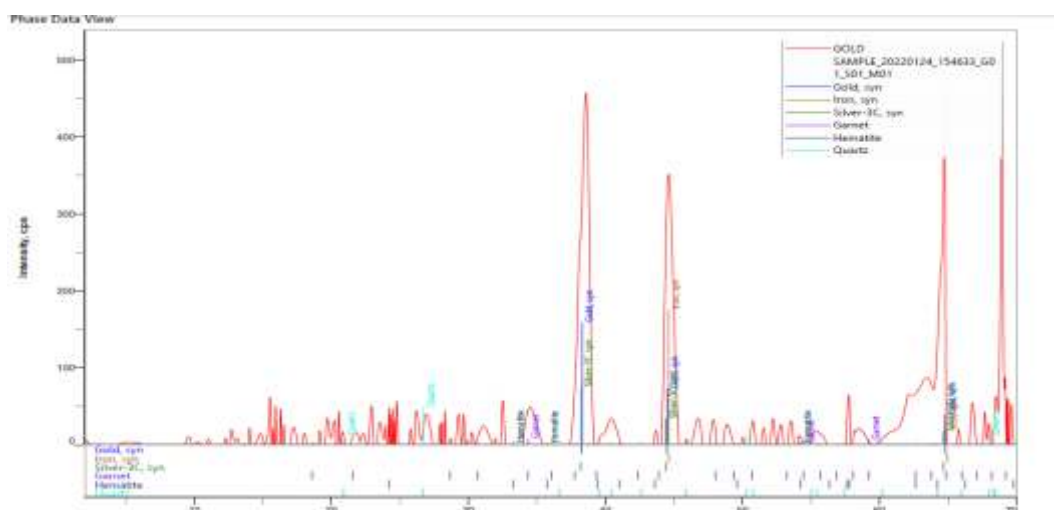
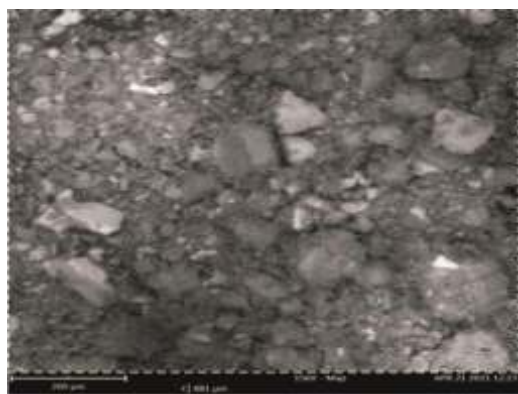
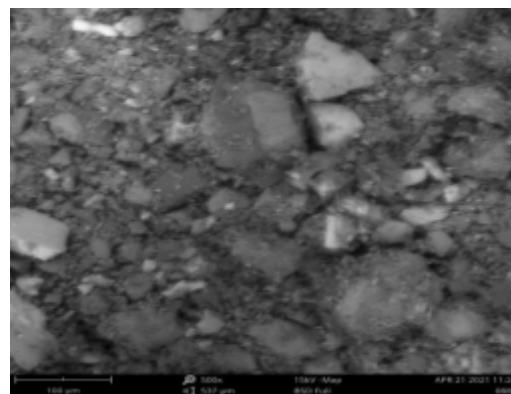


Figure 4. X-ray diffractogram Pattern of the Deru Complex ore



A



B

Figure5. SEM micrographs of crude ore at (A) 200μm and (B)100μm magnification

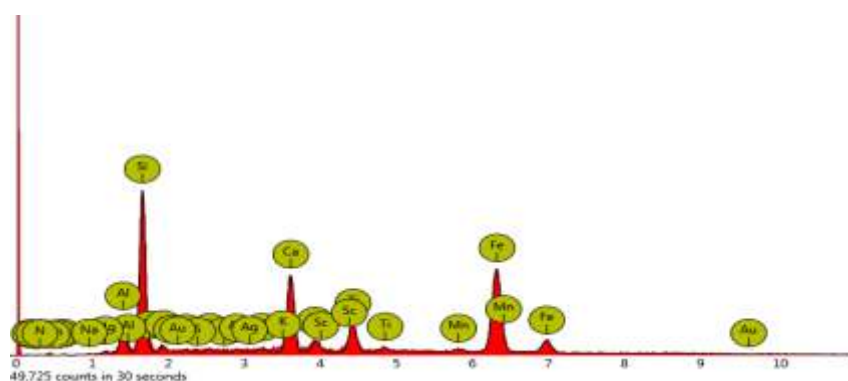


Figure6: EDX Patterns of homogenized Deru Complex Ore (SEM microscopic of crude ore at 100um magnification)

4. Conclusion and recommendations

The characterization of the Deru Complex ore was carried out. The chemical analysis revealed that the ore contains mainly 12.2g/t Au, 256g/t Ag, 29.09% Si, 40% Fe, 3.45% Pb, and 3.15% Zn

on the average for XRF and 11.2g/t Au, 266g/t Ag, 34.09% Si, 45.47% Fe, 3.45% Pb, 3.15% Zn and 3.01% Al on the average for ICP-AES. The analysis for both analysis shows the present of gold and silver in the sample, Mineralogical

analysis carried with SEM showed that the ore contains quartz, hematite, silver, garnet and gold in significant quantities and thus represent the major minerals. Average value obtained for bulk density is 6.73g/cm^3 and the comprehensive strength of 193.9 MPa. The SEM/EDS analysis results revealed the interlocking nature of the minerals within the ore matrix. It is observed that the minerals are separated by quartz grain boundaries which may facilitate intergranular liberation and produce high percentage of free particles during comminution. Particle size analysis revealed that the various mineral phases are evenly distributed in all the various sieve size fractions ($+710\mu\text{m}$ to $-45\mu\text{m}$). The results obtained are compared with that of the literatures cited. Deru complex ore deposit may be another potential source of silver-gold that can be extracted after beneficiation and supplied to smelting and industries.

Based on findings in this research, it is recommended tests for the amenability to different concentration techniques of the complex ore and actual separation test should be carried out.

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**Economic Assessment of Artisanal Gold Mining in Uke Community,
Nasarawa State, North-Central Nigeria**

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Abstract

This research examined the economic assessment of artisanal gold mining in Uke Community, Nasarawa State, North Central Nigeria, using economic parameters such as productivity, extraction cost, net profit, selling price, government revenue and foreign direct investment. Primary data collected through field studies, administered questionnaires and oral interview, and secondary data sourced from literature review were also used to assess artisanal gold production and the general economy of the area. The processed, interpreted and analysed data were then subjected to Microsoft Excel for further analysis. Economic analysis of gold mining in the area showed that economic parameters such as high productivity, moderate extraction cost, high net profit and high selling price show positive leaning towards improved gold mining business in the area. However, government revenue and foreign direct investment indicated low rating as they were non-existent in the area due to various socio-economic factors. From the results of the study, gold mining in Uke was found to be sparsely mechanized. The productivity of the area per annum was approximately found to be 74,592 grammes, while the annual operating cost for the year 2021 and the unit cost of production were approximated to be ₦5,421,666.667 and ₦ 903.611 respectively. The cost of mining equipment totaling 366 including Jack hammers and excavators was ₦32,180,000, while the annual operating and annual gross profit amounted to ₦5,421,667 and ₦108,158,400 respectively. Hence, results of the study indicate that artisanal gold mining in Uke community has brought relative economic development and is profitable, although this is not reflected in the overall economy of the area. It was recommended that regularization of artisanal gold mining and provision of adequate statistical database to prospective investors, among other measures, would boost productivity in the area to attain optimum contribution to the national economy.

Keywords: Artisanal gold mining; economic assessment; productivity; net profit.

1.0 Introduction

Mining can be described as a process of extracting naturally occurring minerals from the earth (Olure-Bank and Gbadebo, 2016). It is one of the oldest economic activities in Nigeria dating back to prehistoric times when man crudely exploited different minerals for the production of his cosmetics, crude implements and utensils. The mining industry has been viewed as a key driver of economic growth and the development process (Bradshaw, 2005), and as a lead sector that drives economic expansion which can lead to higher levels of social and economic wellbeing (Bridge, 2008). Artisanal and small-scale mining (ASM) is a means of livelihood adopted primarily in rural areas (Veiga, 2003). It is sometimes referred to as informal sector, which is outside the legal and regulatory framework (Azubike, 2011). When not formalized, organized, planned and controlled, ASM can be viewed negatively by

governments and environmentalists, because of its potential for environmental damage, social disruption and conflicts (Opafunso, 2011).

Artisanal and Small-scale Gold Mining (ASGM) can be defined as gold mining activities carried out by individuals, groups, families or cooperatives with minimal or no mechanisation (Salati, 2015). ASGM is generally characterised by lack of long-term planning and the mining activities are largely uncoordinated because the people involved lack the technical know-how, use inappropriate methods, tools and equipment, and have no regard for the environment. Consequently, mineral production in ASGM is inefficient and has attendant environmental, health and safety challenges, coupled with chaos in the minefields. Most artisanal miners work in difficult and often very hazardous conditions in the absence of the required safe mining regulations to safeguard the operations (Veiga, 2003). Despite serious dangers

posed by this activity, artisanal gemstone mining operations continue to spread due to; rise in the demand for gemstone and unattractive nature of other means of livelihoods such as farming in the rural areas where the mineral is substantially available (Ako et al., 2014). Figure 1 shows an artisanal gold mining site.



Fig. 1: A Typical Artisanal Gold Mining Site in Nigeria

The Nigerian mining industry is currently dominated by massive informal mining activities, especially, artisanal gold mining (AGM). This is due to its relatively inexpensive entry cost and lack of effective monitoring by the government. Although when properly exploited, it can serve as a means of reducing poverty by providing employment; yet, Nigeria has lost huge amount of revenue due to illegal mining and exportation of unprocessed gold (Adamu et al., 2022; Amosu and Adeosun, 2021; Chuan-Pole et al., 2017). Consequently, the activities of AGM operators as a result of the use of the none scientific mining method cannot produce the required grade and quantity of gold to meet up with the forces of demand and supply (ELI, 2014; IGF, 2017). Thus, assessing the economic contribution of gold mining activities would give an overview of the extent of its value addition or otherwise to the mining communities. Hence, this study attempts to examine the case at Uke community in Nasarawa State, North-Central Nigeria. In this study economic indices for assessing AGM in the study area would be identified, while the identified economic indices would be used to examine AGM activities in the area with a view to determining their overall economic impact and ascertaining their profitability or otherwise.

2 Materials and Methods Used

2.1 Location and Accessibility of the Study Area

Uke is located about 18 miles or 29km south-East of Abuja (the country's capital). Uke is a village in central Nigeria as found in Karu Local Government Area of Nasarawa State. It is regarded as a suburb of

Abuja due to its close proximity to Nigeria's Federal Capital Territory and Karu urban area. This community lies on longitude 8°32'N 8°18'E and Latitude 8.533°N 8.300°E and is characterized by a tropical sub-humid climate with two distinct seasons; wet and dry seasons (Ihuma et al., 2016).

2.2 Brief Geology of the Study Area

Nasarawa state is known to be home of solid minerals and the state is endowed with abundant minerals resources unlike other states in Nigeria. The three major geological components that make up the geology of Nigerian namely basement complex, younger granites and sedimentary rocks are all pronounced in the state (Adewumi and Salako, 2018).



Fig. 2: Satellite Imagery of the Study Area (Source: Google Earth, 2021)

2.3 Field Studies and Data Collection

Field studies carried out in this study involves the administration of questionnaires and conduct of oral interview for the collection of information on AGM from respondents in the area. Collection of primary data, complimented by researchers' observations on AGM's economy and structure in the area, and secondary data sourced from literature also form part of field studies and data collection. The processed, interpreted and analyzed data were then subjected to Microsoft Excel for further economic analysis and projections for general discussions.

The economic parameters used for the assessment including productivity, extraction cost, net profit, government revenue and foreign direct investment were carefully deployed to determine their level of satisfaction of AGM in the area. The economic assessment technique adopted by Barreto et al. (2018) in their study was partly employed in this work, although the mineral of interest in their work (gemstone) is different from gold mined and assessed in this study. Despite difference of parameters for economic assessment, both studies used simple

economic approach to measure economic contribution and economic impact of AGM in their respective mining communities. The approach to economic appraisal adopted by Melodi and Ajibade (2019) especially concerning gold mining profitability assessment was employed and found suitable from every economic point of view. Thus, economic assessment of AGM in Uke community area of Nasarawa State represents an evaluation of a purely informal gold mining activities which require varied economic approaches due to the nature of people and working tools involved.

3 Results and Discussions

The results of the study on economic assessment of artisanal gold mining in Uke community in Nasarawa state are presented and discussed from Tables 1 to 6. The data collected in this study came largely from the results of questionnaires distributed among respondents in the study area. Tables 1 to 5 show the details of the economic parameters used in assessing AGM in the area, total artisanal productivity per month as well as annual production rate in the community. Table 6 also shows the summary of questionnaires findings including the data profile of the respondents as well as their general opinions under the economic assessment of artisanal gold mining in the community.

As shown in Table 1, the highest AGM production was 725,000g which was recorded in February 2021. Conversely, the least product of 217,500g was recorded in the month of August. Also, the highest cost of extraction is ₦14,856,000 for the purchase of jackhammer/compressor, while the least cost of extraction is ₦40,000.

The net profit from AGM business in the area as shown in the Table 3 is ₦30,969,600 which is considered high and promising. From Table 4, it is implied that the selling price of gold in Uke community is higher compared to other communities dealing in AGM in the North-central communities. As shown in Table 5, artisanal production in December 2021, appears to be the highest operational cost for the year 2021.

The decline in production trend as implied in Tables 1 to 7 suggests that the production rate from January, February, March and April have the highest production rate, while the month of May, June, July, August, September and October have lowest production rate due to raining season. However, in November and December the production rate is a bit high. The price of gold is also shown to be expensive due to the high cost of production and equipment hiring as some of the equipment used in the mine are

hired, such as excavator and motor cycles for transportation. Also, as shown in the tables, payment of royalties and fueling of compressor are other factors affecting the high cost of gold in the community as these add to the mining cost of gold mining and processing.

From the results of questionnaire administration as shown from Figure 3 to 14, it is obvious that gender, age, religion, tribe, marital status, number of dependents, number of children and level of education influence the pattern of mining activities in the area, shaping the activities, since most of the workers are young, agile and highly committed to their community norms and values. However, it is evident that there is apparent need to support their investment as most of the pits are sole proprietorship businesses since most of the business activities are AGM in nature which is the only source of their livelihoods. Hence, lack of government support to artisanal miners is a prevalent factor as most respondents deny receiving any government help or support.

The study has demonstrated clearly that there are substantial economic benefits in terms of income generation to Uke community, although they do not come automatically and their sustainability remains a key issue. In terms of foreign direct investment (FDI), the assessment scores AGM in Uke community zero. This is clearly evident as the overall economic contribution of AGM in the area remains insignificant compared to the expected outcome at the national economic scale. The prevailing insecurity in the country is a major compliment to this low productivity. Hence, FDI would have to wait until improved security and safe mining environment for foreign investors to operate, formalized and organized AGM outfits and strong political from the government are in place. With all these in place, the resource would be well-managed and can be used as an engine for overall economic growth and the outcome of AGM can thus produce a significant impact on national economy.

In terms of government revenue, the assessment also scores AGM in the area very low due to revenue loss through the avoidance of paying taxes, fees and royalties, under reporting of production, loss of miner's income, smuggling of unprocessed minerals due to poor enforcement and low capacity. However, the AGM sector would bounce back whenever it is organized as an entity and operators function legally thereby generating the expected revenues for the government.

Table 1: Total production rate in the year 2021

Month	Production (grammes)
January	652500
February	725000
March	667000
April	507500
May	435000
June	406000
July	362500
August	217500
September	333500
October	319000
November	580000
December	623500
Total	5829000

Table 2: Cost of Extraction

Equipment	Cost (Naira)
Jackhammer/compressor	14,856,000
Excavator	8,640,000
Explosive	2,184,000
Motorbike	14,000,000
Pan	67500
Big/small hammer	385,000
Chisel	75,000
Shovel	40,000
Total	40,247,500

Table 3: Net Profit

Revenue/Expenditure	Cost(naira)
Royalty	1,329,600
Cost o mining	3,600,000
Cost of processing	4,200,000
*Worker's allowance	5,040,000
Cost of fuel	16,800,000
Total	30,969,600

Table 5: Equipment Required

Equipment	Quantity
Big Hammer	20
Chisel	100
Shovel	50
Small Hammer	150
Motorbike	40
Jackhammer	5
Excavator	1
Total	366

Table 4: Selling Price

Month	Price(naira)
January	1,136,800
February	1,299,200
March	1,177,400
April	1,566,000
May	12,180,000
June	11,205,600
July	9,744,000
August	8,769,600
September	10,718,400
October	14,616,000
November	16,564,800
December	17,539,200
Total	88,995,539

Table 6: Quantity and cost of Equipment

Equipment	Rate (₦)	Qty	Total Cost (₦)
Motorbike	350,000	40	14,000,000
Big Hammer	8,000	20	160,000
Chisel	750	100	75,000
Shovel	800	50	40,000
Small Hammer	1,500	150	225,000
Pan	1,500	45	67500
Jackhammer	3,500,000	5	17,500,000
Excavator	180,000	1	180,000
Total	-	-	₦32,180,000

Table 7: Showing monthly operational cost for year 2021 in monetary value

Months	Cost of Jack hammer (₦)	Cost of fuel (₦)	Cost of equipment depreciation (₦)	Cost of Maintenance (₦)	Salary/police /Royalties (₦)	Cost of mining/ processing	Cost of explosive	Total cost
Jan	1,800,000	1,400,000	59,000	150,000	420,000	650,000	780,000	5,259,000
Feb	1,600,000	1,400,000	59,000	200,000	420,000	650,000	780,000	5,109,000
Mar ch	1,500,000	1,400,000	59,000	180,000	420,000	650,000	780,000	4,989,000
April	1,300,000	1,400,000	59,000	250,000	420,000	650,000	780,000	4,859,000
May	1,400,000	1,400,000	59,000	140,000	420,000	650,000	780,000	4,849,000
June	1,700,000	1,400,000	59,000	100,000	420,000	650,000	780,000	5,109,000
July	1,500,000	1,400,000	59,000	130,000	420,000	650,000	780,000	4,939,000
Aug	1,400,000	1,400,000	59,000	160,000	420,000	650,000	780,000	4,869,000
Sept	1,500,000	1,400,000	59,000	158,000	420,000	650,000	780,000	4,967,000
Oct	1,600,000	1,400,000	59,000	139,000	420,000	650,000	780,000	5,048,000
Nov	1,056,000	1,400,000	59,000	200,000	420,000	650,000	780,000	4,565,000
Dec	2,000,000	1,400,000	59,000	220,000	420,000	650,000	780,000	5,529,000
							Total	65,060,000

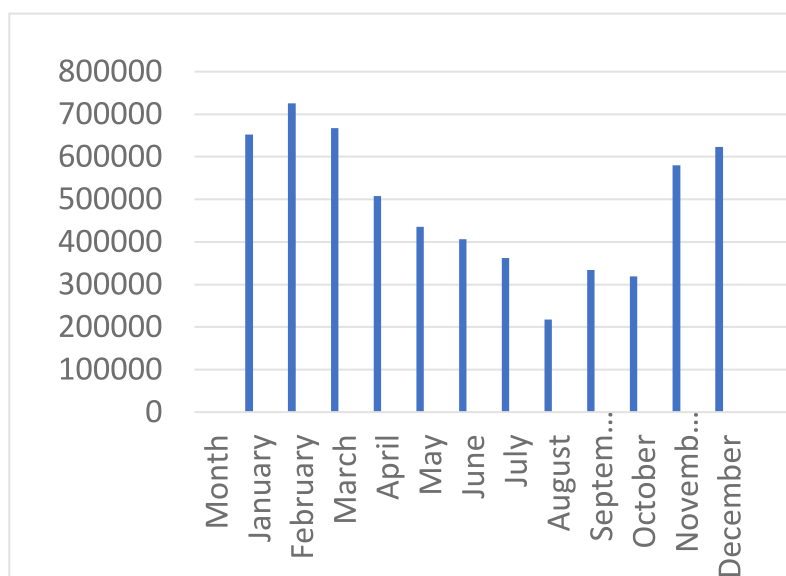


Fig. 3: Artisanal Production for the year 2021 in Uke Community

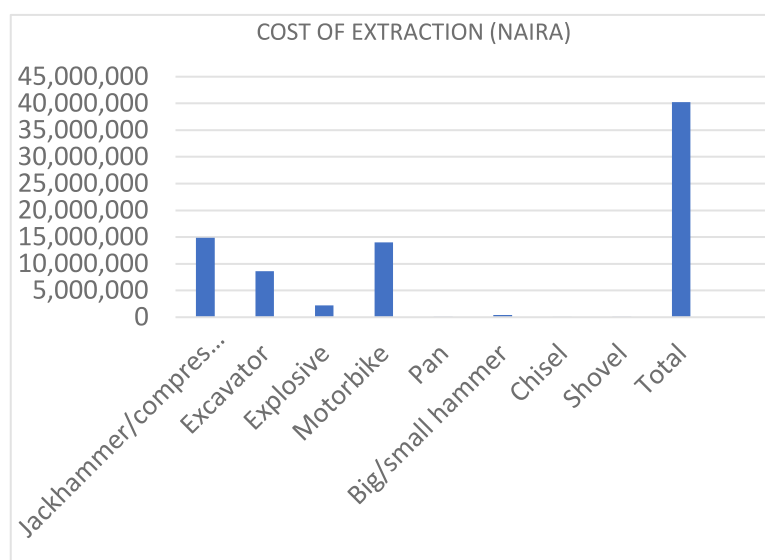


Fig. 4: Cost of Extraction of gold in Uke Community

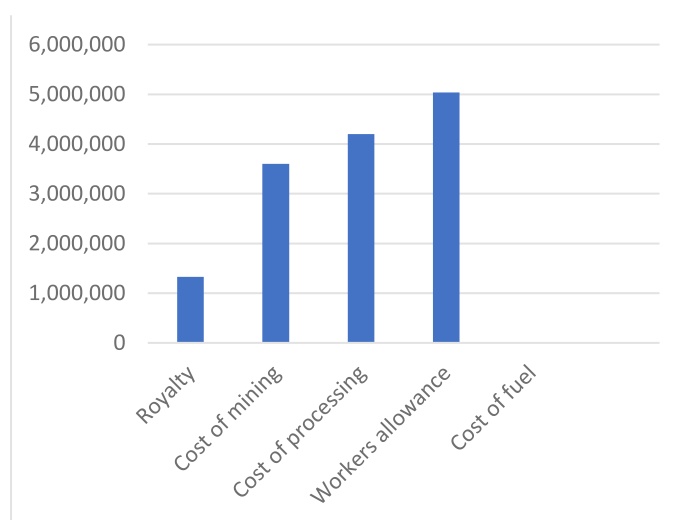


Fig 5: Net profit of AGM Business in Uke Community



Fig 6: Selling Price of Gold in the Study Area

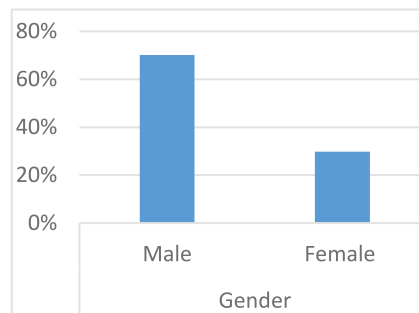


Fig 7: Gender Distribution of the Respondents

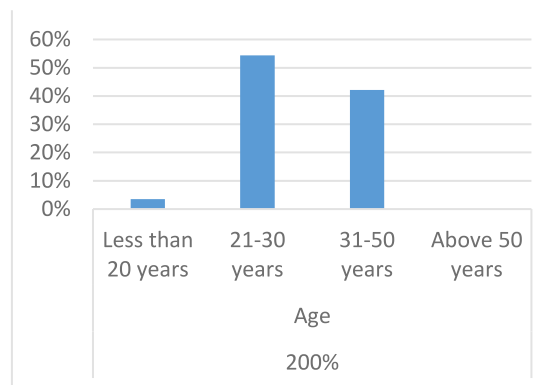


Fig 8: Age Distribution of Respondents

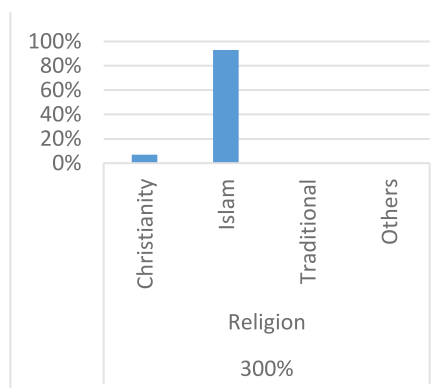


Fig 9: Religion of the Respondents

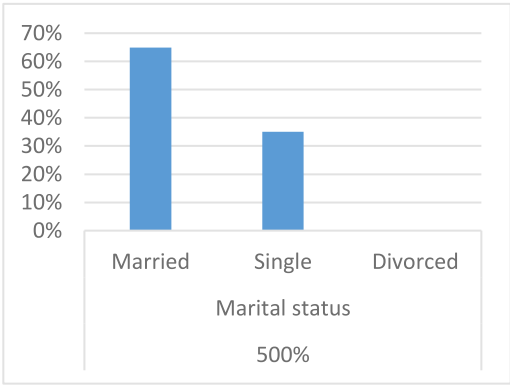


Fig. 10: Marital Status Representation of the Respondents

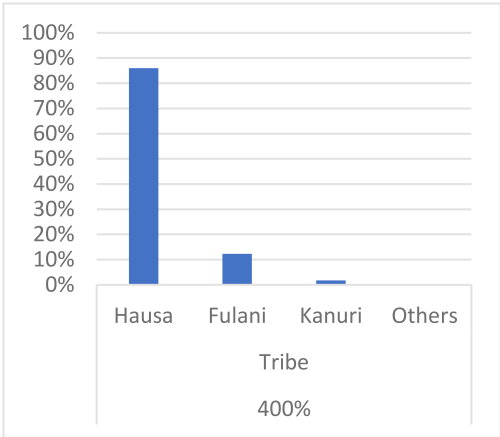


Fig. 11: Tribes of the Respondents

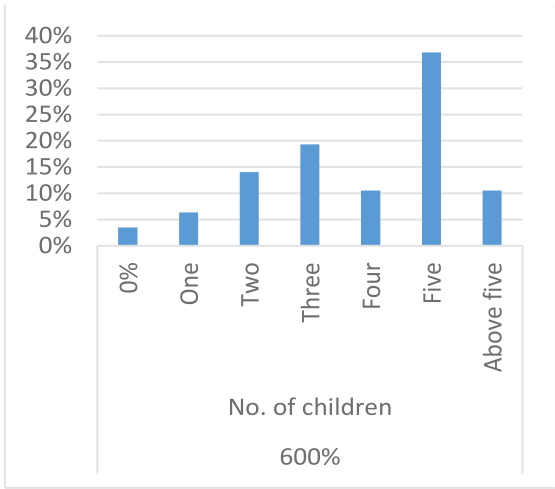


Fig. 12: No of Children of the Respondents

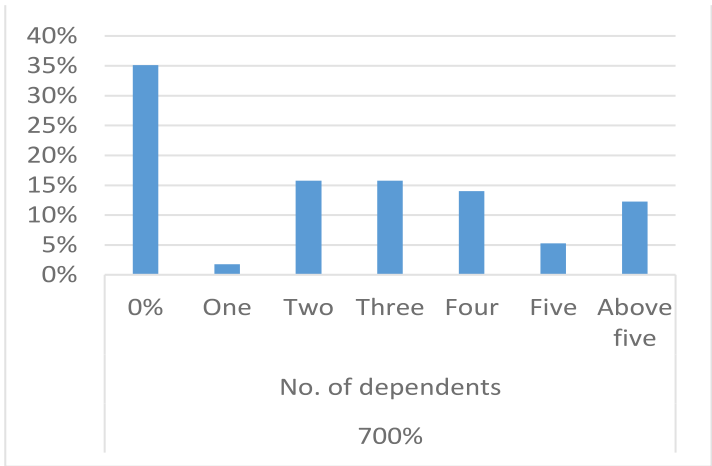


Figure. 13: No of the Dependents of the Respondents

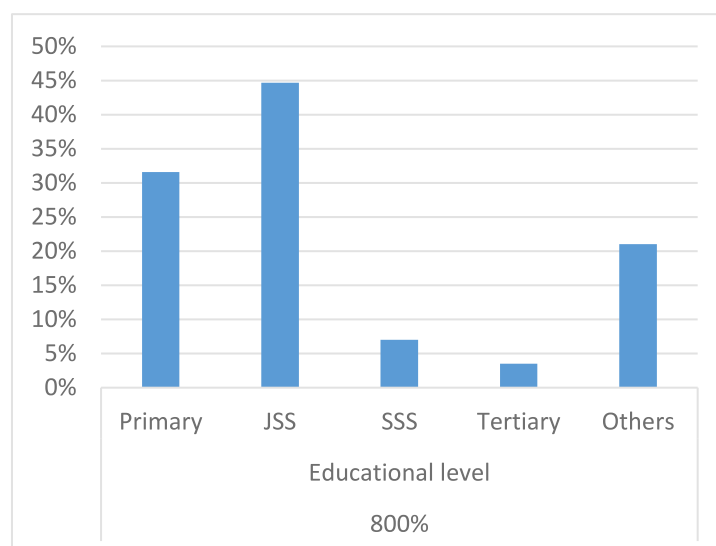


Fig. 14: Educational level Representation of the Respondents



Fig. 15 a: Compressor used in the Area



Fig. 16 a: Miners with Mineral Samples



Fig. 15 b: Some Artisanal Miners in the Area



Fig. 16 b: Sluicing at Uke Community



Fig. 17 a: Extracted Gold with Impurities



Fig. 17 b: Miners Posing with Researchers



Fig. 18 a & b: Some of the AGM Activities in the Study Area

4 Conclusions and Recommendations

The study on the economic assessment of AGM in Uke community, Nasarawa State, North-central Nigeria, has been carried out. From the results of the study, the following conclusions can be drawn:

- i. AGM constitutes the main source of employment within the communities surrounding the mine and more than half of the residents in this communities derive their incomes from it more than in agriculture and other sectors;
- ii. AGM business income does not translate to overall economic prosperity to the community due to insignificant production and output;
- iii. Based on availability of active population of the community, there is bright prospect of booming AGM activities in the future, if incentives are provided by the government;
- iv. Uke gold mining community is desirous of mechanized gold mining to make the business more economically viable; and
- v. High productivity, high extraction cost, high selling price and high net profits from AGM business in the area have not translated to improved government revenue and foreign direct investment due to tax evasion, illegal mining and smuggling of unprocessed minerals, among other factors.

In view of the observations made from the study, the following recommendations are hereby proffered:

- i. There should be a political will to reform the current legal processes which will enable the attainment of the potentials of the AGM sector, so as to capture its economic assessment in general.
- ii. Government as a matter of urgency formalize the AGM sector and integrate it into the mainstream mining sector so as to enable its operators to get the needed support for greater economic prosperity.
- iii. There is need for security to be entrenched in the country so that AGM sector can be conducive for both local and foreign investments.

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**Geochemical and Economic Potential of Calcite Deposit from Owa
Kajola, Ifelodun LGA, Kwara State, North Central, Nigeria**

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Abstract

Geochemical and economic potential of calcite deposits in Owa Kajola, Ifelodun Local Government Area, Kwara State were examined for their possible industrial application. Nine samples were collected and taken to laboratory for treatment and standard laboratory preparation prior to analysis and thin section preparation. Mineralogical analysis of major minerals was done using X-Ray Diffractometer (XRD) and geochemical analysis of major oxides was carried out. It is evident that all samples are rich in calcite as the dominant carbonate mineral in addition to a variety of minor oxides. The chemical analysis of end products shows that CaO content varies from 51.12 to 53.14 wt%. Other impurities are Fe₂O₃ varying from 0.17 to 0.37 wt%, Al₂O₃ from 1.04 to 3.15 wt %, MgO from 0.24 to 1.45 wt% and SiO₂ from 0.40 to 1.60 wt%. On the basis of chemical composition the marble/calcite deposit in Owa-Kajola is suitable for the manufacture of cement, poultry feed, fertilizer, refractory lime, filler/extender, water treatment, paper industry and glass. Hence, the calcite/marble is suitable as a raw material in the industrial sector.

Keywords: Carbonate rock, calcite, chemical, composition, industrial, major oxide, mineralogy

1 Introduction

Rock is a natural porous material and many engineering problem in rock mechanics and Engineering geology are closely related to rock pore structure (Canshou, *et al.*, 2015). Limestone is a sedimentary rock composed largely of mineral calcite (CaCO₃), formed by either organic or inorganic process (Serra, 2006). Marble is a metamorphic rock composed essentially of calcite (CaCO₃) dolomite [CaMg(CO₃)₂], or a combination of the two with a fine coarse grained crystalline texture (Serra, 2006). Marble is a metamorphosed limestone. Limestone and marble are carbonate rocks, dominated by the mineral for calcite (CaCO₃). Limestone and marble, the principal raw material for cement manufacture, are very essential for a rapidly growing nation like Nigeria. These industrial rocks can be said to be already in extensive use in Nigeria. They are used mostly for one purpose, the production of building and construction materials. Several cement factories have been built by government and even individuals to utilize the limestone and marble deposit in their respective areas. The output of cement from those

companies is quite high, though grossly insufficient to cope with the high demand caused by the appreciable rise in domestic construction. Limestone and marble are extremely valuable industrial raw materials and construction and cement manufacturing industries are the principal consumers. They are also used in the production of chemicals, fertilizer, abrasives, industrial fillers and ceramics etc. Limestone and marble occurrences and resources in Nigeria have accumulated over the years. Marble is a metamorphic rock formed when limestone is subjected to change in heat and pressure. Marble is formed under such condition because the limestone undergoes a re-crystallization process in the solid state (Given, 1982). Marble is a rock composed primarily of calcite (CaCO₃) and usually contains other impurities such as muscovite, biotite, pyrite, graphite and chlorite etc. The variety of colours exhibited by marble are a consequence of minor amount of the aforementioned minerals incorporated into the system during metamorphism. Calcite is a rock forming mineral with a chemical formular of CaCO₃. It is extremely common and found throughout the world in sedimentary,

metamorphic and igneous rocks. Some geologist considers it being a “ubiquitous mineral” and it is a very common minerals. Calcite is the principal constituent of limestone and marble. These rocks are extremely common and make up a significant portion of earth's crust they serve as one of the largest carbon repositories on our planet. Calcite is used as an acid neutralizer in the chemical industry in area where streams are plagued with acid mine drainage. Crushed limestone is dispensed into the streams to neutralize their waters. Calcium carbonate derived from high purity limestone or marble is used in medicine, mixed with sugar and flavoring. Calcium carbonate is made into chewable tablets used in the neutralization of so much acids. It is also an ingredient in nume-medications used to treat digestive and other ailments.

1.1 Marble Metamorphic

Marble is a metamorphic rock formed when limestone is subjected to change in heat and pressure. Marble is formed under such condition because the limestone undergoes a re-crystallization process in the solid state (Given, 1982).

1.2 Uses of Calcite

Marble is a rock composed primarily of calcite (CaCO_3) and during re-crystallization the resulting marble rock is typically composed of interworking grading of crystals with the primary sedimentary structure and texture. Typically monitored marble consist of swirls and item of many coloured varieties which are due to mineral impurities which include quart 2, tremolite, actinolite, chert, biotite, muscovite, for sterite, hematite, serpentine, pyrite (Philip, 2009). The basic raw materials for Portland Cement (PC) making are lime (CaO), silica (SiO_2), alumina (Al_2O_3), magnesia (AlO) and sulfur trioxide (SO_3) derivable chemically from either marble or limestone as the chemical components and standard proportions required for cement production (Obasi and Isife, 2012).

Marble finds wide spread application as raw material in many industries depending mostly on their purity or chemical content. Therefore, prior and concise chemical characterizations are necessary before any industry application. Nigeria is a developing nation with abundant minerals resources, especially meta-carbonate which occur in an estimated proportion of 60% dolomite marble and 40% calcitic marble. These meta carbonate deposit usually occur within the Schist belt (Muotoh *et al.*, 1998, Okunlola, 2001). Marble is one of the industrial rocks that gain prominence in the manufacturing sector of the

Nigerian economy (Romania and Fredrick, 2012).

2 Materials and Methods Used

2.1 Geographic Location and Geomorphology of the study Area

The study area is a marble deposit with associated rocks at Owa Kajola town. Owa Kajola town is located within Ifelodun local government in Kwara state about 50km from Ilorin the state capital. The area lies between $\text{N}08^\circ 30''$ to $\text{E}005^\circ 00''$ to $\text{N}08$ to $\text{E}005^\circ 13''$. The area is not too accessible by motor able road network; Owa Kajola is even less accessible due to the undulating topography of the area. These areas are transverse by bush parts created by lumber jacks, farmers and herdsman. Owa Kajola belongs to the sub-equatorial climate zone, characterized by heavy rainfall and short dry season. The mean annual rainfall is 1500 mm and the mean annual humidity is about 80%. The mean annual temperature is about 26.6°C (Emofurieta, 1984).

The study area is covered mainly by tall palm trees and grasses typical of rain forest vegetation is thick and has been greatly affected by human interference through farming, bush burning with the development of seasonal forest in some of the area.

The study area and its coordinates: The Latitude and Longitude presented in Table 1 and Figure 1 and Satellite imagery of Owa Kajola, Ifelodun L.G.A., Kwara State.

Table 1: Coordinates of the Study Area

Loc.	Coordinates		Elevation (m)
	Latitude	Longitude	
A.	$08^\circ 16' 48.25''\text{N}$	$005^\circ 08' 20.95''\text{E}$	387.38
B.	$08^\circ 17' 36.27''\text{N}$	$005^\circ 08' 32.55''\text{E}$	386.91
C.	$08^\circ 16' 41.67''\text{N}$	$005^\circ 08' 33.04''\text{E}$	372.46
D.	$08^\circ 16' 58.30''\text{N}$	$005^\circ 08' 06.34''\text{E}$	422.83

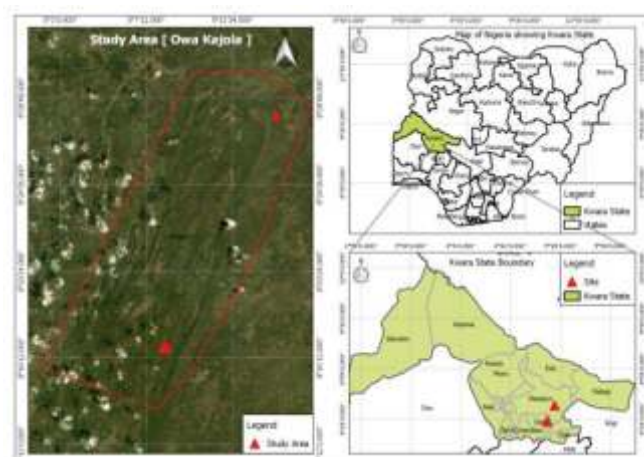


Figure 1: Map of Nigeria Showing the Location of Nigeria and the Generalized Satellite Imagery Map of the Owa Kajola, Ifelodun L.G.A., Kwara State.

2.2 Sample Collection

A number of geological tools were employed for this study and they include the Global Positioning System (GPS), compass clinometers, the sledge hammer, sampling bag, field note books, and writing material. Nine fresh rock samples were collected using sledge hammer from different locations of the calcite bodies in the study area. The GPS was used to determine the coordinates where the samples were collected. The rock samples were labeled and kept in the sampling bags. The samples were sent for geochemical analysis at Afe Babalola University, Ado Ekiti, Ekiti State, Nigeria.

2.2.1 Sample Preparation and Analysis

A reconnaissance survey where detail lithological description of the out crop at each location, taking into consideration the colour, texture, field characteristics, prominent sedimentary structures and composition was conducted. A total of three Calcite samples were collected at different sampling points. The samples collected were taken to laboratory for treatment and standard laboratory preparation prior to analysis and thin section preparation.

2.2.2 Main Parameters for Raw Mix Design

Equation 1 – 2 show the apply formula (as per British Standard) for Silica Ration (SR), Alumina Ration (AR) and Lime Saturation Factor (LSF)

Silica Ratio (SR)

$$SR = \frac{SiO_2}{Al_2O_3 + Fe_2O_3} \quad 3.1$$

2.3 Alumina Ratio (AR)

$$AR = \frac{Al_2O_3}{Fe_2O_3} \quad 3.2$$

2.3.1 Lime Saturation Factor (LSF)

$$LSF = \frac{CaO \times 100}{2.8 \times SiO_2 + 1.65 \times Al_2O_3 + 0.65 \times Fe_2O_3} \quad 3.3$$

3 Results and Discussion

3.1 Geochemical Results

The results from the XRF analysis are shown on Figure 1. CaO from 51.12-53.14 wt%, MgO from 0.24 – 1.45 wt%, SiO₂ from 0.40 – 1.60 wt%, Fe₂O₃ from 0.17 – 0.37 wt%, Al₂O₃ from 1.04 – 3.15 wt%, K₂O from 0.02 – 0.08 wt%, P₂O₅ from 0.06 – 0.40 wt% and Na₂O values range of 0.07 – 0.15%. The low MgO values indicates warm and humid climate during deposition of the carbonate sediments (Kotoky and Katakya, 1993)

3.2 Discussion on The Laboratory Analyses

Over Nine surface samples have been taken across most parts of location. The samples were sent to Afa Babalola University, Ado Ekiti for analyses. The

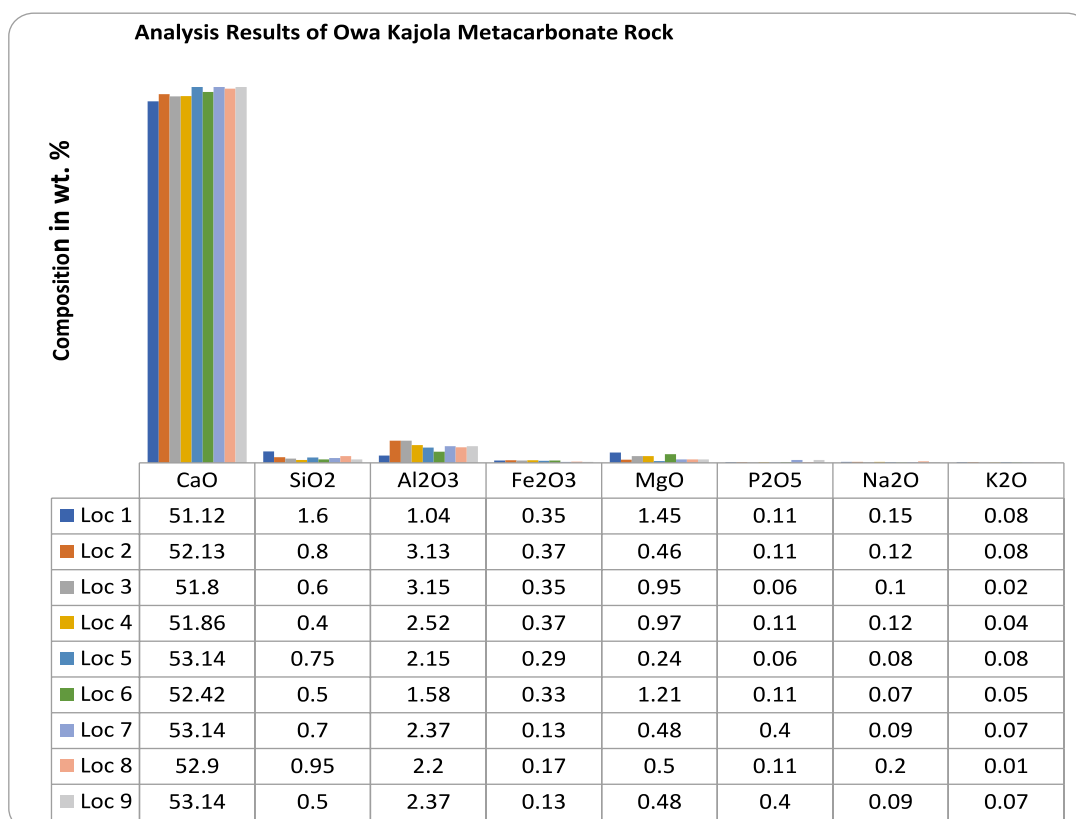


Figure 2: Analysis Results of Owa Kajola Metacarbonate Rock

results from the laboratory are as shown in Figure 2 and are discussed as follows.

Calcium Carbonates

The Calcium Oxide (CaO) contents of the surface samples ranges 51.12 - 53.14%. It is worth noting that the highest CaO content in pure limestone is 56%. None of the sample show equivalent Calcium Carbonate content of less than 75% which is the minimum required content while many showed 90% and above purity.

Magnesia

Magnesia (MgO) content in limestone for cement manufacture is very critical and must not exceed 5% content. The magnesia content for the surface sample range between 0.24 – 1.45 which are all within acceptable limits.

Iron

Iron contents of limestone for cement should not be higher than 2.5%. The samples showed Iron contents of between 0.17 – 0.37 which are within acceptable limits.

Alkalis (Sodium and Potassium Oxides) – NaO + K₂O

The total alkalis do not exceed 0.8% in all samples which are within acceptable limits.

Silica (SiO₂)

Maximum silica acceptable is 6%. All samples taken from the designated limestone source areas showed contents of ranges 0.40 – 1.60% which is good.

3.2.1 economic benefits and industrial application of owa kajola marble

Profit

After break-even, the marble will be making average net project of about N100 billion annually. If the Government of Kwara State has 10% equity in the production of cement using Owa Kajola marble, it stands to reap a \$1 billion technically as profit share. This will double if the capacity of the plant is doubled.

Employment Opportunity

A cement plant of about a million tons capacity in Nigeria will employ about 600 people directly for the plant using fully automated European Technology. Other ancillary staff like security guards and casual workers will be about 200.

Other Benefits of Owa Kajola Marble

Kwara indigenes particularly will benefit from the following directly and indirectly. Contracts/Supplies, Distributorship and Transportation

The economics of the immediate area of operations of the plant will improve dramatically as a new settlement will spring up around the plant. Local business will be able to provide for the daily needs of

workers, contractors, transporters and others. Banks that will provide employment for Kwarans will spring up nearby town like Omu-Aran, Oro-Agor, Oke-Onigbin and Ilofa. The State capital also will feel the positive socio-economic impact of the cement plant.

3.2.2 Calcite Uses in Other Industries

Paper Industry

The calcite is used as filler and coating material in most paper-producing industries to harden or smoothen, as necessary. Calcite allows rapid paper drying in the paper-making process due to its oil absorption feature. This makes it a useful ingredient in newspapers, magazines, and high – quality paper-making factories. Calcite is also used as a filling material for cigarette paper.

Pesticide Production

In pesticide production (calcium arsenate), arsenic acid is reacted with a milk lime firming calcium arsenate lime of CaO > 65% is required. Based in the specification, the Owa Kajola calcite/marble is suitable for the manufacture of pesticide as it contains lime CaO > 65%.

Paint Industry

Calcite is used as a pigment material to prevent steel war, increasing water and chemical resistance.

Glass Use

Glass industry requires high calcium marble, Iron and other coloring matter like carbon are regarded as objectionable. Calcite increase resistance to chemical effects in glass which is why it is used in glassmaking. It is also used in bottles and window glass making because it brightens the colour of the glass. Fe₂O₃ should not be more than 0.2%. For colorless glass, marble should contain >65% CaO, Fe₂O₃ should not be more than 0.04%. Based on the above specification, the Owa – Kajola calcite is not suitable for the manufacturing of glass as it contain < 52.41% CaO, > 0.28 of Fe₂O₃ and >0.76% SiO₂.

Agriculture Uses

To obtain large agro-product from acid-bearing soil types, it is important to supply Ca in increased quantities this is how life under Earth can be improved, the pH must be between 6 and 7.5. Soil liming is one of the oldest uses of raw or calcined marble (Ojo *et al.* 1998). The marble or lime function as a neutralizer of acid soils and plant nutrient enhancer. The requirement is low grittiness. Marble is also used as grit in the manufacture of poultry feed. For this purpose, the degree of purity of the marble is insignificant but alumina content must be low < 1.55. Based on this specification, Owa Kajola calcite is suitable for use as grit in the manufacture of poultry

feed as it contains 2.28% Al_2O_3 .

A more recent use of limestone/calcite/marble is in the manufacture of calcium ammonium nitrate fertilizer. For this purpose, the marble should contain $\text{CaO} > 47.6\%$, $\text{SiO}_2 < 5\%$. On the basis of this specification, the Owa Kajola marble is suitable for the manufacture of fertilizer as it contains CaO (52.41 %) and SiO_2 (0.76 %).

Filler/Extender Use

Marble is useful as fillers/extenders in manufacture of paint, rubber, plastics, pulp and paper, animal feed, tooth paste and pharmaceuticals. The general specification for this use is $\text{CaO} > 52\%$, $\text{Al}_2\text{O}_3 < 0.2\%$, $\text{Fe}_2\text{O}_3 < 0.2\%$, MgO and SiO_2 must be low ($< 3\%$), $\text{SO}_3 < 0.2\%$, $\text{P}_2\text{O}_5 < 0.15\%$). Based on this specification, Owa Kajola is suitable for use fillers/extenders as it contains $< 52\%$ CaO , $> 0.2\%$ Al_2O_3 , $> 0.2\%$ Fe_2O_3 and $> 3\%$ SiO_2 .

Metallurgical Use

There are numerous applications of raw marble/calcite and their lime products in the metallurgical industry. However, the largest specific application is for fluxing steel. Eight-Five percent of total lime produced worldwide is used as steel flux (O' Drascoll, 1988). In steel manufacture, marble is used first to lower the temperature of melting and second to form calcium silicate by combining with silica of the iron ore which comes out as slag. Specifications for metallurgical lime include $\text{CaO} > 65\%$, SiO_2 (1 – 1.5%), SO_3 (0.05 – 1%). Another metallurgical application of lime is as refractory lime. It is used for lining open hearth. The specification for this use is similar to those of fluxes except that the silica requirement is less stringent (2 – 4%).

Based on the above specifications, the Owa Kajola is unsuitable for use as steel flux as the SiO_2 content in it is higher than the recommended upper tolerable lime of 1.5%. However, the marble meets the specification for use as refractory lime as its silica content (3.14%) falls within the accepted range of 2 – 4% required for refractory lime.

4 Conclusions and Recommendations

Conclusion

The marble deposit in Owa Kajola, Kwara State, North-central, Nigeria based on its chemical composition is a pure carbonate and a typical calcitic – typical marble. On the basis of its chemical composition, the marble deposit can be used for the manufacturing of cement (although it may have to be blended with appropriate quantity of clay and laterite to lower the Lime Saturation Factor (LSF) from the relatively high value to fall within (Industrial Specification of India (ISI) the recommended range of 213 – 417 required for a

typical cement kiln feed). The very high CaO/MgO ratios and the high content of CaO in the rock makes these marble to be considered as very good raw materials for the industrial sector.

Recommendations

From the results of the research study the following are noted:

Further uses may be found for the marble deposit if physical and geotechnical properties of the marble are determined.

It is recommended that geophysical exploration and drilling be employed in delineating accurately the extent of the marble deposit and subsequently determining the reserves of the deposit.

Quality of the limestone (calcitic marble) deduced from chemical analyses will ensure the production of high quality cement.

Location of the deposits to the Omu-Aran Ilorin highway is about 10kilometers and a road can therefore be constructed from a point between Omu-Aran and Oke-Onigbin directly to the Owa – Kajola deposit.

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An Appraisal of Reclamation Method of Mined Out Area: Case Study of Bua Cement Quarry Plc, Sokoto, North Western Nigeria

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Abstract

Generally, surface mining causes adverse changes in the environment by altering or destroying many natural soil characteristics and reducing its productivity for agriculture or biodiversity. Reclamation of mined-out areas is a major concern for mining companies because of increasing global awareness and rapidly expanding environmental demands. This study appraised reclamation process adopted at BUA Cement Company in Sokoto and considered its suitability in compensating for adverse changes caused on the environment. The study revealed that the company adopt back filling method where the exploited waste material from quarry is used to fill the quarry void in order to establish a desired landform. This is followed by planting varieties of trees based on the concept of land reclamation. In the on-going reclamation, highly degraded land of 8- 9 meters in depth were returned to a productive, suitable, and stable state and by which some measures of biotic function and productivity is returning to pre-mining state to about 80% restoration. It is recommended that the company needs to acquire more equipment so as to speed up reclamation that will in turn pave way for a robust restoration program.

Keywords: Overburden, reclamation, back filling, landform, and degraded land.

1 Introduction

Mining of mineral ore like limestone has the potential of causing environmental degradation. Surface mining of Limestone brings about deforestation, soil erosion, gulling and dis-configuration of the landscapes. Generally, the cycle of mining in anywhere would not be completed without restoring the mined-out area to its pre-mining state. Mine reclamation is the combined process by which adverse environmental effects of surface mining are minimized and mined land are returned to a beneficial end use. In practice, The reclamation process begins before any excavation of limestone. Normally, experts have to study the area's ecology with a view to returning it to its original state after the mine is finally closed (Mallo, 1999).

BUA Cement Company (formally Cement Company of Northern Nigeria, CCNN), is situated in the North west zone of Northern Nigeria, Kalambaina in Wamakko Local Government Area of Sokoto State, Nigeria is used as a case study to assess the methods employed for its reclamation. As part of the life cycle of a limestone mine, mined-out areas must undergo

rehabilitation. Mine rehabilitation is the restoration of the post-mined landscape to ~~the~~ a beneficial end use. Mine rehabilitation minimizes the environmental effect of mining and keeps the surrounding land healthy by ensuring the stability and sustainability of the land, soil and water of the mine site. When mining ends, operators must restore the land to its approximate original contour (AOC) or leave the land graded and suitable for a higher and better post mining land use (PMLU) that has been approved as part of the original mining permit application. Exceptions are provided when a community or surface owner is in need of flat or gently rolling terrain. Acceptable post mining land uses include commercial, residential, recreational, agricultural or public facility improvements (Orounye *et al*, 2016).

1.1 Overburden Removal

In the operation of a quarry or open pit mine, overburden or waste rock are usually removed first before extracting the valuable material. ~~Hence~~ The stripping ratio (SR) of limestone extraction at BUA Cement Company. Generally, the whole extraction

process is done by stripping due to the soft formation.

The occurrence of the overburden materials overlying the limestone are soil, laterite and shale. At the top is the topsoil which is sandy, with thickness ranging from 0.5 – 1.0m, and dark brown in color. The laterite has more composition of iron ore and 1 - 5m thickness, and is brown glacial of unsorted material and agriculturally poor in nature. Shale is brown and claying in nature that overlying directly on the limestone deposit with thickness ranging from 5-8m. The topsoil is the overburden to the limestone used for the production of cement. The excavated overburden materials are used for reclamation of the mined-out areas. The laterite, shale and sandy are scooped from the active mine face and dumped by the dump truck on the preceding mined-out face where restoration work is carried out using a bulldozer.

1.2 Reclamation Process

As already mentioned, mine reclamation is the process of restoring land that has been mined to a natural or economically usable state. Although the process of mine reclamation occurs once mining is completed, the planning of mine reclamation activities occurs prior to a mine being permitted or started. Mine reclamation creates useful landscapes that meet a variety of goals ranging from the restoration of productive ecosystems to the creation of industrial and municipal resources (Ellen, 2015). As part of the life cycle of a Limestone quarry, completed mined-out areas must undergo rehabilitation. When mining ends, operators must restore the land to its approximate original contour (AOC) or leave the land graded and suitable for a higher and better post-mining land use (PMLU) that has been approved as part of the mining permit application. Exceptions are provided when a community or surface owner is in need of flat or gently rolling terrain. Acceptable post-mining land uses include commercial, residential, recreational, agricultural or public facility improvements (Ellen, 2015). There are two reclamation approaches recommended:

(a) Forestry reclamation approach: Within the past decade, a new approach to reforestation the Forestry Reclamation Approach (FRA) has been promoted by state mining agencies and the Office of Surface Mining Reclamation and Enforcement (OSMRE) as

an appropriate and desirable method for reclaiming limestone mined land to support forested land uses under Surface Mining Control and Reclamation Act 1977 (SMCRA). The FRA establishes guidelines for achieving successful reforestation on mined lands, and can be summarized in the following five steps (Landhausser, 2015):

- (i) Create a suitable rooting medium for good tree growth that is no less than 1.2 m deep and made of topsoil, weathered sandstone, and/or the best available material.
- (ii) Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium.
- (iii) Use groundcovers that are compatible with growing trees.
- (iv) Plant two types (or more) of trees: early succession species for wildlife and soil stability, then commercially valuable crop trees.
- (v) Use proper tree planting techniques.

(b) Holistic approach: When the top succession species for the local environment is not forest due to local microclimate conditions, reclamation may be better accomplished by establishing rangeland instead. Holistic management has been championed by Dan Dagget and others for mine reclamation in these types of situations. When the best available material is not topsoil, topsoil can be made on site by using early succession species of native hardy perennial grasses and other plants, combined with livestock (Lanhausser, 2015). In line with the new government policy on mining, progressive reclamation is supposed to be incorporated for implementation in any approval for industrial mining activity as stipulated in the Nigerian Minerals and Mining Acts 2007. Progressive reclamation will enable the prospective mining company undertake reclamation of depleted section of a mined area while active mining in other sections of the limestone quarry continue. This requires that mining activity and reclamation exercise takes place at the same time. Materials from newly opened areas are used to reclaim abandoned or exhausted site. As the minerals are removed, the depressions created as a result of excavation are filled backwards (in the reverse order) with the heaps of the overburden. The red lateritic material followed by the topsoil at the site. As these depressions are filled up with the overburden waste, tree seedlings are planted on the

reclaimed land to facilitate stabilization and total restoration of the mined land (Narten, 1983). Different methods of mine reclamation include but not limited to the following: (a) Back filling method; (b) Hydraulic Reclamation Method; (c) Sand spreading; (d) Direct dumping; and (e) Pumping inside the Bunds (Encyclopedia, 2019).

2 Materials and Methods Used Field Visitation

The study area was visited and various quarry sites were observed. At the time of visit, the reclamation work was carried out on some pits and this was captured along with features and landscape of mined out areas.

Interview: Personal interview and verbal communication were conducted with the quarry supervisor, staff and operators at the quarry site, Information and data which include reclamation and rehabilitation activities, equipment used for reclamation were obtained.

Photograph: Photograph of strategic and important



Fig 1: Komatsu Excavator use for overburden scooping.

(b) Dump trucks: This equipment is generally used for haulage of both Limestone materials and overburden. It is flexible and maneuverable and can handle any type of deposits including coarse and block rocks. (Fig 2).

c) **Bulldozer:** The equipment is used for heavy capacity operations and transportation of material; spreading of dumped materials by ~~from~~ trucks; cleaning and leveling around loaded overburden material for site clearing and reclamation (Fig 3).

places were taken using camera. Areas such as reclaimed and unclaimed pits and equipment used for reclamation operation were captured.

Data Analysis: Raw data acquired were carefully studied, prepared and organized using Microsoft excels to achieve a readable format that makes it easier to extract actionable insights.

2.2 Equipment for Reclamation and Rehabilitation

The equipment used for Reclamation and rehabilitation of the Limestone mined out area include Excavator, Bulldozer and Dump truck. However, the selections of this equipment are based on the following conditions:

(a) Excavator: This equipment (Fig 1) is favorable and maneuverable for operations. The overburden is soft and loose and materials consist of Sandy,? Laterite and Shale!! Thus, the overburden does not require any form of blasting as it can be easily excavated and loaded using the excavator.



Fig 2: Dump trucks for hauling overburden.

2.2.1 Compliance of the Mine with Environmental Provisions

The restoration process at BUA quarry involves:

(I) Reclamation by backfilling the overburden freshly stripped using excavator, re-grading of the 20 to 30m high pit walls using bulldozer for spreading, compacting and leveling of the top soil layers.

(ii) At the time of visit, excavators were used for scooping the stockpile and dump trucks used for

transporting and dumping while bulldozer was used for spreading and leveling on the re-graded surface (Fig 2).

(iii) Owing to the fact that it is quite impossible to develop a mine without cutting down trees or disturb



Fig 3: Bulldozer in Operation for Backfilling and Leveling.

the landscape in general, BUA Cement Company has an Environmental impact Assessment (EIA) which contains the process of managing and rehabilitating the mined-out areas. Some of the environmental management plan is to develop good drainage system and eventual collection of water in a sump.



Fig 4: Tress planted on reclaimed land.

3 Results

Reclamation is an integral part of the production processes such as site preparation, part of the production, limestone loading and reclamation to arrive at a well-designed mining system. The reclamation processes at Bua Cement Company Sokoto include backfilling, re-grading, re-vegetation and restoration.

a) Backfilling: Back filling methods was used in the mine reclamation processes in order to reclaim the devastated mine land to its natural or nearly natural state. The equipment used for removal of the overburden includes excavator, dumb trucks and bulldozers.

b) Re-grading: is done by bulldozer and grader for surface stabilization which includes the provision of water quality maintenance, compaction, layering, sealing the layers and therapeutic action to reutilize the surface or prepare it for re-vegetation. The topsoil is spread on the re-graded soil.

c) Re-vegetation: direct seeding with commercially available plants is mostly done at the study area to enhance natural re-vegetation processes. But at the time of visit, the trees planted were cut down so as to expand trucks yard.

d) Restoration: ~~degraded land to its former state~~ is being done by restoring degraded or disturbed land to its former state. At BUA cement quarry, it was observed that the land is being restored to about 80%.

The main goals of the reclamation processes ~~is~~ are ~~desire~~ to restore the chemical and structural state of soils, and to ensure the security of the exploitation terrain and its surrounding areas, as well as to decrease the visual impact of a quarry. The challenges of modern mining development are how to achieve minimum disturbances on the environment without compromising economic growth and quality of life. Mining operation irrespective of the techniques used, from mineral explorations to production and transport have a devastating effect on the environment in many ways, these effects include deforestation, loss of top soil, accelerated soil erosion, soil contamination, qualitative and quantitative depletion of surface and ground water resources, migration of wild life and avian fauna, and addition of air pollutants. Many of these problems are exceptionally difficult to avoid in surface mining as practiced in the Bua Cement Limestone Quarry in Sokoto. The reclamation of Bua Cements Company essentially intends to address suitability of reclaimed lands to stock material, assembling and repairing of trucks and also

expansion of the trucks packing yard (Fig. 5 and 6). It was observed that the land is being reclaimed using backfilling process with laterite and shale first before the top soil which enhance the soil structure recovery and favors the growth of vegetations. Reclamation was established in the study area to prevent accidents which could result from abandoned mine pits and this



Fig 5(a): Truck yard Pack.

3.1 Discussion

Reclamation process at BUA quarry comprises of back filling, re-grading and re-vegetation of degraded land of about 8 to 9 meters in depth which the land is being reclaimed to a suitable, stable, compacted state and resistant to soil erosion. The mined-out area is being restored to between 75 to 80%. The trees planted on reclaimed land have been cut down for the purpose of creating parking yard for additional 500 Trucks being purchased for cement transportation. The mined-out areas had been effectively reclaimed since the company came into being in 1968.

4 Conclusions.

Driven by its corporate values, but also due to increasing global awareness and rapidly expanding environmental demands, BUA Cement PLC continues to respond with a determined commitment to discharge its duties as a responsible corporate citizen. The on-going reclamation and rehabilitation process at BUA Cement PLC ensures stability and sustainability of the land and soil of the quarrying site as the ecosystem is returning to pre-mining state approaching about 80% restoration. and The land restoration process involves typical

research work assess the further use of the reclaimed land. The present re-vegetation exercise of the BUA Cement Company demonstrated that reclamation of mined out pits and rehabilitation of the ecosystem is an operation that span through different phases from exploration to construction, production, and eventual mine closure.



Fig 5(b): Truck yard Pack.



Fig 6: Stock-pilled overburden.

backfilling, re-grading and re-vegetation, which is in line with section 115 of Nigerian Minerals and Mining Act, 2007.

4.1 Recommendations

In view of the foregoing, the following recommendations are made:

- i. The mine needs to acquire more equipment so as to speed up reclamation that will in turn

pave way for a robust environmental rehabilitation and restoration programme.

- ii. Special reclamation unit should be established within the company.

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A Review of the Causes, Effects and Controls of Pipe Sticking in Hole Cleaning

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Abstract

Hole cleaning is one of the problems encountered in drilling operation. The challenge encountered in removing cuttings bed during drilling arises because of the interaction of the drilling fluid with cuttings in the cuttings' bed to form a cuttings bed gel. When hydrocarbon is to be drilled, then bottom hole cleaning is taken into consideration as poor well hydraulics leads mostly to poor bottom hole cleaning. This paper reviews the critical causes and effects of one of the most prevalent drilling issues caused by differences in pressure and eventually leads to pipe sticking in well drilling and hole cleaning. The study also presents a very simplified method to critically reduce the chances of pipe getting stuck in drilled holes by the introduction of nano-particles that alters the mechanical properties of the mud. In addition to the simplified method, conventional techniques are also discussed which enhances well stability and borehole control.

Keywords : Hole Cleaning , Viscosity, Cuttings, Drill Fluids.

1.0 Introduction

Over several years oil industry is facing troubles associated with the stuck pipes. Differential pipe sticking is one of the stuck pipe mechanisms with a major impact on drilling efficiency and well costs (Adams, 1977; Weakley, 1990; Wisnie and Zheiwei, 1994). Stuck pipe is a major cost issue in some drilling in most drilling operations. Differential sticking is, for most drilling organizations, the greatest drilling problem worldwide in terms of time and financial cost. It is a condition, for which the drill string cannot be moved (rotated or pushed up and down) along the axis of the wellbore. Differential sticking typically occurs when high-contact forces caused by low reservoir pressures, high wellbore pressures, or both, are exerted over a sufficiently large area of the drill string. (Islam and Hossain, 2021).

Stuck pipe mechanisms are grouped into either mechanical or differential mechanisms. When a portion of the drill string casing or logging tool is embedded in a hard mud filter cake and held by significant differential pressure. Mechanical sticking of the tube occurs during drilling and is recognized when the lower hole assembly (BHA) cannot be rotated or moved due to hole debris. One of the primary technical issues in the drilling sector has been stuck pipe occurrences, which often result in a large amount of downtime and corrective expenses. The recent increase in drilling activity, shortage of

experienced personnel and equipment, and drilling in higher-risks areas have increased the risk of stuck pipe events in all drilling operations (Yarim *et al.*, 2007).

Poor hole cleaning can lead to drilled cuttings accumulation into the annulus causing stuck pipe. This problem can be more difficult when drilling deviated wells. The cutting beds can form on the low side of the well bore. It is common as rig site practice to pump sweeps and circulate bottom up before tripping out of the hole to avoid such situations. Increased torque and drag are indications of inappropriate hole cleaning and remedial actions have to be taken to remove the cutting beds by pumping sweeps. The sweeps program depends on the type of the well, high viscosity pill can be pumped when drilling vertical wells, whereas low viscosity and high-density pill can be used to clean high deviated wells. The use of pills has to be accompanied by rotating the drill string to create agitation to make cutting beds removal more effective.

Drilling operations are disrupted by pipe sticking, which is time-consuming and costly. Pipe sticking can be predicted if certain warning indicators are seen. To avoid a stuck pipe, these symptoms usually necessitate prompt action from the drill team. Sticking of tubes is also a common problem that has a significant impact on drilling efficiency and cost in the oil industry.

This paper is aim at investigate the causes, effects, and solutions for differential pressure sticking and stuck pipes in borehole oil and gas drilling operations. Differential pressure sticking and jammed pipes are two of the most common problems encountered during oil and gas well drilling.

2.0 Pipe Sticking in Hole Cleaning

Drilling a well requires a drill string (pipe and collars) to transmit the torque provided at the surface to rotate the bit, and to transmit the weight necessary to drill the formation. The driller and the directional driller steer the well by adjusting the torque, pulling and rotating the drill string. When the drill string is no more free to move up, down, or rotate as the driller wants it to, the drill pipe is stuck. Sticking can occur while drilling, making a connection, logging, testing, or during any kind of operation which involves leaving the equipment in the hole (Anon, 1997).

2.1 Types of Pipe Sticking

2.1.1 Differential Pipe Sticking

Differential pressure pipe sticking occurs when the drill string becomes embedded in a mud solid, filter cake, filter cake, usually across a permeable zone, and is held in place by mud pressure that exceeds the formation pressure. The occurrence of differential sticking can be diagnosed when the drill pipe cannot be rotated or moved up or down but unrestricted mud circulation is still possible. It has a major impact on drilling efficiency and well costs (Gray and Darley, 1981; Chilingarian and Vorabatur, 1983; Bradly, 1991; Simon et al., 2005).

2.1.2 Mechanical Pipe Sticking

The fundamental principle of mechanical pipe sticking are the inadequate removal of drilled cutting from the annulus; borehole instabilities, such as hole caving, sloughing, or collapse, plastic shale or salt sections squeezing (creeping), and key seating. This mechanism can occur due to many reasons;

- a) Accumulation of drilled cutting
- b) Borehole instabilities
- c) Key seating

(a) Accumulation of Drilled Cuttings.

Poor hole cleaning can lead to drilled cuttings accumulation into the annulus causing stuck pipe. This problem can be more difficult when drilling deviated wells. The cutting beds can form on the low side of the well bore. It is common as rig site practice to pump sweeps and circulate bottom up before

tripping out of the hole to avoid such situations. Increased torque and drag are indications of inappropriate hole cleaning and remedial actions have to be taken to remove the cutting beds by pumping sweeps. The sweeps program depends on the type of the well, high viscosity pill can be pumped when drilling vertical wells, whereas low viscosity and high density pill can be used to clean high deviated wells (Anon, 2016).

(b) Borehole Instability

Depending on the weight of the mud and the composition of the mud, the shale can exfoliate or move plastically inward, causing the pipe to become mechanically stuck. Another type of formation that can flow plastically if the mud weight is not high enough is salt. Also, using a low drilling fluid density can cause the hole to collapse and the tube to stick (Anon, 2022). An increase in pressure and torque are indications about borehole instability.

(c) Key Seating

Key seating is caused by creating a groove into the wall of wellbore when combining the rotation of the drill sting and applying side force on it. The lateral force tends to push the drill string against the wall causing mechanical erosion and creating what is called a key seat. Long bit runs may cause key seats and as good practice to avoid such problem is making wiper trips or using stiffer bottom hole assemblies in order to minimize high dogleg occurrence (Anon, 2016).

2.2 Effects of Pipe Sticking in Hole Cleaning

A stuck pipe can cause breaking or losing a part of the Drill String in the hole. Its result is very expensive. They include:

- a) Drilling time lost (working on the stuck).
- b) Cost & time spent on working on the fish (to retrieve the lost part of the Drill String or the Bottom Hole Assembly BHA).
- c) Loss of pipe in the hole as it is difficult or costly to retrieve it.
- d) Perform a sidetracking well which is also a waste of time and cost (Anon, 2022).

2.3 Primary Causes of Pipe Sticking in Hole

2.3.1 Inadequate Hole Cleaning

If the cuttings are not removed from the well properly, they will settle around the drill string, usually the bottom hole assembly (BHA), causing the drill collars to become stuck. The problem is worse in over gauge sections where the annular velocity is

lower. Cuttings will build up and eventually slump in the hole. The cuttings are scraped by the stabilizers and the bit when the BHA is moved up the hole at a connection or a trip out. The over pull will increase until the cuttings will stick the BHA. The hole cleaning differs with the inclination of the hole. The annular velocity required to clean the hole increases with inclination.

2.3.2 Chemically Active Formations

Different formations have a different degree of absorbing water. It is thus important for a field engineer to understand the characteristics of the formations that have and will be drilled. Some high clay content rocks absorb water and swell. The amount of swelling varies from highly reactive “gumbo” (fast absorption rate) to shales, which absorb water very slowly. When drilling with water-based mud, the water is absorbed into these types of formations (Commonly shales), causing them to swell and weaken. As a result, chunks of shale will break-off and fall into the borehole. The water-absorbed (hydrated) shale tends to stick to the drill string and accumulate in sufficient quantities to fill the entire annulus around the BHA, causing it to become stuck.

3.0 Methodology

3.1 Methodology of Pipe Sticking Detection

3.1.1 Automation Approach

Careful monitoring of drilling and tripping trends is crucial to a successful drilling operation. The approach discussed in this paper discusses the real time detection of leading signs of stuck pipe incidents using the combination of pattern recognition in the drilling data and the physics of stuck pipe discussed earlier. These include Drilling Automation Approach. The options are to optimize drilling processes actively by controlling mud cake, reducing loss circulation by optimizing drilling fluids, improving hole cleaning efficiency. The automation approach however is consistent of the hardware and software (Alshaikh et al., 2018).

3.1.2 Statistical Method

Jardine et al. (2009) proposed a method for warning of pipe sticking during drilling operations based on computing the third order moment, skew, of the stand pipe pressure (SPP) and correlate the skew with the normalized standard deviation of the torque (TRQ) signal. However, the SPP signal contains information related to the mud pressure throughout the entire circulating system. Consequently, increases in the

SPP signal may be caused by wellbore mechanics unrelated to poor hole cleaning, e.g. fluctuations in the pressure drop across the mud motor and blocked nozzles in the drill bit.

3.2 Mitigation Methods

3.2.1 Using Nanoparticles to decrease Differential Pipe Sticking

An important way to reduce the chance of pipe sticking is to use nanoparticles in the excavation mud. This causes some changes in the properties of the mud. These nanoparticles are soot particles that are added to the drilling mud to perform some function. It is known that presence of ordinary materials in drill mud can cause increased viscosity and mud weight. This high mud weight can cause damage to sub-surface formations, plugging of production zones, hole erosion, decreased penetration rate, pipe failures, stuck pipe and lost circulation (Ford et al., 1990, Amoco, 1996, BHI, 1998, Reid et al., 2000 and Njobuenwu and Nna, 2005).

In order to decrease probability of stuck pipe we make use of new materials in which do not increase viscosity and mud weight very much. Because as mentioned this increase in viscosity and mud weight may lead to some problems that one of them is stuck pipe. The advantage of carbon black which has Nanometer size particles causes to make a mud cake which is more continues and integrated (it means that mud cake has low permeability). So by having integrated and low permeability mud cake, we have less volume of filtrate and therefore mud cake thickness is less than usual cases.

3.2.2 Artificial Intelligence

This approach uses the combination of automation and human knowledge in mitigating drilling problems has been presented by Sadlier et al. (2013) and Ferreira et al. (2015). The model uses pattern recognition incorporated in an automated decision support tool. This tool provides real-time case-based reasoning to assess the risk and mitigate stuck pipe incidents in collaboration with an expert. The tool uses case-based reasoning (CBR) to match the real-time patterns with historical analogous cases where the same problem occurred. This allows providing automated recommendations for corrective actions based on the recognized patterns and the historical match. The experts are to collaborate in a timely manner with the decision support tool to provide guidance in mitigating the problem. The third

approach published in the literature uses analytical models such as torque and drag, or hydraulics models, in identifying potential drilling problems.

3.2.3 Conventional technique of removing a stuck pipe

Industry accepted main conventional recovery methods include:

- a) Rapid reduction of hydrostatic pressure through removing drill and mud solids with dedicated mud cleaners and centrifuges, and/or displacing the mud with lighter fluids such as treated water or Diesel, within the limits required for maintaining well control and borehole stability.
- b) Spotting dedicated friction reducing lubricants or pipe release agents around the stuck pipe part, to break down the filter cake reducing the bond between cake and pipe.

4.0 Conclusion

The cutting transport in hole cleaning is critical in the highly-deviated and horizontal wells due to the influence of gravity settling. In general, poor hole cleaning may result in stuck pipe, reduced rate of penetration (ROP), transient hole blockage leading to lost circulation, excessive drill pipe wear, extra cost for special drilling fluid additives and wastage of time by wiper trip maneuvers. The drilling fluids with high performance and drill-string rotary are beneficial for hole cleaning.

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Tackling Security Challenges in the Mines: A Case of Illegal Mining and Banditry in Northern Nigeria

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Abstract

The growing insecurity confronting the Nigerian mining industry, especially in the North-west and parts of North-central Nigeria, has created an array of problems including theft of mineral ores, killing and kidnapping of miners among other challenges. Consequently, artisanal and small-scale mining (ASM) operators have been driven from the mines thereby reducing mineral production. This paper examined the various security challenges facing mostly the ASM sites in the country, their causes, relationship between illegal mining and banditry and its implications on the national economy; and preferred possible solutions to the problems. Primary and secondary data collected through field studies, questionnaires administered to the relevant respondents and oral interviews conducted and literature review were examined respectively. Data collected were then interpreted, analyzed and subjected to Microsoft Excel for further analysis. The findings revealed that illegal mining is a major factor attracting armed banditry to the mining sites, which has further fueled other violent crimes, often resulting in the death of miners as well as smuggling and loss of unprocessed minerals. As a result, artisanal mineral production decreased to around 4,000 tonnes in the Northwest geopolitical zone between 2016 and 2021. Hence, proffered solutions to the problems include tackling the root causes of insecurity through community policing initiatives, exploring robust diplomatic channels with the neighbouring countries to curb foreign nationals' involvement in illegal mining, decentralizing the ownership and control of minerals down to the lower levels of government and inclusive administration of the Nigerian mining industry through critical engagement of stakeholders.

Keywords: Insecurity; artisanal and small-scale mining; illegal mining; violent crimes; mineral production.

1.0 Introduction

Artisanal mining can be defined as informal mining activities by group of persons working in small size operations using low technology, rudimentary and primitive techniques, with little or no capital. In spite of its inefficient productive capacity, artisanal mining, together with small-scale mining, contributes 20% to 25% to global annual production of gold, diamonds, tin, tantalum, and cobalt (Schwartz, 2021). Artisanal mining is obviously an already established method of exploiting mineral deposits in the country and it is estimated to be over 95% prevalent (Oramah et al, 2015), while 95% of it is also illegal (Mallo, 2012). It involves over 500,000 persons across the affected states (Hayes, 2008). Nigeria has gone through difficult stages of insecurity since the advent of insurgency in 2009 but such instability reached its peak few years ago when elements of insecurity such as banditry, kidnapping, cattle rustling and other violent crimes emerged as the major links to illegal mining in Northern Nigeria. Therefore, artisanal mining sites across the country have become apparent enclaves for bandits and other criminal

gangs, who ambush the unsuspecting miners and kill them to steal their mineral ores. Figure 1 shows major artisanal mining sites in Nigeria.



Fig. 1 Artisanal Mining Sites in Nigeria

Historically, artisanal mining in Nigeria has, over the years, been prone to massive safety and environmental hazards (Salati and Mustapha, 2016). However, reports of fraudulent deals, theft of ores and criminal acts in artisanal mines had remained inadequate, scanty, and unverified until 2019 when armed conflict, banditry, violent crime and

kidnapping took the center-stage in Zamfara State due to gang rivalry over the control of gold mines across the State (Amosu and Adeosun, 2021). According to the United Nations (UN) report, the first half of 2019 saw Nigeria witnessing worsening rate of insecurity tagged 'volatile 61' attributed to Boko Haram insurgents, resulting in worsening humanitarian conditions such as population displacement and food insecurity (Anon. 2021). In the same vein, the Global Terrorism Index (GTI) covering events of 2019/2020 ranked Nigeria third place, resulting from terrorist attack deaths and recording the second largest reduction in deaths from terrorism in 2019; it is a reduction of 39.1% compared to the previous year and 83% lower than its peak period in 2014. Insecurity in North-western Nigeria and by extension, greater part of West Africa's Sahel Region, is apparently rooted in mineral resources-related conflicts. Shortage of water and limited land driven by environmental degradation and climate change is often cited as the major cause of such violent competitions (Aina and Quinn, 2021). Figure 2 shows artisanal gold mining and processing activities within communities in Shiroro Local Government Area of Niger State, North-central Nigeria.

Fig. 2 Alluvial Gold Miners in Shiroro LGA of Niger State

Report of a research conducted by Villegas et al. (2021), focusing on potential links between gold mining and violent competitions in twenty-four (24) selected gold mining origin countries of which Nigeria is part, is apparently in concurrence with other global indicators concerning the high rate of mining-based conflicts. In the report, mining-related conflicts in the North-western Nigeria gold mining communities are reputed to have claimed the lives of 6,139 people, including women and children; bandits in these areas use women and children for arms smuggling and sex trafficking thereby subjecting the country's mining industry to higher domestic violence incidences than other sectors of the economy.

Zamfara, and to a lesser extent, Katsina and Kaduna States top the Northern Nigerian regions where

bandits gain access to artisanal mining sites and engage in high profile killings and mineral ore theft. The Zamfara crisis is particularly fueled by competition for agricultural land use and grazing between farmers (who are also the artisanal miners) and herders on one hand and struggle for access to water by both parties on the other hand (Bartrem et al., 2022). Simultaneously, cattle rustling and kidnapping of miners and farmers in mining communities have become almost daily occurrences with majority of the residents running away and abandoning their farms and mining pits. There are, however, strong indications that influential individuals, including politicians with mining stakes in such communities, connive with bandits who besiege the gold mining pits to kill miners and steal their gold ores to trade them in exchange for arms and ammunition (Donald, 2019). Consequently, mining communities are deserted as artisanal miners and their families flee to safer communities to take refuge and find alternative means of livelihoods. In view of the aforementioned scenarios which have significantly reduced mineral production amid increasing illegality and created a sustainability gap, this paper attempts to ventilate issues surrounding insecurity and artisanal mining in Nigeria with view to searching for a lasting solution towards sustainable mineral production. Figure 3 shows artisanal gold mining activities in Bukuyyum community in Zamfara State, North-western Nigeria.



Fig. 3 Artisanal Gold Mining in Bukuyyum Community, Zamfara State

2 Resources and Methods Used

The use of primary data in this paper was to access information on insecurity issues in Nigeria as it affects artisanal mineral production. This involves collection of production data from selected mining sites in Zamfara, Katsina, Kaduna and Niger States. Information on miners killed, injured or displaced by banditry across the affected communities as well as mineral transactions and smuggling within mining communities was also gathered to aid discussions and inference. To assess the impact of insecurity on artisanal mineral production, conceptual analysis as

adopted by Salati *et al.* (2014) on artisanal and small-scale gold mining (ASGM) was also employed.

Questionnaires were administered to local miners in the Zamfara, Katsina and Kaduna States which are the states with the most prevalent cases of armed banditry, kidnapping and cattle rustling around their ASGM sites. The questionnaires were administered to the respondents to collect their opinions on the rate and extent of insecurity in their communities; respondents' opinions were also sought on threats posed by the activities of bandits and other criminal elements to their livelihoods and environment and the impacts of such threats on their overall environmental and economic survival. One hundred and ninety eight (198) questionnaires were randomly administered to miners in the affected ASGM communities, out of which one hundred and seventy eight (178) were returned, while twenty (20) copies could not be retrieved. One hundred and sixty-three (163) copies were acceptable for analysis after careful screening for adequacy and sufficiency of information and fifteen (15) copies rejected.

Apart from questionnaire administration, structured interviews were also conducted for Ministry officials, district and village heads, and other selected stakeholders, including the leadership of the local miners in the study areas to complement data already collected and get sufficient information on insecurity in the selected states as it affects artisanal mineral production. Secondary information obtained mainly from the print and mass media such as newspapers, magazines, television, radio, etc. as well as literature from industry, academics and government bulletin was also used to complement the available primary data for the study as the subject of insecurity in minefields often makes headlines and serves as a means of valuable information. Practical experiences from field and narrations from victims and survivors of attacks, especially on ASGM sites which usually corroborate the existing data were also collated to justify evidences from literature and other sources.

2.1 Illegal Mining and Insecurity in the Northwest: Any Relationship between them?

A comparative analysis was done in the paper to examine the relationship between illegal mining and elements of insecurity such as banditry, kidnapping and cattle rustling with a view to bringing to the fore their common peculiarities. Northwestern Nigeria has, over the years, become the strongholds of bandits who wreck havoc on mostly rural areas of the region (Anon. 2021); they often attack mining sites, especially high value mineral deposits like gold reserves which cut across Katsina, Zamfara, Sokoto,

Kebbi and other states in the region. Zamfara State is a hub of both massive crop and livestock farming and this serves as another point of attraction for the armed actors who besiege their farms to rustle cattle and rob the farmers of their money and other valuables. Since the artisanal miners also engage in farming activities, the proximity between their farms and mines provides an easy link for the attackers to strike. There is an apparent increasing rivalry among the various armed groups operating in the North-western States of Katsina and Zamfara States whose attacks on mining sites and farms have only stopped based on agreed terms of conditions by their victims (Amosu and Adeosun, 2021).

2.2 Illegal Ore Transactions and Smuggling of Minerals Across Borders

ASGM communities in Zamfara State such as Anka, Bukkuyum, Maru and Bungudu are good case studies in this respect. Gold reserves in Zamfara State are quite massive and cut across many communities which share borders with other North-western states in Nigeria as well as Niger Republic. In these gold-rich communities, gold trade is an important source of income to the armed bandits to purchase weapons and ammunition through which they unleash terror on the villagers and miners (Donald, 2019). According to Igwe (2021), a strong and glaring nexus has been established between the activities of bandits and illicit mining. Hence, trade in gold and other minerals in the State has also helped to fund the bandits' war against the government forces over the years. These violent local conflicts and rural banditry, associated with illegal mining, have traversed most parts of Kaduna, Katsina, Kebbi, Sokoto and Zamfara states where over 3,600 people were kidnapped between 2011 and 2019. In Zamfara State alone, 6,319 people, including women and children, were reportedly killed between June 2011 and May 2019 (Ogbonnaya, 2020).

Chinese nationals are identified as major players in illegal mining operations and illicit ore transactions across artisanal mining sites in Nigeria, and together with influential individuals in those mining communities, fund their activities (Ogbonnaya, 2020; Salati, 2015). Other foreign nationals from neighbouring African countries like Niger, Chad, Cameroun and Mali also massively participate in massive illegal mining and illicit ore trade, especially in gold mining and processing. According to Amosu and Adeosun (2021), these activities translate to smuggling of gold ores from the mining sites across the porous borders passing through various countries until the ores reach the world mineral market unprocessed. Currently, the Birni-Gwari axis

of Kaduna, referred to as 'the axis of danger and hazards' and the Katsina-Kebbi-Zamfara axis, popularly known as 'the epicenter of rural banditry' are some of the routes leading to these gold deposits where the criminal elements attack the miners and steal their ores (Ogbonnaya, 2020). Data from UN Comtrade revealed that between 2012 and 2018 about 97 tonnes of gold worth over 3 billion dollars were smuggled out of Nigeria (Igwe, 2021). Ogbonnaya (2020) also quoted the former Nigerian Minister of Mines and Steel Development as attributing the loss of 353 billion naira (over US\$900 million) by the country to the activities of illegal miners and smuggling syndicates between 2016 and 2018. The various armed groups often besiege artisanal mining sites to hijack mining activities by killing the miners and stealing their ores which are either undergoing processing or unprocessed; the stolen ores are then transported and smuggled through the borders outside the country for further transactions. Hence, there are glaring evidences that these criminal networks fuelling insecurity in the North-western Nigeria and spreading fast to other parts of the country thrive in collaboration with traditional rulers, politicians and foreign opportunists who are exploiting the mineral deposits to fund their activities.

3 Results and Discussions

3.1 Surging Banditry and Shrinking Mineral Production in Northern Nigeria

Analysis of data collected through questionnaire administration and interviews was done using Microsoft Excel and Statistical Package for Social Sciences (SPSS). The questionnaire administration and interviews mainly focused on general insecurity in the mining communities across the North-western states and their correspondent impacts on artisanal mineral production. One of the major findings corroborated by both primary and secondary data collected is the effect of the Federal Government ban on all forms of gold mining in Zamfara State in 2019 which was a response to a dire security situation. The ban was responsible for miners leaving Zamfara mining communities for other parts of the country to continue their mining activities. The resulting impact of the ban is a significant reduction of mineral produced by the artisanal miners in Zamfara State in particular and Northwest in general. Also, as confirmed by Ogbonnaya (2020), state governments in this geo-political zone have held negotiations and dialogues with the criminal groups and illegal miners to curb the loss of lives and properties created by illegal mining and banditry but to no avail as these acts of illegality have continued unabated, along with

associated conflicts. Also, as shown in Figure 4 from the level of education of the respondents, illiteracy/ignorance remains a major factor contributing to the declining artisanal mineral production as all efforts to bring modernity and innovation to gold mining and processing techniques in the mining communities are defied, thus worsening the insignificant mineral production by miners as alluded to by Salati (2015). The fact that there is a glaring decline in gold production in the North-western region of Nigeria is an overwhelming affirmation by the artisanal miners as shown in Figure 5 depicting the summary of the responses of respondents. In the same vein, the overwhelming acceptance by the respondents interviewed is a strong attestation that insecurity is responsible for a decline in artisanal gold production in North-western Nigeria as indicated in Figures 6 and 7.

Donald (2019) is also in concurrence with the findings from questionnaires and interviews results on factors fueling banditry in Zamfara State. This agreement is a confirmation that trade in gold and other minerals from Zamfara State has helped to fund years of fighting between bandits and government forces in the country's North-west zone. Clearly, a major source of funds for the bandits is the mines where minerals are stolen and carted away after the miners have been killed. Thus, there is significant reduction of miners working in the mines with a corresponding reduction of artisanal minerals produced (Table 1 and Figure 6). Therefore, as surging banditry claimed over 5,000 lives in five years (Donald 2019), artisanal mineral production also dwindled significantly. As revealed from both primary and secondary sources of information, bandits demand money and processed mineral from miners as a condition to allow them to operate in the minefield; thus, miners who agree to their terms of condition engage in insignificant mineral production, while majority of them flee their mining sites for fear of being killed or kidnapped.

3.2 Identified Solutions to Insecurity and Boost to Sustainable Mineral Production

The need to bridge the gap created by increasing insecurity in Nigeria's mining communities and its correspondent stunted artisanal mineral production requires proactive measures that are capable of improving security and boosting mineral productivity. In furtherance of this gap - bridging effort, the paper is in total concurrence with the following identified measures which would serve as panaceas to removing impediments of insecurity in mining communities with a view to restoring sanity and sustainable mineral production:

- i. Amendment of the current Mineral and

Mining Act, 2007, with a view to decentralising the ownership and control of mineral resources to the State Level rather than saddling such with the Federal Government alone as suggested by Salati (2015) and Oramah et al. (2015);

ii. Exploring robust diplomatic channels with the neighbouring countries such as Niger, Mali, Cameroon, Chad, etc. and consolidating on the existing security bonds among them would help secure the porous borders and curb the involvement of foreign nationals in illegal mining and other forms of criminality within the vulnerable mining communities;

iii. Engaging experienced and seasoned mining professionals in critical sectors of the economy such as the Ministry of Mines and Steel Development and Ministry of Environment by using them to evolve policies that are meant to trigger accelerated mineral development and environmental protection in the country; and

iv. Initiating community policing through responsible traditional leadership and mutual collaboration between government agencies and community security outfits to secure the rural areas including the mining communities is an essential ingredient necessary for peace and development.

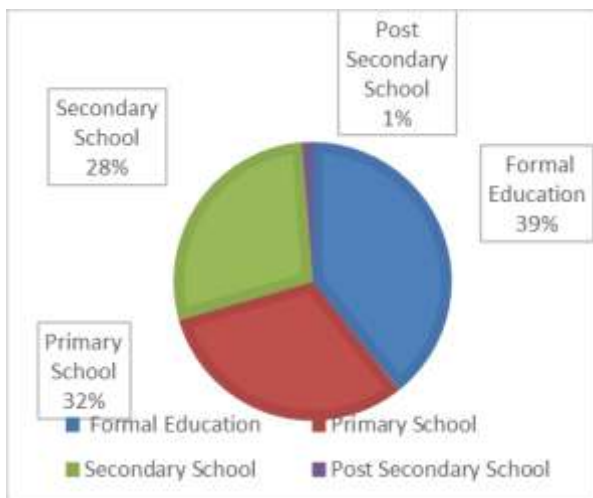


Fig. 4 Educational Level of Artisanal Miners Interviewed



Fig. 5 Response to Question was there perceived decline in Gold Production in the Zone?

Table 1 Estimated Artisanal Mineral Production in Northwestern Nigeria 2016 – 2021

State	Mineral Produced (Tonnes)					
	2016	2017	2018	2019	2020	2021
Zamfara	442	503	526	517	132	48
Kebbi	183	229	209	204	219	100
Sokoto	Nil	Nil	Nil	Nil	Nil	Nil
Katsina	Nil	Nil	Nil	Nil	Nil	Nil
Kaduna	Nil	Nil	Nil	Nil	Nil	Nil
Kano	Nil	Nil	Nil	Nil	Nil	Nil
Total	625	732	735	721	351	148

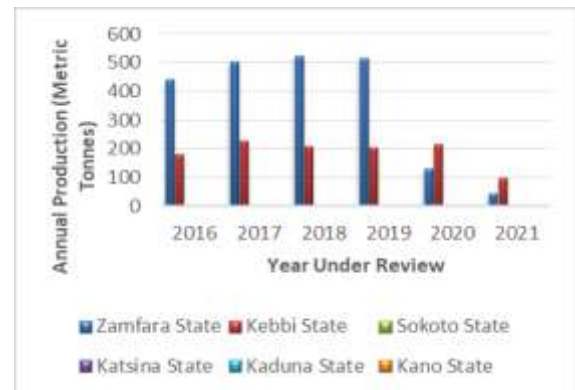


Fig 6 Estimated Artisanal Mineral Production in North-western Nigeria 2016 – 2021

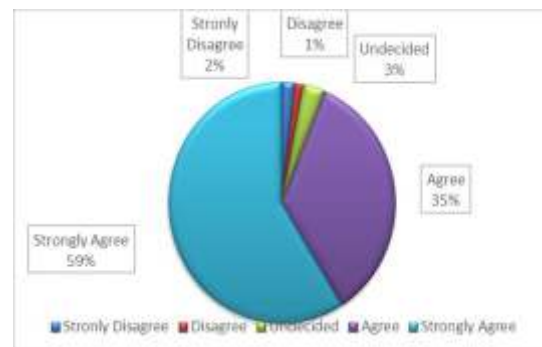


Fig. 7 Responses to Questions that Insecurity caused Decline in Gold Production

4 Conclusions and Recommendations

4.1 Conclusions

In this paper, the gap created between insecurity in mining communities and insufficient mineral production by artisanal miners has been examined and it was concluded as follows:

i. The security of mining communities in Northern Nigeria has been compromised giving rise to banditry, kidnapping, cattle rustling, and other forms of criminality and leading to massive loss of miners' lives and insignificant mineral production;

ii. There is a strong link between illegal mining and banditry thereby fuelling insecurity in the mining communities;

iii. Due to armed banditry and smuggling of unprocessed minerals, artisanal mineral production in Nigeria has been significantly reduced;

- iv. Illicit mineral transactions are used in funding banditry, kidnapping and other criminal activities in the mining communities; and
- v. Politicians and influential persons with mining stakes are identified to be the sponsors of banditry and kidnapping in the affected communities.

4.2 Recommendation

In view of the aforementioned conclusions, it is strongly recommended that the government develops a formidable framework to facilitate the implementation of all the identified panaceas for curbing insecurity and boosting artisanal mineral production in Nigeria. This is realizable, if there is collaboration among government agencies, the leadership of mining communities and other stakeholders in the Nigerian mining industry.

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Computer Software and Its Application in Mineral Exploration and Mining

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Abstract

Computer Software is a collection of programs designed to operate, control and extend the processing capabilities of the computer itself. While, mineral exploration is the process of searching for evidence of any mineralization hosted in the surrounding rocks, mining is the extraction of valuable minerals or other geological materials from the Earth, usually from an ore body, seam, reef or placer deposit at a profit. In order to achieve this, there is need for computer application software which help the end user to perform single or multiple tasks easily. During mineral exploration, a lot of geochemical data are acquired and generally contains broadband information, these data were filter to enhance spatial correlation. Some standard geochemical data processing tools include; 1. basic and extended statistics, 2. spatial filters and 3. Gridding. These statistics allow basic and extended statistical analyses with numerical means of determining how to process and evaluate data. In addition, the mineral explorationist also rely on extended statistical reporting, such as sum of squares, standard deviation, variance, standard error, mode, geometric mean, kurtosis and skewness. In mining, the mine design and schedule, haulage roads, pit optimization etc. are now aided by computer softwares such as surpac, micromine, leapfrog and 3DMine.

Keywords: Computer, Software, Mineral, Mining, Statistics

1 Introduction

The mineral explorationists in their bid to understand geological processes and geochemical signatures therefore need to study the distribution and migration of the individual chemical elements in the various parts of the earth (minerals and rocks) with the objective of discovering principles governing this distribution and migration. To achieve this, quite a lot of geochemical are required. More challenging is how this data can be used to obtain information about geological processes and to find mineral deposits. Conservatively, geochemical data are subdivided into four main categories: the major elements, trace elements, rare earths elements (REEs) and isotopes.

1.2. Data acquisition, processing and interpretation

At the processing stage, the mineral explorationist's objective is to convert raw data into information, such as classified and filtered data, or various types of grids so that the spatial relationship of data can be evaluated.

Geochemical data processing involves adding value to the existing knowledge. Thus, it comprises of all major activities that will require specific computer

assisted tasks to transform raw data into information, knowledge and decisions. The process comprises of five major components:

Acquisition of data: Facilitates access to observation and supporting information.

Data Processing: Provides capabilities for converting raw data to information.

Propose Models: Provides capabilities for converting processed data into geologically information and models.

Visualization/Integration of data: Provides capabilities for applying knowledge through the mineral explorationist's experience in extracting information from visual representations of data and information.

Presentation: Provides facilities for creating maps, graphs and tables on which decisions and actions recommended.

In the achieving the above, it is important that the software chosen allows you to interact with your data in an effort to ensure that derived information correlates with the geology.

2 Analytical and Methods in Geochemistry

Quite a number of analytical methods for major and trace elements during mineral exploration have been

in routine use by geo-analysts. Well-proven analytical techniques include the following:

1. X-Ray Fluorescence (XRF), Instrumental Neutron Activation Analysis (INAA) and
2. Atomic Absorption Spectrometry (AAS): The immense improvement in laboratory techniques of major and trace elements in rocks over time saw to the introduction of;
3. Inductively Coupled Plasma (ICP), which was provided a readily available, rapid and cost-effective method for trace elements, includes the REEs. This made it possible to determine major, minor and trace elements in a single sample preparation almost similar to what is obtainable with the XRF.

Other analytical techniques include but not limited to:

4. Mass Spectrometer (Isotopic dilution-thermal ionization mass spectrometry ID-TIMS)- like the INAA, they are established methods for the determination of isotopes and the REEs. They are both relatively time consuming and expensive techniques.
5. SHRIMP (Sensitive High Resolution Microprobe)- used in the analysis of rocks and mineral grains, good for the measurements of isotopes of U, Th, Hf, Ca, Ti, REEs and S; suitable for U-Pb zircon dating.
6. DCP-AES (Direct Current Plasma Atomic Emission Spectrometry)- most commercial laboratories prefer this instead of the ICPAES.
7. ICP-MS (Inductively Coupled Plasma Mass Spectrometry)- used for the determination of isotope ratios.

3 Geochemical Data Processing

Some of the standard geochemical data processing tools include:

Basic and extended statistics
Spatial filters
Gridding

These tools are very important in mineral exploration. These statistical analyses include the ability to report the number of samples and missing values (dummies), minimum and maximum values, data range, mean and median. In addition, the explorationist may rely on extended statistical reporting, such as sum of squares, standard deviation, variance, standard error, mode, geometric mean, kurtosis and skewness. Basic and extended statistics provide the geochemist with numerical means of determining how to process and evaluate data.

Geochemical data acquired generally contains broadband information. It is therefore necessary to filter the data so as to enhance the data.

Gridding enables the spatial correlation of our data. Gridding can be completed using various algorithms.

The most commonly employed for geochemical data are the kriging and minimum curvature methods. Kriging is suitable for data that is variable or clustered, while minimum curvature is ideal for well data.

3.1. Using Geochemical Data in Petrology

As mentioned above, explorationist frequently apply standard statistical techniques in geochemistry which are now available in computer packages and pocket calculators. For Example:

1. **Averages:** Used for comparative studies with the composition of the average rocks. e.g., average values of MORB and Chondrites are frequently used as normalizing values in trace element studies.

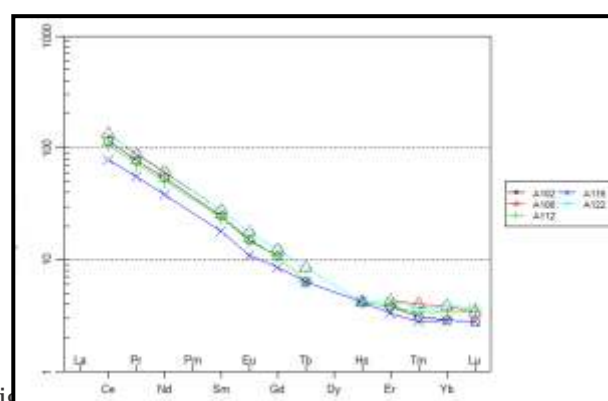


Figure 1. REE patterns of four samples (A102, A118, A106, A122) after (Chappell and White, 1974; 1992).

1. **Source:** Used for deducing petrogenetic source of rocks within geological environment with their elemental composition. e.g., Binary plot of granites in the distinction of S-type and I-type granites after (Chappell and White, 1974; 1992).

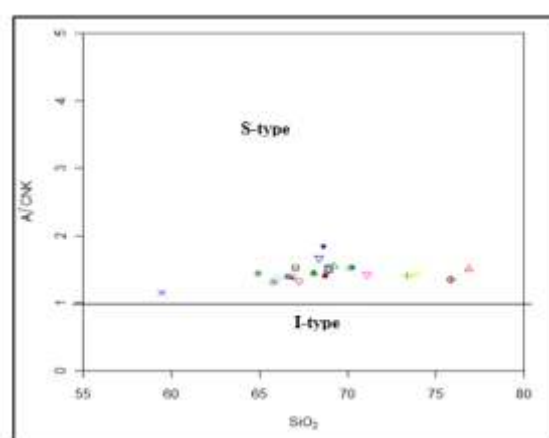


Figure 2. Binary plot of granites into S-type and I-type granites after (Chappell and White, 1974; 1992).

2. **Correlation:** In a set of geochemical data, the geochemist enquires what are the associations between element, e.g., the variation between Zr and Σ REE or if there is a linear correlation between them.

This will require the use of the statistical techniques of correlation.

	A76b	A13	A102	A106	A112	A116	A122
Zr	74	267	156	155	166	164	170
Σ REE	46.2	163.0	149.1	170.5	139.2	105.4	169.2

*Pearson correlation of Zr and Σ REE = 0.702

Figure 3a: Positive Correlation Coefficient

i). Correlation coefficient: Correlation is a measure of the strength of association between two variables measured on a number of individuals and is quantified using correlation coefficient (Pearson product-moment coefficient of linear correlation). Others are Correlation matrix, Correlation coefficient patterns etc.

ii). Regression: A measure of the intensity of the relationship between two variables. It is usually measured by fitting a straight line ($y = a + bx$) to the observations.

	Au	Ag	Pb	Cu	As	Ba	Sr	Rb
Ag	-0.47							
Pb	0.323	-0.65						
Cu	-0.188	0.241	-0.426					
As	-0.169	0.145	-0.382	0.995				
Ba	-0.264	0.96	-0.521	0.281	0.179			
Sr	0.979	-0.284	0.238	-0.174	-0.177	-0.065		
Rb	-0.188	0.533	-0.531	0.935	0.893	0.597	-0.102	
Cs	-0.344	0.669	-0.58	0.878	0.824	0.7	-0.238	0.98

Figure 3b: Correlation Coefficient

3. Discriminant Analysis: Ideal in the investigation of relationships between the major and trace element chemistry and the tectonic setting of volcanic and sedimentary rocks. Examples: in igneous petrology; Classification of basalts by (Pearce *et al.*, 1984); Subdivision of granites to indicate a subduction arc-related features from within plate source for the granites (Muller, *et al.*, 2001)

3.2. Using Geochemical Data in Mineral Exploration

The task of mineral exploration lies in reporting trace element variability within a target area. Thus, rocks, sediments and soils samples are collected as required for geochemical studies. Once the geochemical analyses are done, the geochemical data is investigated for anomalies (single or multiple elements) that may be related to the presence of mineralization.

In order to appreciate the data better, the data is subjected to further analysis or modelling with the application of relevance software so as to enhance information that improves knowledge of mineralization and its geology largely within a

specific exploration environment.

In mineral exploration applications, a successful exercise hinges on the following: The ability to:

Identify fundamental relationships within a suite of geochemical data. This can only be done with application of statistical software.

Determine the spatial distribution of elements or multiple elements of interest that are either direct indicator of economic mineralization. The approach here includes statistical analysis and more complex forms of statistical analysis, such as various multivariate analysis techniques. Currently, visual approaches are increasingly being employed also. Histograms provide a visual means of identifying fundamental relationships in elemental datasets. Histograms are a familiar method for displaying numerical information and providing a visual representation of the data in which:

The total range of data in a sample is apparent

Modes can be easily recognized

The range of greatest abundance of values can be estimated rapidly

The general form of the density distribution of data is apparent.

Histograms are also useful for distinguishing between background and anomalous values (i.e., quality control), or for recognizing a bimodal data distribution (i.e., interpretation).

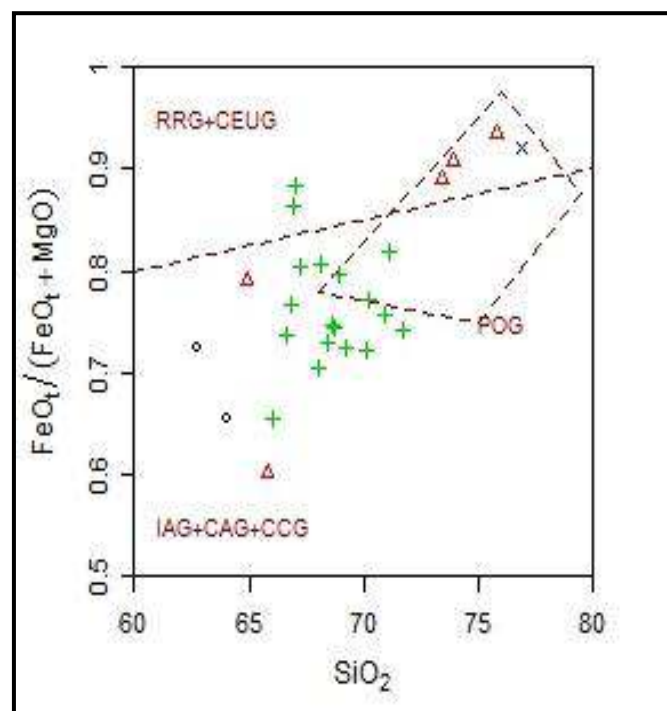


Figure 4: Tectonic discrimination diagram after Maniar and Piccoli (1989)

In addition, spatial relationships are essential in:

Evaluating data populations and subgroups that may be related to geology or other special features.

Classifying the selected data using spatial distributions. These classifications can be displayed on a map, or used to generate a new sub-set database that contains only the selected data population.

4. Conclusion

The achievement of any geochemical investigation centers upon the strong understanding of the geology of the area. An appropriate consideration of the relationships between samples and their relationship to the regional geology is essential to the understanding of the geochemistry of the samples. Therefore, geochemical investigations must always be carried out in a clear understanding of geological relationships. Various software tools are available for working with data and information, and it is important that the mineral explorationists understands their roles and how each of these tools is used in petrology, geochemistry and mineral mapping. However, most of the software are very expensive for individuals and small organizations, but there are many free online sourced Software. Some of the Software commonly used in geochemical data analysis either for petrology,

geochemistry, mineral exploration, mine design and planning are:

- ✓ ArcGIS,
- ✓ Map Info
- ✓ GCDKit,
- ✓ Petrograph
- ✓ Surfer,
- ✓ Oasis Montaj
- ✓ Strata
- ✓ Global Mapper
- ✓ Minitab,
- ✓ SPSS
- ✓ Auqa Chem
- ✓ 3D Mine,
- ✓ GEMCON Minex
- ✓ Surpac,
- ✓ Leapfrog etc

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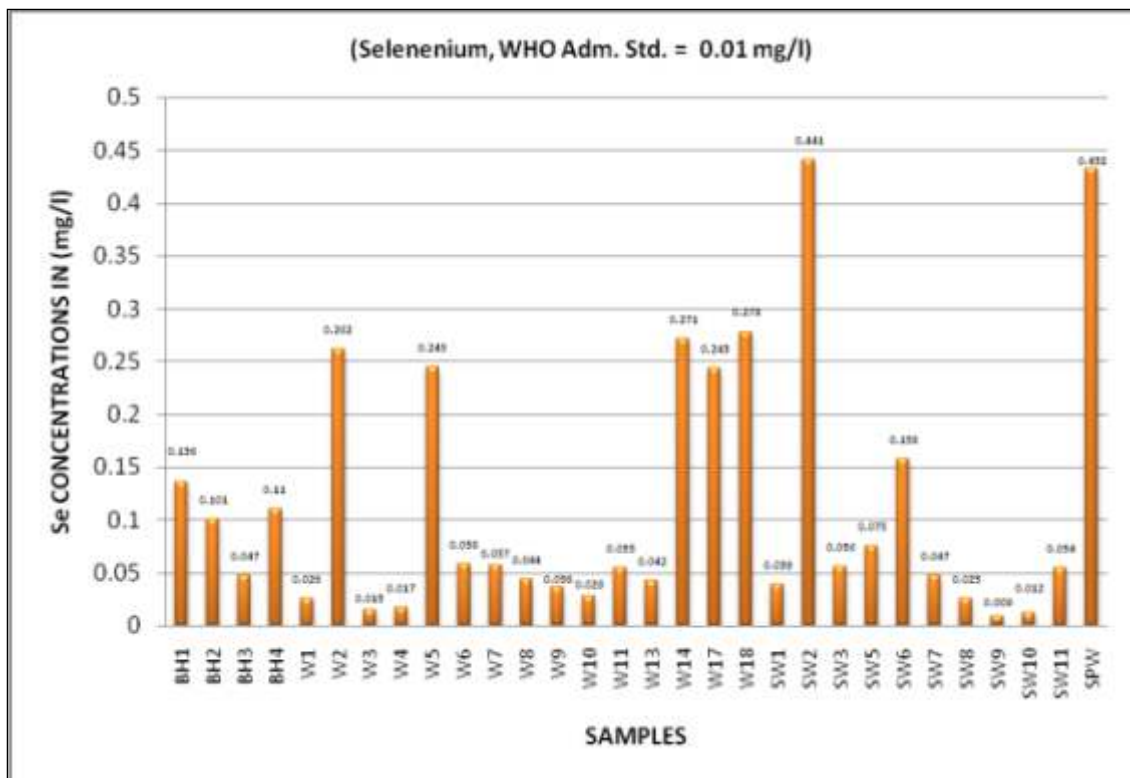


Figure 5: Bar Chart

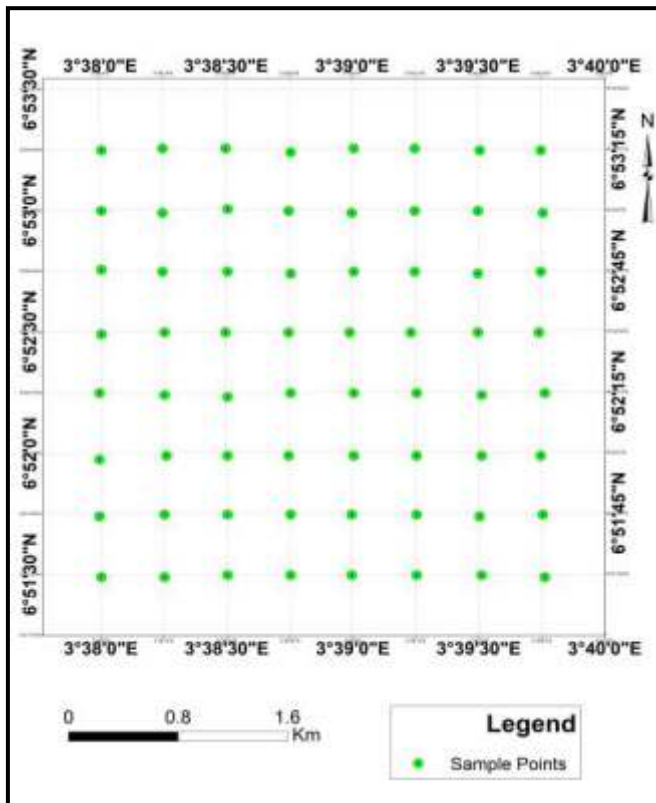


Figure 6: Systematic sampling in a grid form

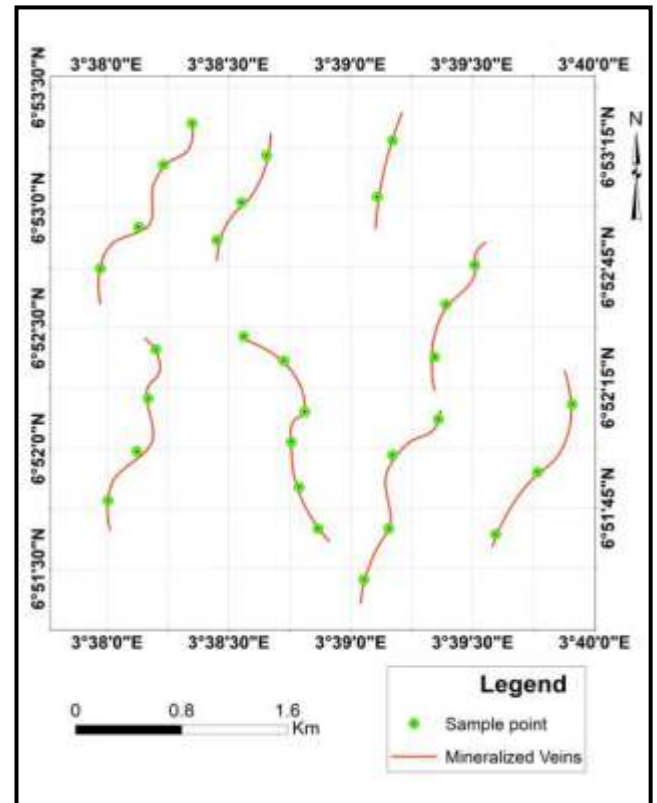


Figure 7: Random sampling along a mineralized vein

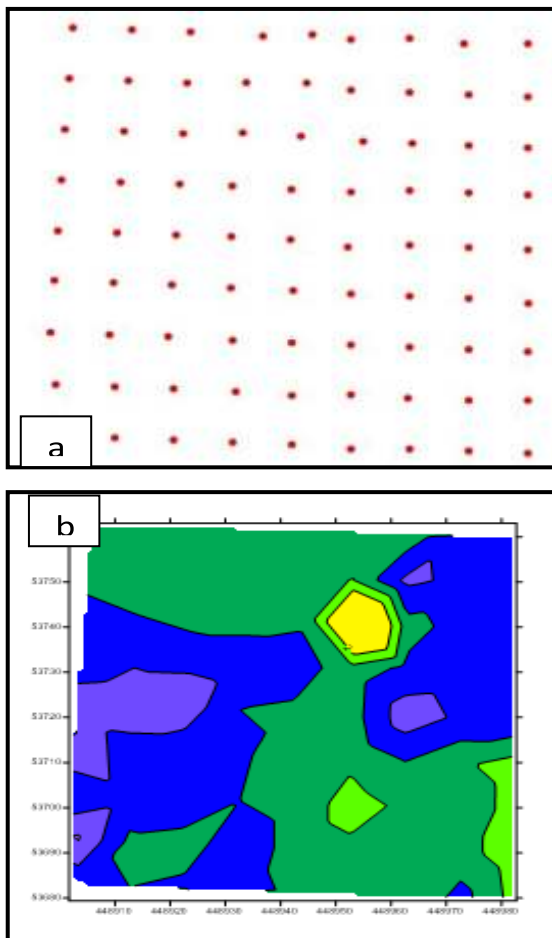


Figure 8: (a) Systematic sampling and (b) Corresponding map

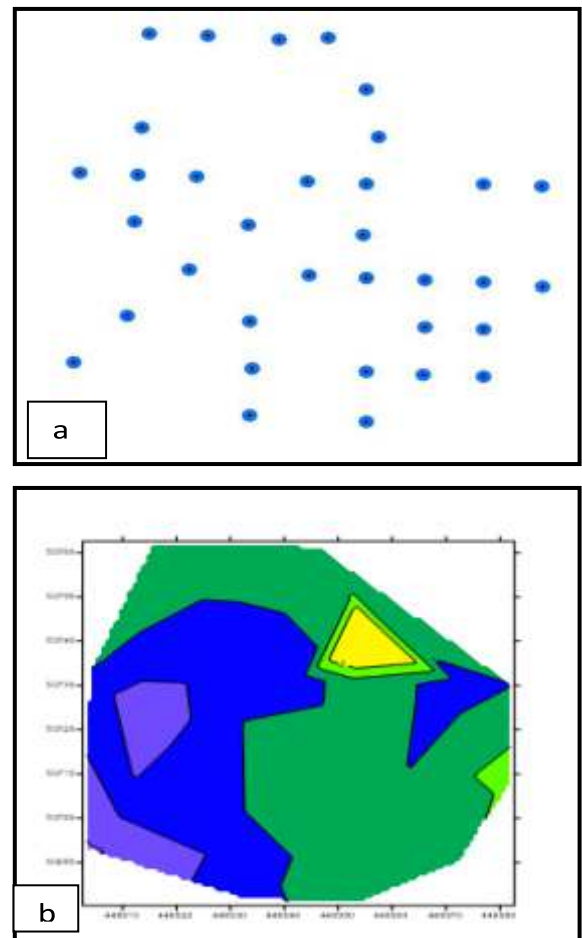


Figure 9: (a) Random sampling and (b) Corresponding map

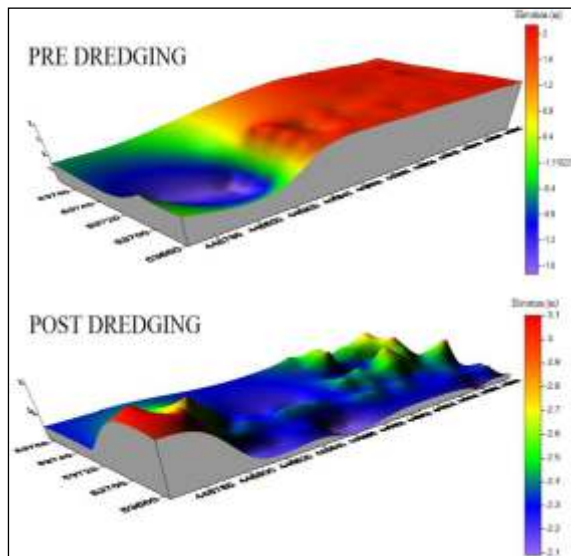


Figure 10: 3D Surface Map

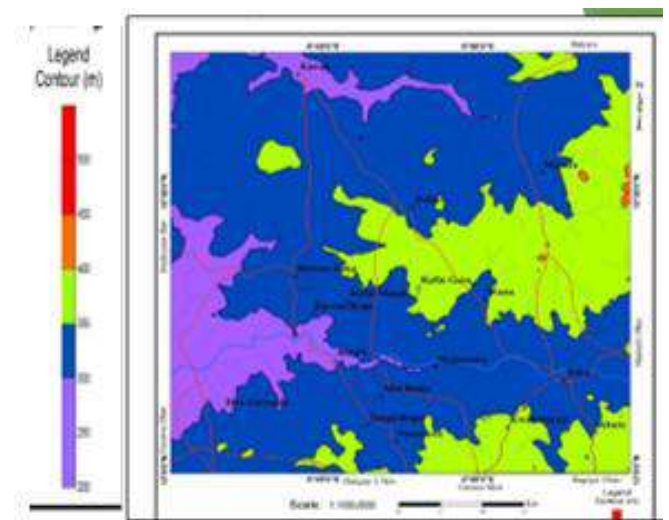


Figure 11: Elevation map showing variation within a study area.

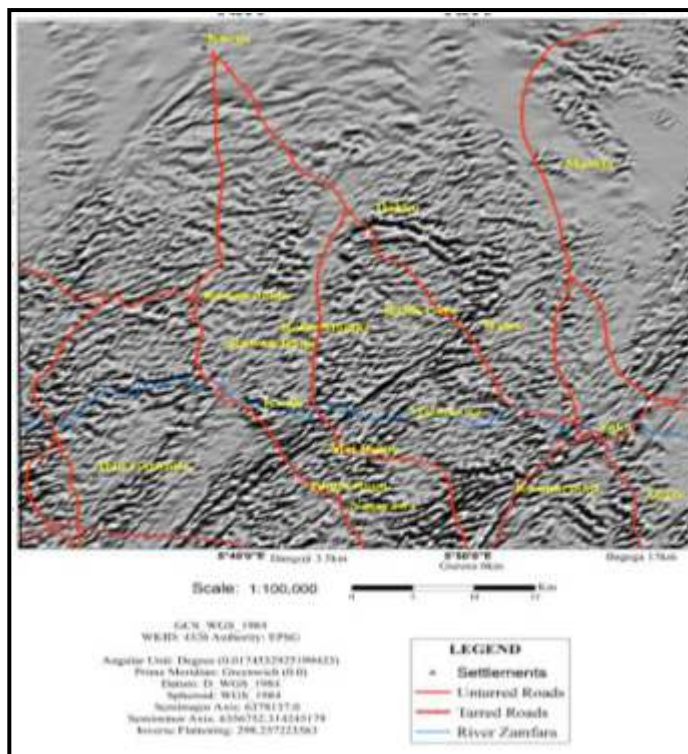


Figure 12: First Vertical Derivative (1VD) map of an area showing lineament

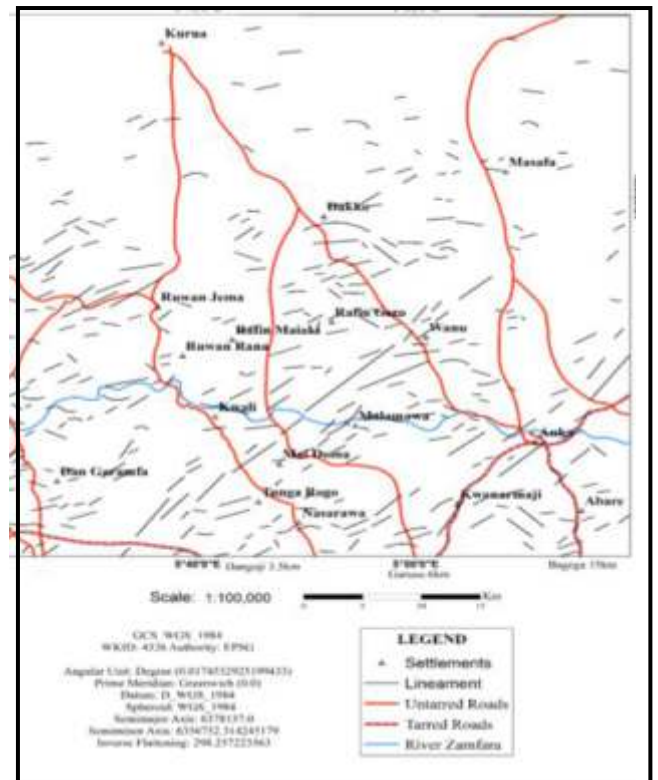


Figure 13: Lineament map of an area deduced from 1VD map

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Activation of Faya Clay Using Different Sodium Compounds

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Abstract

Faya clay was activated using sodium hydrogen carbonate (NaHCO_3), sodium hydroxide (NaOH) and sodium sulphate (NaSO_4) as activators. Samples of faya clay were collected from Faya in Lantang South Local Government area of Plateau State. The samples were crushed and homogenize to form the head sample. Part of the head sample was used for chemical analysis while the rest was used for bench work. The sample was subjected to flotation from which the concentrate obtained was activated using the three activation agents. The head sample of Faya clay contains 38.7% BaO 16.6% Al_2O_3 , 35.6% SiO_2 , 0.559% K_2O , 0.084% aO, 6.133% Fe_2O_3 , 0.91% TiO_2 0.022% CuO, and 0.37% Ag_2O . Upgraded Faya clay contains 52.2% BaO, 18.6% Al_2O_3 , 23% SiO_2 , 0.559% K_2O , 1.22% CaO, 2,050% Fe_2O_3 and 0.990% TiO_2 . The crude Faya clay has a swelling of 3.6 and the upgraded clay has 3.8. The activated clay using the three activation agents has 13 with NaHCO_3 , 10 with NaOH and 11 with NaSO_4 activators. Although the swelling of Faya clay has been improved by activation in each case, the result did not match with that of sodium clay (14 - 15). It is therefore essential to carry out experimental design for the activation of Faya clay.

Key Words: Activation, Upgrading, Flotation, Clay, Homogenize, Sample.

1.0. Introduction

Montmorillonite occupies a prominent position among industrial minerals. It is the main constituent of bentonite and the detrimental factor of its properties. Regardless of origin or occurrence, montmorillonite and bentonite and the determine factor of its properties. Regardless of origin or occurrence, montmorillonite and bentonite are two names of exactly the same mineral.

The electrical neutrality is attained by other cabins' (external to the lattice) that reside in the inter lamina region between the lattice layers. The cautions (usually, Na^+ or Ca^{2+}) are reactively easily exchange on given montmorillonite high caution exchange capacity phenomenon (Solomon, 2013).

The Nigeria economy is known to be highly dependent on the oil and gas industry as far as foreign exchange is concern. Over the years, researchers have confirmed that drilling activities performed by oil companies either needed to import either the materials required for the fluid's formulations or customized drilling fluids design to fit necessities of the Niger Delta formations (Ameloko, 2020). The related expense of the import of these materials can amount millions of dollars per years, causing having to the country's economy

(Afolabi et al., 2017). The importations of bentonite for drilling of wells in the oil and gas industry has continually diverted huge sum of foreign exchange that could be budgeted for the socio-economic stability of Nigeria (Dew et al., 2011). Nigeria bentonite has no notable utilization despite its substantial deposit at various locations in the country because of its difficulties being excessive fluid these difficulties being excessive fluid these difficulties one more, bentonite used in Nigeria for drilling activities is mainly imported into the country (Apogu-Nwosu et al., 2011).

Appropriable measures have not been made regarding the alteration of this clay before it can be utilized in the preparation of drilling mud. It is also vital and proper to enhance the properties of this clay. These needs have increased the research on the utilization of local clay. In the application of darling fluid in the oil and gas industry (Martins, 2011). As the interest for bentonite clays rises, there is a need to go improve the Nigerian properties to correspond to the API standard (Afolabi et al 2017). In order to be used in an industrial application such as drilling mud, Nigeria bentonite must be turned sodic and a high smelly capacity. In this process, clay is treated with NaCO_3 , causing a double exchange variation in

which the cast cautions of the clay combine with (CO_3) coming from the sodium carboxymethyl cellulose (cmc) is primarily a fluid loss reduce but also produce viscosity in fresh water and saline minds whose salt content does not excused 50.000 mg /c (Blecer et al. 1993) plateau is the twelfth largest state of Nigeria, and is located approximately in the centre of the country. It is geographical unique n Nigeria because bounders surround the los plateau having the entre plateau it central and within past. The capital is Jos. Plateau State is celebrated as the home of peace and tourism, an image that have been fracture in recent years by Muslim – Christian, clash in the state. Plateau State guts its name from the Jos. Tis has a population of around 3.5 million people. The Jos plateau is thought to be an area of younger granite which was intruded through an area of older granite rock making up the surrounding status. These 'younger' granite is thought to be about 160 million years old. This create the unusual scenery of the Jos Plateau. The state is best known for a mining production.

Agriculture is the major occupation of the people. Faya is located in Langtang south local government area of Plateau state. It has its head quarter in Mabudi town. It has an area of 838 km^2 and a population of 106,305 at the 2006 census, plateau state is located in Nigeria 26,899 square kilometers, the state has an estimated population of about three million people. It is located latitude 80'24m and longitude 80° 32 and 160°38 East. Baxevoock are scattered across the grass land, which over the plateau (Alexanders, 2005). The activation of Faya benthonic was carried by ion exchange using sodium carbonate (Dodo, 2019). The activated Faya

clay has a swelling index of 10, as against the 14-15 swelling is limited to the used of different sodium compound toward accessing the level of activating of Faya clay with different sodium compounds.

Methodology

This work involved chemical analysis of the head sample of Faya clay using X-ray fluorescence, X-met 5100, model XMDS 26700. Faya clay and NaHCO_3 were added to 1000ml of boiling water according to mass ration of 5, 10 and 15%, and was allowed to boil for 1 hour. The dispersion was allowed to settle for 48 hours and the supernatant suspension was decanted. The sediment was again dispersed in water and allowed to settle and the supernatant was decanted. The procedure was repeated for the various mass ratios, until the bentonite was no longer dispersed in the supernatant. The supernatant was collected concentrated by evaporation and dried in an oven at 1050°C. The experiment was repeated for NaOH and Na_2SO_4 as activation agents.

Procedure for Swelling Test

Test method ASTM_DS890 is used to determine the swell index. 2g sample of dried and finely ground activated faya clays were dispersed into 9100 ML graduated cylinder in 0.1g increments. A minimum of 10 minutes was passed between additions to allow for full hydration an and settlement of the clay to the button of the cylinder. The volume of the dried 2g of the activated clays were noted and used to estimate the swelling capacity of the upgraded and activated faya clay.

Results/Findings

Table 1: Chemical Analysis of Head Sample of Faya Clay

Elements (oxide)	Al_2O_3	SiO_2	SO_3	K_2O	CaO	CeO_2
Ppm	166000	356000	56000	5590	840	200
% Composition	16.6	35.6	0.56	0.559	0.084	0.02
Elements (oxide)	TiO_2	MnO	Fe_2O_3	CuO	Ag_2O	BaO
Ppm	9120	510	61330	220	7370	38700
% Composition	0.912	0.051	6.133	0.022	0.737	38.7

Table 2: Chemical Analysis of products of Froth Flotation of Faya Clay

Chemical Composition	Al_2O_3	SiO_2	SO_3	K_2O	CaO	TiO_2	MnO
% Composition	18.60	23.00	0.510	0.678	1.122	0.990	0.039
Chemical Composition	Ag_2O	BaO	CeO_2	Eu_2O_3	Fe_2O_3	CuO	
% Composition	0.760	52.20	0.008	0.020	2.050	0.023	

Table 3: Result of Swelling of Faya Clay

Item	Initial volume cm ³	Final volume cm ³	Swelling
Crude clay	2	7.2	3.6
Ungraded clay	2	7.6	3.8
Activated clay with NaHCO ₃	2	26.6	13.3
Activated clay with NaOH	2	20.2	10.1
Activated clay with NaSO ₄	2	22.4	11.2

Discussion

Table 1 present the result of chemical analysis of the head sample of Faya clay. The result indicated that the sample contain 16.6% Al₂O₃, 35.6% SiO₂, 0.559% K₂O, 0.084% CaO, 6.133% Fe₂O₃, 0.912% TiO₂ and 38.7% BaO. Other compound in traces include CuO, Ag₂O, CeO₂ and SO₃ (Okerie et al. 2015), reported that most of Nigerian clays are predominantly calcium / potassium based and required some measure of beneficiation to be effective for use as drilling mud. Also impurities such as iron, in the form of hematite and silica reduces the specific gravity of the clay.

The result of concentration test of Faya clay shows that BaO composition has been improved from 38.7% in the head sample to 52.2% SiO₂ composition reduced from 35.6% SiO₂ in the head sample to 23%. In the concentrate Fe₂O₃ composition decreased to 2.050%. Other compounds that witness increase in composition are K₂O, Al₂O₃ and CaO (Table 2).

Table 3 represent the result of the swelling test of crude clay (as mined clay) beneficiated and activated faya clay using three activation agents, NaHCO₃, NaOH and NaSO₄. From the result, the crude clay swells about 4 times its original volume. The upgraded clay showed a similar respond owing to the fact that there was no conversion in any way. However; the activated clay showed a swelling of 13 times with NaHCO₃, 10 times with NaOH and 11 times with NaSO₄ activator.

Conclusion

From the findings of this research, the following conclusions were made:

- Faya clay contains 38.7% BaO 16.6% Al₂O₃, 35.6% SiO₂, 0.559% K₂O, 0.084%CaO, 6.133% Fe₂O₃, 0.91% TiO₂, CuO, Ag₂O, CeO₂ and SO₃.
- Upgraded Faya clay contains 52.2% BaO, 18.60% Al₂O₃, 23% SiO₂, 0.559% K₂O, 1.22% CaO, 2.050% Fe₂O₃, 0.990% TiO₂
- Crude Faya clay has a swelling of 3.6, the upgraded clay has 3.8 while the activated Clay has 13 with NaHCO₃, 10 with NaOH and 11 with NaSO₄ activator.

Recommendation

Although the swelling of Faya clay has improved by activation in each case, the result did not match with that of sodium clay (14-15). There is the need activated faya clay, through cycle, of while varying parameters o 9.8.the result did not match with that of sodium clay (14). There will be the need for experimental design for the activation of Faya clay.

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Environmental Footprints of Sand Mining in Nigerian Coastal Regions

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Abstract

In Nigerian coastal regions, the impact of sand mining on the environment is enormous. Dredging perturbs marine environments by increasing suspended sediment concentrations, increasing sediment deposition, and increasing turbidity (water cloudiness), resulting in reductions in light and the burial of benthic communities. With the rising population and the advancement in technology and infrastructural development, the need for sand is on the high side, and dredging happens to be the only solution to meet this mounting need. However if dredging operation is not controlled, impact on the infrastructure can be very fatal. Mitigation of these negative environmental effects requires a detailed understanding of the environmental impacts and the consequences of this process. From the environmental impact assessment, all the environmental impacts will be identified, mitigation measures will also be identified, and there will be a management plan to be able to take care of any foreseeable environmental impact from sand mining in Nigerian coastal regions.

Keywords: Sand, Mining, Dredging, Environmental Impacts, Turbidity, Sediment, Mitigation.

1 Introduction

Sand mining, in simple terms is the extraction of sand from its natural configuration. Sand is used for all kinds of projects like construction, land reclamations, the creation of artificial islands, manufacturing, infrastructures and coastline stabilization. These projects have economic and social benefits, but sand mining can also have environmental problems. Environmental problems of sand mining in coastal regions mostly occur when the rate of extraction of sand, gravel and other materials exceeds the rate at which natural processes generate these materials. The morphologies of the mining areas have demonstrated the impact of mining with the prowess to destroy the cycle of ecosystems. Numerous publications have been written with respect to these effects, and the next step is what to do to minimize, prevent or correct these environmental effects, the so-called mitigating measures (Pielou, 1966).

Over the years, sand has been of great utility, majorly in the construction sector. In recent times, the demand for sand continues to increase due to the need to reclaim more lands, produce more glassware, produce more ceramics, fill more roads, and construct more buildings and infrastructures to suffice the rising population. and dredging happens to be the only solution to meet this needs. Dredging practitioners, in conjunction with relevant resource or regulatory bodies such as Nigerian Inland Waterways Authority (NIWA), Lagos State Waterways

Authority (LASWA), Federal Ministry of Mines and Steel Development (FMMSD) etc., Must work to ensure that sand mining is responsibly orchestrated and conducted.

Abiodun (2016) claimed in an interview that new guidelines have been released by the National Inland Waterways Authority (NIWA) to the Dredgers Association of Nigeria, considering the impact of dredging activities on the environment, which they are expected to align with. This includes, undertaking an Environmental Impact Assessment (EIA) before Dredging activities, in order to protect the environment. From the environmental impact assessment, all the environmental impact will be identified, mitigation measures will also be identified, and there will be a management plan to be able to take care of any foreseeable environmental impact from the activities.

2 Sand Mining in Nigeria

Mining Industries and Mining practice in particular are vastly known for their hazardous working conditions and the unstable nature of the earth-crust which mineral extraction causes thereby threatening the life and properties of the society if not properly orchestrated (Abubakar *et al.*, 2011). A lot of waste materials are being deposited at the mining sites which consequently pollute the environment and also the underground and the surface water of the surrounding. Solid minerals and their products have served the need of humanity from immemorial and

will continue to do so perpetually (Okonkwo, 1998). According to Okonkwo (1998), solid minerals exploration and exploitation are related integrally with the environment. They disturb landscape, soil, surface water, underground water and air. Minerals and their products are essential, and so also is a clean environment.

There arises the need to set standards in the degree of disturbance to the environment. Any attempt to maintain 'zero' disturbances as a standard would result in 'zero' exploration activities, mining and processing, with 'zero' availability of minerals and their products to the industry. Standard that should be set must, therefore, be such that will create a reasonable compromise between these activities and the environment. Disturbance arising from dredging operations should be controlled to the barest minimum during the operations and adequately normalized thereafter (Abubakar *et al.*, 2011).

2.1 Environmental Impacts of Sand Mining in Coastal Regions

Physical impacts of sand mining include reduction of water quality, destabilization of the stream bed and banks, and obstruction to navigation of other water vessels. Mining can also disrupts sediment supply and channel form, which can result in a deepening of the channel (incision) as well as sedimentation of habitats downstream. Channel instability and sedimentation from in-stream mining also can damage public infrastructure (bridges, pipelines, and utility lines). Impacts to the biological resources include removal of infauna, epifauna, and some benthic fishes and alteration of the available substrate. This process can also destroy riverine vegetation, cause erosion, pollute water sources and reduce the diversity of animals supported by these woodlands habitats (Byrnes and Hiland, 1995).

Apart from threatening bridges, sand mining transforms the riverbeds into large and deep pits; as a result, the groundwater table drops leaving the drinking water wells on the embankments of these rivers dry. Bed degradation from in-stream mining lowers the elevation of stream flow and the floodplain water table which in turn can eliminate water table-dependent woody vegetation in riparian areas, and decrease wetted periods in riparian wetlands. For locations close to the sea, saline water may intrude into the fresh water body (Ashraf *et al.*, 2011).

In-stream sand mining activities will have an impact upon the water body's water quality. Impacts

include increased short-term turbidity at the mining site due to re-suspension of sediment, sedimentation due to stockpiling and dumping of excess mining materials and organic particulate matter, and oil spills or leakage from excavation machinery and transportation vehicles. Increased riverbed and bank erosion increases suspended solids in the water at the excavation site and downstream. Suspended solids may adversely affect water users and aquatic ecosystems. The impact is particularly significant if water users downstream of the site are abstracting water for domestic use. Suspended solids can significantly increase water treatment costs (Ashraf *et al.*, 2011).

In-stream sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures. Continued extraction may also cause the entire streambed to degrade to the depth of excavation (The Ojos Negros Research group: Sand Mining Facts, 2015).

2.2 Regulatory Bodies in Nigeria

Underdeveloped and developing countries including Nigeria, are confronted with the lack of effective monitoring systems, environmental legislation and regulations related to sand mining process. The lack of adequate information represents one of the causes that are limiting the regulation of extraction in these countries. Other countries do not understand the importance of environmental protection so they are not taking immediate action to formulate a legal and regulatory framework related to sand exploitation issue. Another issue for these countries is the lack of tools and manpower to properly enforce the environmental regulations. Monitoring sand exploitation requests adequate technology and social costs that sometimes cannot be implemented due to existing corruption. Another issue for these countries is the lack of tools and manpower to properly enforce the environmental regulations (Graviletea, 2016). The major regulatory bodies that are inclined with sand exploitation in Nigeria includes Nigerian Inland Waterways Authority (NIWA), The Nigerian Maritime Administration and Safety Agency (NIMASA), Lagos State Waterways Authority (LASWA) and the Ministry of Mines and Steel Development (MMSD).

3 Methodology

A well planned site investigation, which may include subsurface and geophysical investigations, Environmental Impact Assessment (EIA) and Environmental Evaluation Report (EER), is very necessary in order to understand the site conditions and to be able to successfully execute the project without causing more harm to the environment. A thorough integrated site investigation with an office design can enhance the efficiency, profitability and effectiveness of mitigation against unacceptable environmental impacts (Ekun *et al.*, 2016)

3.1 Environmental Impact Assessment

A complete EIA requires an appreciation of what the community considers the valued environmental resources to be. Communication with the public about their perceptions is essential. Stakeholders need to be informed and an explanation of the assessments made should be offered. In some cases, the public may identify additional impacts and might ask for broader impact consideration or further mitigation. A well-executed and thorough EIA can lead to cost-effective mitigation and/or enhancement. When environmental challenges arise and mitigation is necessary, integrating measures as a fundamental part of the project design, rather than as an add-on exercise, will reduce project costs and lower community costs. Environmental Impact Assessments are generally speaking compulsory and follow strict regulatory guidelines from the governmental agency that oversees a particular dredging project (IADC, n.d.)

Dredging, an essential activity of coastal infrastructure development, has the potential to impact the marine environment. As part of the Environmental Impact Assessment (EIA) process, dredge plume modelling is routinely undertaken to help predict the intensity and extent of potential impacts to marine benthic habitat. To improve the quality and robustness of impact prediction, CSIRO has led the development of a practical guideline on key aspects of dredge plume modelling which require careful consideration and analysis. The Guideline represents a synthesis of extensive literature review, new research, and key learnings from the Western Australian Marine Science Institution (WAMSI) Dredge Science Node (Themes 2 and 3). The Guideline strongly recommends that a public database to support dredge plume modelling be established and all relevant data be made available. The database will greatly improve the availability of reference information at the EIA stage, assisting both

those responsible for the EIA preparation, and for interpreting and approving the dredge activity. It is hoped that the dredge plume modelling guideline will provide increased confidence in modelling outcomes, leading to a reduction in the monitoring and management burden required by regulators and increased transparency and public confidence in the EIA process (Chaojiao *et al.*, 2020).

The imposition of restrictions on disposal of dredge materials in open waters is due to the impact of such disposal on the marine environment. In particular are contaminated or polluted materials, which have led to placement of such materials in designated containment facilities or not permitting dredging at all. The list of potential contaminants is very long but include trace metals, bacteria, petroleum hydrocarbons and man-made organic compounds. Pollution occurs when the concentrations of various chemical or biological constituents exceed a level at which a negative impact on amenities, the ecosystem, resources and human health can occur. Thus it is very important in the planning of dredging projects to carefully characterize and describe the nature of material to be dredged, not just in an overall sense but location by location and at sediments which are truly contaminated that require special handling and those which are a little different from natural sediments in the region and could therefore be disposed at open water sites. Significant financial savings can be obtained by not having to contain or handle in a special fashion all of the dredged materials. A special purpose map prepared by a surveyor can give a bird's eye view of such data as an essential tool in pre-dredge project planning and eventual implementation (Chukwuma, 2007).

3.2 Mitigation of Sand Mining Environmental Footprints

Graviletea (2017) was able to identify the following three major measures that can be adopted to reduce the negative environmental effects of sand exploitation.

3.2.1 Reducing Sand Consumption

Substitutes for sand or optimizing the use of existing buildings and infrastructure represent only a few steps that can be made to reduce sand consumption. Different substitutes are available, depending of the type of sand that is required. For example, waste products, crushed granite, barite powder, quarry dust, etc. are sand substitutes in concrete, while waste glass is used as sand replacement in cement mortar. Replacing sand partially by quarry dust determines a better performance of blocks and also the costs for these replacements are not very high. In

addition, partial replacements of sand with crushed rock in concrete production preserve its properties and determine a decrease of the concrete price.

3.2.2 Adoption of Clean Technologies

Technological innovation solves environmental problems and plays an important role in environmental sustainability. Fortunately, modern methods and clean technologies for mining operations have been developed to minimize damages to the environment. However, transition to clean technologies is not very simple, even if we are talking about developed countries such as USA. Government needs to develop programs especially designed to provide incentives for using new and clean sand mining technologies to encourage companies from this industry to use them. Supporting companies to research and develop emerging technologies for mining sector can also be a strategy to reduce the environmental impact. Bedload removal in in-stream mining can be calculated so the exploitation is realized in a way that does not affect the environment. A prediction of the replenishment rate of rivers helps specialists to determine the sand quantity that will be exploited with minimal environmental impacts.

3.2.3 Enacting Environmental Laws, Regulations and Standards Related to Mining Process

Governments try to ban or to restrict sand mining in specific areas to limit the environmental impacts. Mining operations in countries such as Canada, Australia, Finland, Sweden, or Russia require obtaining environmental permits designed to achieve positive environmental outcomes.

A reduction of in-stream mining for example can be achieved by state regulation. In-stream mineral mining is strongly regulated in countries such as Portugal, Italy, and New Zealand and is prohibited in countries such as France, the Netherlands England, Germany, and Switzerland. The exploitation of beach sand deposits is another issue that must to be solved by imposing strict rules and regulations. To solve environmental problems related to sand exploitation, it is necessary to establish a complex regulatory system that comprises: environmental regulation, sand exploitation regulation, and land use planning regulation.

Ashraf *et al.* (2011) identified other mitigation measures that should be observed in sand dredging to tackle the detrimental effect.

3.2.4 Mathematical Model Simulations

During the study phase of the project mathematical simulation studies can be applied to investigate the dispersion and settlement of the resuspended sediments during the sand mining process. These simulation models can be used to test various execution methods and strategies in order to minimize ecological effects. As this can be a rather costly exercise this measure is usually only applied in case of large scale sand mining projects or in case of sand mining projects in or near very sensitive areas.

3.2.5 Limiting the Overflow Losses

Selecting a modern trailing suction hopper dredger, which has a central overflow system and releases the overflow mixture underneath the bottom of the dredger, can minimize overflow losses. A more technical mitigating measure, which is to be carried out by the dredging contractor, is to adjust the loading process. By reducing the pumping flow during the final stages of the loading process or by reducing the total loading time (stopping earlier) the overflow losses can be reduced significantly. This will result in reduced suspended sediment levels.

3.2.6 Restoration and Reclamation

Allowing the natural restoration of the impacts of in-stream mining may require reduction or cessation of sand and gravel extraction. The time required for a stream to naturally recover from impacts caused by sand and gravel mining is highly dependent on the local geologic conditions. Recovery in some streams can be quite fast. Human reclamation of river or stream environments requires a design plan and product that responds to a site's physiography, ecology, function, artistic form, and public perception (Arbogast *et al.*, 2000).

3.2.7 Environmental Dredging

Environmental dredging is performed specifically for the removal of contaminated sediments for the purpose of remediating environmental risks. It has historically been most frequently chosen as the remedial option to address contaminated sediments (NRC, 2007). Environmental dredging reduces ecological and human health risks from exposure to contaminated sediments by removing the source of contamination (i.e., the contaminated sediment). It is effective in removing contaminant mass from near-surface sediments. Contamination in near-surface sediments may become re-suspended and transported by natural erosive processes, so that near-surface contaminated sediment may be classified as a contamination "source". Dredging removes this type of source. Environmental dredging

to remove contaminated sediments requires special considerations to manage these impacts during and after dredging (FRTR, n. d.). A detailed description of these environmental dredging impacts and assessment and management considerations can be found in *The Four Rs of Environmental Dredging: Re-suspension, Release, Residual and Risk* (USACE, 2008). Figure 3.1 shows a schematic of residuals from environmental dredging.

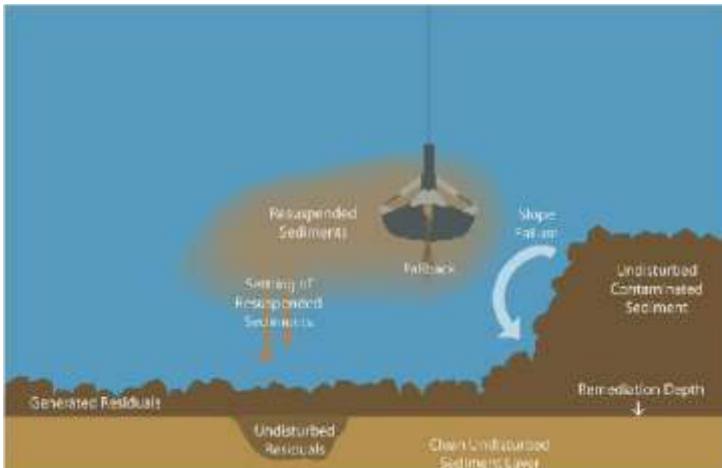


Figure 3.1: Schematic of Residuals from Environmental Dredging (Clay *et al.*, 2018)

Conclusion

As observed in the previous chapters, sand mining causes multiple negative physical and ecological effects to the environment. Mitigation of negative environment effects requires a detailed understanding of the environmental impacts and the consequences of this process. Quoting Abiodun (2016) in an interview with Onepage Africa - From the environmental impact assessment, all the environmental impact will be identified, mitigation measures will also be identified, and there will be a management plan to be able to take care of any foreseeable environmental impact from that activity.

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