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EDITORS: Abdulrahman, A. S., Odusote, J. K., Abdulkareem, S., Shuaib-Babata, Y. L.

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PREFACE

Glory be to Almighty God for granting us journey mercies to be here for this year National Conference and General Meeting of the National Institution of Metallurgical, Mining and Materials Engineers. I sincerely welcome all of you to this year conference.

The theme of this year Conference is **"The Nigeria Mining Industry in Retrospect and The New Frontiers"** which is very apt for discussion during this Conference. This is to critical look into the contribution of the mining sector into the economy of the country, since it is now obvious that there is no way Nigeria as a country could only depend on oil and gas and compete successfully in the global economy. In addition, no meaningful techno-economic progress can be made without harnessing the available important solid minerals for their application in the various industries.

The technical papers to be presented in this conference cover all areas that will support the diversification of the economy from mono-product using the abundant solid minerals available in the country. The papers also addressed the processing/production route of the solid minerals to generate engineering materials in the manufacturing industries for economic growth.

On behalf of the Technical Committee, I want to appreciate all the delegates especially those that presented lead and technical papers, and all those that participated in all the sessions. I am also using this medium to solicit for your continuous participation in all the activities and programmes of NIMMME, and support to the new Executive committee of our great Institution.

Engr. Jamiu K. ODUSOTE, PhD
Chairman, Technical Committee,
2021 Annual Conference

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IMPROVED LOCALLY FABRICATED HAMMER CRUSHER WITH LOADED SPRING SIEVE FOR VALUE ADDITION IN MINERAL PROCESSING

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Abstract

Material crushing is an integral part of processes involved in construction, mineral processing, ceramics, cement and other manufacturing industries. It involves breaking down of natural materials/ores into smaller aggregates or even powder depending on the applications. This project aimed at the development of an improved locally fabricated hammer crusher using local materials as well as incorporating vibrating mechanism for easy discharge of materials. The prime mover of the hummer crusher is a medium speed electric motor of 11 kW, with a 4-groove pulley/V-belt drive of length 3,263.61 mm each, and mild steel main shaft of length 765 mm and diameter 45 mm. The crusher has 16 hammers each weighing 12.2625 N. The main shaft speed of the crusher is 1013.2 rpm while the belt velocity is 16.7 m/s. There are 4 (four) hammer shafts inside the crusher chamber, each carrying 4 hammers making 16, arranged radially around the main shaft. A 10 mm thick mild steel material was used as mesh for sieving the crushed materials which was fixed on helical springs mechanism to pave ways for easy vibration and to aid the discharge of the material without clogging onto the mesh during operation. The developed machine can produce 700 kg/hour (5.6 tons in 8 hours) compared to the imported which produces 600 kg/hour. The machine is designed to crush dry materials only. From the study, development of a hammer crusher using locally available raw materials for the fabrication, would encourage the small and medium scale enterprises (SMEs) to mass produce the machine to boost technological know-how for economic use in the application areas thereby leading to job creation.

***Keywords**:* hammer mill system, crushing, vibrating mechanism, improved productivity, SMEs

1.0 Introduction

Mineral processing operations involve a number of process variables that change randomly with uncertain frequencies. In the field of extractive metallurgy engineering, mineral processing is known as mineral dressing, ore dressing, mineral engineering, mineral beneficiation, and mineral extraction. is defined as the process of extracting valuable minerals from their ores, (https://bulkinside.com/mineral-processing/). To achieve the goal of recovering valuable materials, the raw materials must be reduced to fine size prior to separation. This process is called communition or size reduction.

Comminution may be carried out on either dry materials or slurries. Most mineral processing operations are conducted with water as the medium (https://bulkinside.com/mineral-processing/). This is called wet processing against dry processing. crushing, grinding, milling, and vibration (feeding) are examples of comminution processes. Material crushing is an integral part of processes involved in construction, mineral processing, ceramics, cement and other manufacturing industries (Balasubramanian, 2015). It involves breaking down of natural materials/ores into smaller aggregates or even powder depending on the applications. Different machines are used for material crushing, some of which are Jaw Crushers, Gyratory Crushers, Ball mills, Bur mills, Impact Crushers, etc.

Cement and ceramic materials come to the feed processor from different sources. Many of these materials, particularly, the coarse materials, require some degree of processing before they are ready to be blended for further use. The process of particle size reduction improves ingredient performance during mixing, and in most cases, the surface area of such materials is greatly improved (Saeed *et al*, 2020).

A conventional hammer mill is a device consisting of rotating head with free swinging hammers, which reduce rock, grains or similarly hard objects to predetermined size through a perforated screen (Ezurike *et al*, 2018). The basic principle of operation of a hammer mill crusher is simple. A steel drum containing a vertical or horizontal rotating shaft or drum on which hammers are mounted. The hammers swing freely on the ends of the cross or fixed to the central rotor. The rotor is driven at high speed with the aid of a prime mover, which is a medium speed electric motor or an internal combustion engine (petrol or diesel driven) through belt and pulley, chain and sprocket or gear system. Material to be crushed is fed into the machine through the hopper and the crushing is done by the impact force of the swinging hammers.

Hammer mills are widely used for material size reduction in cement, solid mineral processing, ceramic, food and feed industries. In this work, a hammer crusher with separate sieving device with materials circulating layer, low energy consumption, low sieve wearing and low product temperature will be designed and fabricated. Another innovation in this work includes the incorporation of a vibrating mechanism to enhance sieving and delivery of finer aggregate material from the sieve to the material collector.

2.0 MATERIALS AND METHOD

2.1 Materials

Materials employed in executing this project are mainly ferrous metal of different alloying grades and other non-metallic materials. The ferrous metals are mild steel**:** this includes the housing, the sieve, the main shaft, the hammer shafts, the hammer separators, the hammers, pulleys, and the flywheel.

High strength steel**:** the U-channel used for the machine frame is made of this steel medium carbon steel**:** this is the material for the spring incorporated in the hammer mill as modification to improve discharge. Rubber: this is the material used for the V-belt. Synthetic materials like gasket are also used.

2.2 Tools and Equipment Employed

Scriber, venier calipers, spirit level, lathe, milling machine, mechanical hacksaw, drilling machine, arc-welding machine were some of the tools, equipment and workshop machineries used for this work.

2.3 Method

The method adopted in this research work are:

i. Detailed engineering drawings of the machine was carried out using Solidworks;
ii. Calculation of the necessary parameters;
iii. Selection and procurement of the appropriate materials;
iv. Marking out and cutting operation;
v. Fabrication of the designed hammer crusher components;
vi. Assembling of the fabricated hammer crusher parts;
vii. Testing running of the fabricated hammer crusher;
viii. Modifications after test running;
ix. Evaluation of production capacity and efficiency
x. Evaluation of product quality (in terms of aggregate size distribution)

3.0 Design calculations

3.1. Shaft Design

3.1.1 Determination of the shaft diameter from shear force and bending moment

The following components were weighed and their positions on the main shaft measured from the design drawing to calculate the shear force and bending moment as shown in Fig. 1.
Shaft pulley, hammer assembly (separators, hammer shaft, hammers), fly wheel.

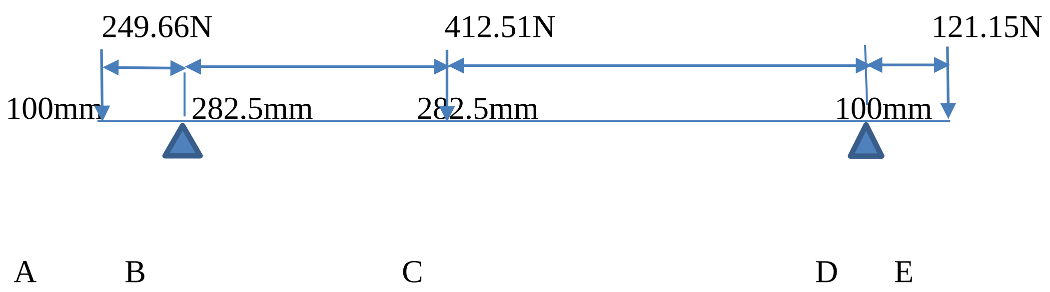

Fig. 1: Shear force and bending moment

Shear Force
Taking reaction about bearing 'B' (Equation 1):

$(R_B \times 565) + (100\times121.15) – (412.51\times282.5) - (249.66\times665) = 0$ (1)

$(R_B\times565) + (100\times121.15) = (412.51\times282.5) + (249.66\times665)$

$R_B = 285.74N$,

But $\sum R = 783.32N$ (2)

$R_D = 497.58N$ (3)

Shear Force Analysis
From point 'A' to point 'E'

At 'A', reaction is -249.66 N (counter-clockwise from pivot 'B')
From Point 'A' to 'B', -229.66 N is maintained.
At 'B', it changes to -298.41+285.74 = 36.08N. This is maintained till point 'C'.

At 'C', we have, 36.08-412.51 =-376.43N (4)

At 'D', the load is in upward direction. Hence, -376.43 + 497.58= 121.15N (5)

At 'E', we have, 121.15-121.15 =0 (6)

Torque (Shear Force) and Bending Moment diagrams are shown below in Fig. 2.

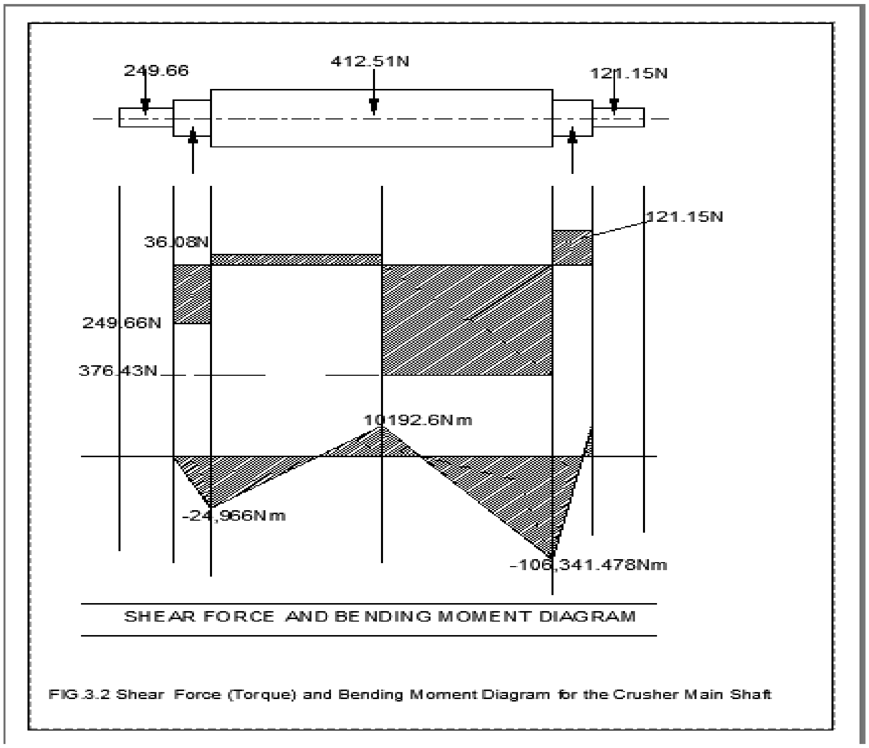

Fig. 2: Shear Force (Torque) and Bending Moment Diagram for the Crusher Main Shaft

The ASTME code equation for a solid shaft having little or no axial loading is (Khurmi and Gupta, 2005):

$$d^3 = \frac{16}{\pi \sigma_s} \sqrt{(k_b m_b)^2 + (k_t m_t)^2} \qquad (7)$$

where,
d = diameter of shaft
σ_s = allowable stress (55MN/$m^2$for shaft without keyway and 40MN/m^2 for shaft with keyway)
K_b = factor for gradually applied load = 1.5
K_t = factor for gradually applied load = 1.0
m_b = bending moment(maximum) = 106.341Nm
K_t= torsional moment
From calculation,
m_b is 106. 341N.m and K_t is 72.443N

$$d^3 = \frac{16}{40MN\pi}\sqrt{(1.5 \times 106.341)^2 + (1.0 \times 72.443)^2}$$

d = 28.15 mm.
Actual diameter=45.0 mm (taken Factor of Safety as 1.6)

3.1.2 Determination of the Torque and Power Transmitted to the Shaft

Power transmission is the movement of energy from its place of generation to a location where it is applied to perform a useful work. Torque is a measure of how much force acting on an object causes that object to rotate.

The Torque generated by the electric motor, T is given by (Khurmi and Gupta, 2005);

$$T = \frac{60P}{2\pi N} \quad (8)$$

where,

T = Torque (N.m), P = power (W) (11kw), N = speed (rpm) (1450 rpm).

$$T = \frac{60 \times 11000}{2\pi \times 1450}$$

$= 72.443$ N.m (72.443×10^3 N.mm)

3.1.3 Calculation of Shaft Speed

To calculate the shaft speed, the following parameters are used (Ezurike et al, 2018):

$$\frac{D_1}{D_2} = \frac{N_2}{N_1} \quad (9)$$

where,
N_1 = revolution of the smaller pulley, rpm(1450rpm), N_2 = revolution of the larger pulley, rpm.
D_1 = diameter of the smaller pulley, mm (220mm), D_2 = diameter of the larger pulley, mm (330mm)

$$N_2 = \frac{N1D1}{D2} \quad (10)$$

$= 1450 \times 220 \div 330$
$= 966.67$rpm

This shaft speed is only obtained when there is no slip condition of the belt over the pulley. When slip and creep condition is present, the value of the rotational speed is reduced by 4% (Spolt, 1988).

3.1.4 Keyway

Using the keyway equation (Khurmi and Gupta, 2005):

l=1.571d (11)

where,

l is the keyway length, d is the shaft diameter, the keyway length = 1.571x45.00mm= 70.70mm. The keyway is however extended to accommodate coupling of hammer holder flanges

3.2 Belt design

3.2.1 Determination of the length of the belt

Belts are used to transfer power through rotational motion from one shaft to another. Belts pulley arrangement has found application in different machines. For a centre-to-centre distance between the larger pulley and the smaller pulley of 1200mm, the length of the belt is given by (Johnand Stephens, 1984; Ezurike *et al*, 2018).

$$L = 2C + 1.57(D + d) + \frac{D+ d}{4C} \quad (12)$$

where,

L = length of the belt, mm; D= diameter of bigger pulley (330mm); d = diameter of smaller pulley (220mm); C = centre to centre distance between larger pulley andthe smaller one, (1200mm).

L = 2(1200) +1.57(330+220) + (330+ 220)/4(1200) = 3,263.61mm

3.2.2 Belt Velocity

Belt velocity, v (m/s) is calculated using the equation (equation 13)

$$v = \frac{\pi dmNm}{60} \quad (13)$$

where,

v = velocity of belt

d_m = diameter of the motor pulley (0.22m

N_m = speed of motor pulley (1450rpm)

v = 0.22**π**x1450/60 = 16.70m.s

3.2.3 Determination of the belt contact angle, β

Belt drives depend on friction to operate, but excessive friction wastes energy and rapidly wears the belt. In other to avoid excessive friction in the machine, the belt contact angle is given by the equation below (Jimoh and Olakunle, 2013):

$$\beta = \sin^{-1}\frac{D-d}{2C} \quad (14)$$

where,

D = diameter of the large pulley, mm (330), d = diameter of the smaller pulley, mm (220),

c = distance between the pulley centers, mm (1200mm)

$\beta = \sin^{-1}\frac{330-220}{2400} = \sin^{-1}(0.045833)$, $\beta = \sin^{-1}0.045833 = 2.63°$

3.2.4Angle of wrap for the pulleys is given by:

$$\theta = (180 - 2\beta)\pi/180\text{rad} \quad (15)$$

$$= 174.74\pi/180 = 3.05\text{rad}$$

where,

θ = angle of wrap for the smaller pulley,

3.3 Hammer Design

3.3.1 Determination of the Weight of the Hammers

$$W_h = m_h g \quad (16)$$

Total weight = w_h × number of hammers

W_h = weight of one hammer, i.e mass (kg) ×g (gravitational force, assumed to be 9.81kg/m^2= 1.25×9.81

Total weights of 16 hammers;

=196.20N

3.3.2 Hammer angular velocity

The angular velocity of the hammer is given by (Khurmi and Gupta, 2005);

$$\varpi = \frac{2\pi rN}{60} \quad (17)$$

where,
r = radius of the rotor (distance from d shaft axis to the tip of the hammer)
N = shaft speed.
$= 2\pi \times 0.2225 \times 966.67 \div 60 = 22.52$m/s

It can be seen that the action of the weight of hammer shaft on the main shaft is not negligible. So, the need to determine the centrifugal forces and the bending moment effect of the hammers on the shaft.

3.3.3 Kinetics of Hammer Rotation
Basic assumptions;

i.) Mass of hammer >> mass of single particle of ground material
ii.) Before impact, linear velocity of the milling hammer is more important than the velocity of the fed particle.

Applying law of conservation of momentum before and after impact (Tesfaye and Getaw, 2019);

$$m_hV_h=(m_h+m_p)V_s \tag{18}$$

initial Kinetic Energy (KE), K_0

$$K_0= 0.5m_hV_h^2 \tag{19}$$

Final K.E,

$$K_f = 0.5(m_h + m_p)V_f^2 \tag{20}$$

As K.E of particles is negligible;

$$K_f= 0{,}5m_hV_h^2 \tag{21}$$
$$=348.4J$$

3.2.4 Determination of the centrifugal forces exerted by the hammers
Centrifugal force exerted by the hammer can be calculated from equation 22 as given by (Ezurike *et al*, 2018);

$$F_c = \frac{m\omega 2}{r} \qquad (22)$$

For one hammer, $F_{h1} = 1.25\times(22.52)^2/0.2225 = 2{,}849.16N$

3.3 Bearing Life

Type of bearing used = spherical Roller bearing, Shaft Speed = 966.67 rpm
Nominal rated speed in hours = 10,000 hours, 8 hours per day, medium shock load
Life of bearing, (in millions of revolutions) (Vijaya Kumar, 2013);

$= 60NL_h/10^6$ (23)

= 60 x 966.67 x 10000/1,000,000

= 580.00million of revolutions

4.0 THE MODIFICATION

Spring loaded mesh

There is a modification in the fabrication and assembly of the grain sizer (mesh) in the new machine. Unlike the old model where the mesh is 12mm grain size and simply assembled beneath the milling chamber, the new model has a grain size of 8mm and is spring-loaded.

This modification is borne out of the observation that, in the old model, material will stick and block the mesh holes during operation. The advantages of the incorporation of the spring-loaded mesh are

a. To allow for the vibration of the mesh during operation which will enhance the effective discharge of the materials.
b. Effective discharge of the materials will reduce overload on the electric motor and prevent possible damage.
c. The new model with spring loaded mesh can produce materials with finer grains.

5.0 PERFORMANCE EVALUATION TEST

5.1 Idle running of the machine

After assembly, the machine was switched on and run idle for the first five (5) minutes. It was then stopped and all the subsystems and components examined. Some bolts were tightened and the machine was switched on again and run for fifteen minutes.

5.2 Machine Productivity

The machine productivity was tested with three different materials, kaolin, clay and lateritic soil (red mud) as in tabular form below; Table 1,2,3.

Table 1: Productivity Test on Kaolin

S/N	Mass before milling (kg)	Mass after milling (kg)	Loss (kg)	Loss (%)	Time (secs.)
1	5	4.96	0.04	0.8	26
2	10	9.88	0.12	1.2	51
3	15	14.72	0.28	1.87	77
4	20	19.58	0.42	2.1	103
TOTAL	50	49.14	0.86	1.72	257

50kg of kaolin was milled in 257seconds and in 1 hour,
50/257 x 0600
=700.39kg≈ 700kg/hour

Table 2: Productivity Test on Clay

S/N	Mass before milling (kg)	Mass after milling (kg)	Loss (kg)	Loss (%)	Time (secs.)
1	5	4.93	0.07	1.4	24
2	10	9.83	0.17	1.7	49
3	15	14.66	0.34	2.27	76
4	20	19.52	0.48	2.4	100
TOTAL	50	48.94	1.06	2.12	249

50kg of clay was milled in 249seconds
In 1 hour, 50/249 x 3600 = 722.89kg ≈ 723kg/hour

Table 3: Productivity Test on Laterite (red soil)

S/N	Mass before milling (kg)	Mass after milling (kg)	Loss (kg)	Loss (%)	Time (secs.)
1	5	4.96	0.04	0.8	21
2	10	9.83	0.17	1.7	46
3	15	14.80	0.2	1.33	80
4	20	19.71	0.29	1.48	94
TOTAL	50	49.3	0.7	1.4	241

50kg of laterite was milled in 241seconds
In 1 hour, 50/241 x 3600 = 746.88kg ≈ 747kg/hour
The minimum production/hour (700kg/hr) is chosen for reliability.

6.0 RESULTS AND DISCUSSION

An improved hammer crusher was fabricated based on design calculations and considerations to meet optimum performance for which it was aimed at.

Fig.3a shows the hammer crusher housing free body diagram and Fig.3b is the fabricated housing which is made of the base and hopper. It is fabricated from 10mm thick mild steel and lined with 10 mm thick mild steel (the bolts holding the linings are shown on the body). The screen with dimension (750x350x10) mm is incorporated with helical springs (Fig. 4) and placed in the grinding chamber between the hopper and the base (Fig. 5). The mesh size is 8mm. The hammer assembly (Fig. 7) is made up of the hammers, hammer shafts and separators (Fig. 6). The complete assembly of the hammer crusher is shown in Fig. 8 A and B. the height is 1.5 meter and the hopper is inclined at about 135° outward making feeding comfortable for the operator. The hopper also has a cover to prevent materials and dust coming out from the machine during operation. The belt drive subsystem is covered with a fabricated mild steel sheet for safety.

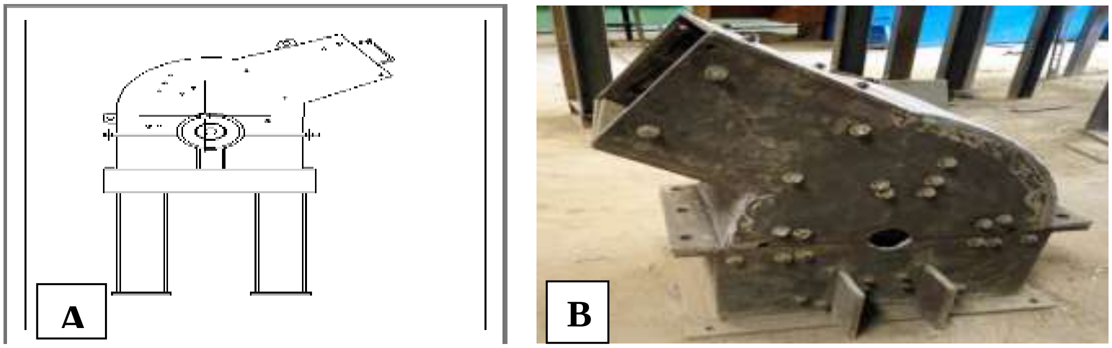

Fig. 3: The Hammer Crusher Housing

Fig.4: The screen incorporated with helical springs

Fig. 5: The screen as it is positioned

Hammers **Hammer shafts** **Hammer separators**

Fig. 6: Hammer assembly components

Fig. 7: Hammers assembly

Fig. 8: The complete hammer Crusher assembly (A-side view; B-front view)

Table 4: Summary of the Calculated Parameters

S/N	Parameter	Symbol	Value	Unit
1	Torque generated by Electric motor	T	72.443	N.m
2	Main shaft diameter	D	45	mm
3	Hammer shaft diameter	d_s	25	mm
4	Main shaft speed	N	966.67	rpm
5	Weight of a hammer	W_h	12.26	N
6	Total weights of hammers	W_{hs}	196.2	N
7	Belt velocity	V_b	16.70	m/s
8	Length of belt	L_b	3,263	mm
9	Hammer angular velocity	Ω	22.52	m/s
10	Centrifugal force of hammer (one hammer)	F_c	2849.16	N
11	Bearing life	L_{10brg}	580.00	Million of rev.
12	Keyway length	L_{key}	66.34	mm
13	Machine production	P_m	700	Kg/hour

7. CONCLUSION

An improved hammer mill crusher was designed and fabricated and it has the following qualities.

The materials used for the components and subsystems are sourced locally. A detailed engineering drawing of the machine was developed. Mathematical calculations for all the components and subsystems were developed and the machine was tested and the performance conform to the desired expectation. The machine can effectively mill dry kaolin, clay and laterite and can produce 700kg of material per hour.

From the study, development of a hammer crusher using locally available raw materials for the fabrication, would encourage the small and medium scale enterprises (SMEs) to mass produce the machine to boost technological know-how for economic use in the application areas (mining and built environment) thereby leading to job creation, increases foreign exchange reserves, and enhances growth of SMEs.

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SUITABILITY OF LOCAL CLAY DEPOSIT FROM SAKPE (BIDA BASIN) FOR INDUSTRIAL APPLICATION

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Abstract

Sakpe clay deposit (in Bida Basin) was investigated using TGA/DTA, XRF, XRD, SEM and physico-mechanical analysis. The chemical analysis of the clay shows 55.73% SiO_2, 29.65% Al_2O_3, 0.92 % Fe_2O_3, 0.07% CaO, 0.05% Na_2O, 0.05% MgO and 0.31% K_2O. The clay deposit was found to be kaolinitic and thermally stable at temperatures observed (950^{0}C, 1050^{0}C, 1150^{0}C and 1250^{0}C) and has refractoriness of ≤1300^{0}C and good thermal shock resistance of 12 cycles. The physico-mechanical properties of the clay sample increased with increased firing temperature as a result of increase in densification. The properties such as flexural strength, Cold Crushing Strength, Elastic modulus and fired shrinkage increased to maximum values of 16.42 kg/cm^2, 135.62 kg/cm^2, 624.17 kg/cm^2 and 5.2% respectively. Other properties such as apparent porosity, Bulk and apparent densities decreased with increase in temperature from 950^{0}C to 1250^{0}C. These properties make the clay sample suitable for the production of tiles, paints, filler in paper making, porcelain insulators, lining of kilns and microwaves.

Keywords: Clay, suitability, Sakpe, Kaolin, Physico-mechanical, characterization.

1. INTRODUCTION

Clay minerals are important industrial minerals and millions of tons are used annually in several applications which include uses in ceramics, construction, agriculture and geology (Mudi *et al*., 2018; Abuh *et al.*, 2018). The major reason of utilizing of certain clay minerals for specific application is due to the fact that their physical and chemical properties are dependent on their structure and composition (Aramide *et al*., 2014). Hence their application in electrical porcelain, sanitary-wares, glazes, high quality tableware, or tiles. Common clays such as kaolin, ball clay, fireclay and others are fine grained and typically exhibit plastic behaviour when wet. These plastic clay materials have the tendency to be formed into many desired shapes, dried and fired to a specific product of required properties (Petrick, 2011).

In general clays are used in manufacturing of many ceramics products and each product requires clays with specific and appropriate characteristics. The plasticity of hardened clays has made them useful since the early days of civilization, for making porcelain, tiles, cooking pots, drainage pipes, and bricks, while the thermal properties of these clay make them valuable and suitable for production of refractory materials used in lining the surfaces of ovens, kilns, and furnaces (Aramide *et al*., 2014).

Nigeria has a reserved estimate of about two billion metric tons of kaolin that has attracted both local and foreign investors and because of its wide applications, its characterization has been of interest to investigators (Abuh *et al.*, 2018). Nigeria continues to import almost everything from items used in our daily life to vehicles; porcelain; drilling fluids; ceramic industry to produce household wares like plates, cups, electrical sockets (insulators), toilet seats, bath tubs, flower verses and refractory bricks. Deposits of clay minerals are widely distributed across Nigeria. However, for profitable utilization of a particular clay deposit, it is necessary to determine the mineralogical composition, examine the microstructural morphology and analyze the various available phases in such clay deposit (Olokode *et al*., 2010).

Hence there is an urgent need for in-depth characterization, beneficiation and processing of these clay deposits in order to ascertain the total ore grade and also exploit and identify the markets for the products in the country as Nigeria government is diverting its attention to solid mineral development as a result of lingering oil crises around the world.

The geotechnical investigation, geology, mineralogy, geochemical and reserve estimation of Kutigi clay deposits was studied by Akhirevbulu and Ogunbajo, (2011). Many researchers have worked on various clay characterization, but only Akhirevbulu and Ogunbajo (2011) work is available on clay deposits of Niger state especially, Bida basin. Therefore, the aim of this study is to characterize and process clay from this local deposit, determine their physico-mechanical and thermal properties with a view to predicting their engineering behaviour and evaluating their economic potentials, for the nation's industrial raw materials data base and on the potential use of the clays in ceramic production.

2. MATERIALS AND METHOD

The materials (clay) used in this research work was obtained from Sakpe community in Edati L.G.A in Niger State (North-Central Nigeria). It is locally used by the people around the area for painting, moulding and bricks making. Clay samples were randomly collected from different points. Pits were dug using a Digger, Shovel and hoe at intervals of 3m from one another for all the deposits. The clay samples were collected at a depth of 2m for each of the pits. The clay samples were collected in a dry clean polythene bag in line with Osabor *et al*., (2009) and Malu *et al*., (2018).

The clay samples were sun-dried for five days and pulverized. The powdered clay was soaked and thoroughly mixed in a plastic bath of water to get slurry of clay, left for two days to settle and the water drained off. This process was carried out to ensure the elimination of impurities to a minimum especially quartz which is conspicuous in clay and soluble materials. The slurry was poured into a stack of sieves connected to a mechanical vibrator to sieve through clay particles of 150μm in size. The clay was finally washed with de-ionized water, dried for days under open shade and pulverized to 150 μm for further use.

The equipment used in this investigation include: Shovel, Pestle, Mortar, Rectangular Mould (100 x 30 x 10 mm), Cylindrical Mould (30 x 30 mm), Rammer, Mixer, Rotary Sieve Shaker, Electric Furnace (XD - 1700M, Brother furnace Company), Electric weighing balance, Universal Testing machine for Cold Crushing Strength and flexural strength (Cat. Nr. 26 100KN capacity, Recherches and Realisations Remy**)**, X-ray diffractometer (Empyrean, PANalytical), TGA/DTA machine (STA 4000 analyzer, Perkin Elmer) and XRF Machine (Genius IF, Xenematrics). The characterization was carried out using XRD, XRF and SEM Equipments to determine the chemical composition, Phases present and Morphologies respectively. TGA/DTA analysis was carried out at 10^0/min and ran from 30^0C up to 950^0C on the raw clay.

The samples for flexural strength (ASTM C1161-18), Compressive Strength (ASTM C133-97)., linear shrinkage (ASTM C356-17), water absorption (ASTM C20-00) and Porosity (ASTM C20-00) tests were subjected to heating/firing (sintering) at temperatures of 950^0C, 1050^0C, 1150^0C and 1250^0C and one hour soaking time as recommended by Atanda *et al.*, (2012) and Mgbemere *et al.*, (2019) after moulding into required shapes. All necessary tests were carried out according ASTM standards.

The physical and mechanical properties of the clay (kaolin) under investigation was determined using the equations below:

$$\text{Linear (Fired) Shrinkage} = \frac{\text{Ld}-\text{Lf}}{\text{Ld}} \text{ X } 100 \quad (1)$$

$$\text{Water Absorption} = \frac{W-D}{D} X\ 100 \quad (2)$$

$$\text{Apparent Porosity} = \frac{\text{W}-\text{D}}{\text{W}-\text{S}} \text{ X } 100 \quad (3)$$

$$\text{Bulk Density} = \frac{\text{W}\,\rho}{\text{W}-\text{S}} \text{ X } 100 \quad (4)$$

$$\text{Apparent Density} = \frac{\text{D}\,\rho}{\text{D}-\text{S}} \text{ X } 100 \quad (5)$$

$$\text{Compressive Strength (C.C.S)} = \frac{\text{Applied Load (F)}}{\text{Cross Sectional Area (A)}} \quad (6)$$

$$\text{Modulus of Rupture (Flexural Strength)} = \frac{3\text{FL}}{2\text{bd}^2} \quad (7)$$

$$\text{Elastic Modulus} = \frac{FL^3}{4bd^3D} \qquad (8)$$

Where, W= Saturated weight, D = dry weight, S= suspended weight, Ld = Dry length, Lf= Fired length, ρ = Density of water = 1g/cm^3, F = yielding/breaking load, L = distance between supports or guage length, d = height/depth, b = breadth, D = deflection and C.C.S = Cold Crushing Strength.

3. RESULTS AND DISCUSSION

3.1 TGA/DTA Analysis

The first reaction occurred around100^{0}C and was related to elimination of water of hydration (the release of water absorbed in pores and on the surfaces at drying stage). The hydration phenomenon occurred below 300^{0}C, and the mass loss could be attributed to the reorganization in the octahedral layer (Aladesuyi *et al.*, 2017). The rather abrupt change in mass loss rate for clay samples from above 275^{0}C to 503^{0}C as shown in studied Figures 1 could be due to the dehydroxylation of kaolinite to form Metakaolin (Aladesuyi *et al.*, 2017). Furthermore, Sakpe clay was observed to have weight loss of 3.6% between 275^{0}C and 503^{0}C (Figure 1).

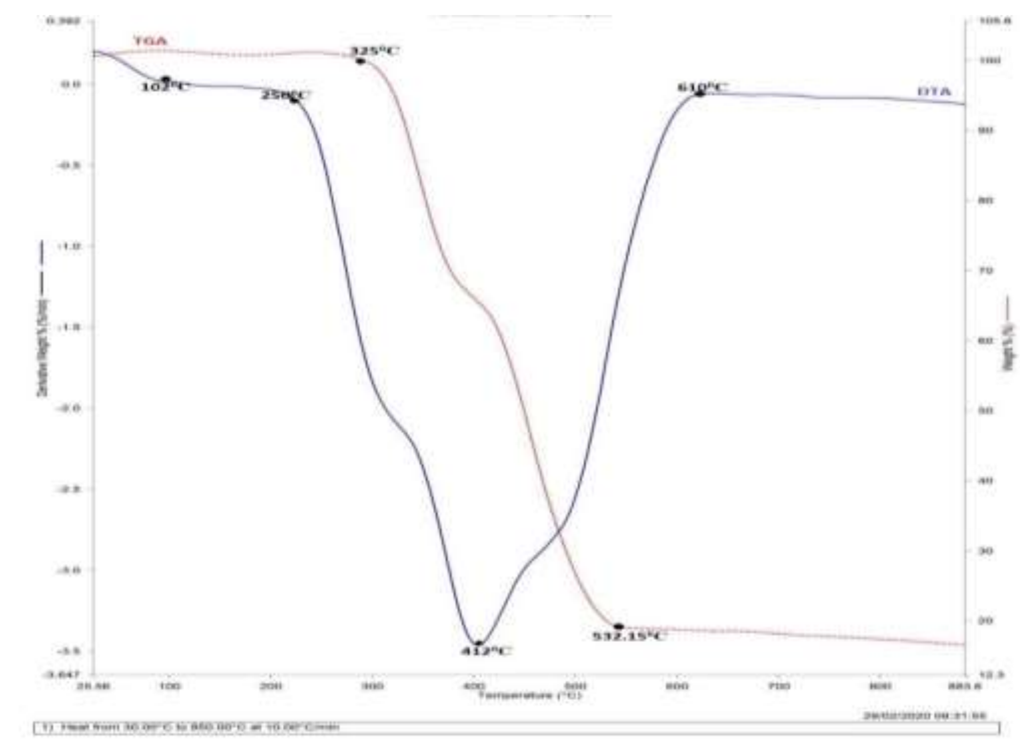


Figure 1: TGA/DTA Curves of Sakpe Clay

The DTA curves also showed broad peak at 387.6^{0}C), which is a multi-step decomposition of the kaolin (endothermic release of constitutional water from the interlayer octahedral sheets). This is immediately followed by an exothermic reaction around 600°C, and this could be attributable to the re-crystallization into spinel, as observed by Mudi *et al.*, (2018) with clay from Ndia (Taraba state). The differential thermal analysis (DTA) curve also manifested material reactions of exothermic (exothermic peak) at 735°C and endothermic at 650°C. The dehydroxylation of the minerals in the clay ensued at these temperatures signified the initial step in the oxidative degradation of the clay material. The flux components (oxides) like CaO, P_2O_5 and K_2O manifested reaction from around 600°C and above which signified the beginning of sintering process, material crystallization and phase change. The above result (Figure 1) showed that the kaolin deposit investigated was found to be moderately stable thermally and therefore suitable for moderate and low temperature applications like microwaves and ovens/kilns. However, it needs to be upgraded or mixed with other additive before use for higher temperature operations.

3.2 XRF and XRD Analysis

The chemical analysis result of clay samples from the study area shows high value of SiO_2 of 55.73%, 29.65% Al_2O_3, low value of Fe_2O_3 of 0.92 %. Also, the clay is low in CaO, Na_2O and K_2O (Table1). This clay deposit has high silica contents of approximately 56% with small to moderate alumina content which is comparable to that of Ejigbo in Lagos state (Mudi *et al.*, 2018).

Table 1: XRF Result of Studied Clay

%	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
Sakpe Clay	55.73	29.65	0.92	0.006	0.05	0.07	0.05	0.31	1.793	0.05	11.36	99.99

LOI: Lost on Ignition

High $SiO_2$and Al_2O_3 play important roles in the production of refractories. Silica content also makes it a good material for synthesis of zeolite, amorphous silica alumina, tiles and bricks production (Aladesuyi *et al.*, 2017). Na_2O and K_2O are fluxing agents in ceramic and as functional filler in paint, rubber, plastic and adhesives, and also helps to reduce the melting temperature of quartz and to control viscosity of glass. Free or low Fe_2O_3 content in these clays make it suitable for use in pottery, tiles and sanitary-wares (Olokode *et al.*, 2010). Their lightness and whiteness and opacity for paints, coating in plastic and paper (Olokode *et al.*, 2010).

In addition, the composition of the studied clays compared with industrial specifications makes the clay deposit important raw material for the production of refractory bricks by upgrading Al_2O_3 level/content to meet raw material for the production of refractory bricks, Pottery production and Ceramics.

Table 2: Mineralogical Composition of the Clay

Location	Quartz	Kaolinite	Muscovite	Anatase	Total
Sakpe	27.8	66.2	4.7	1.3	100

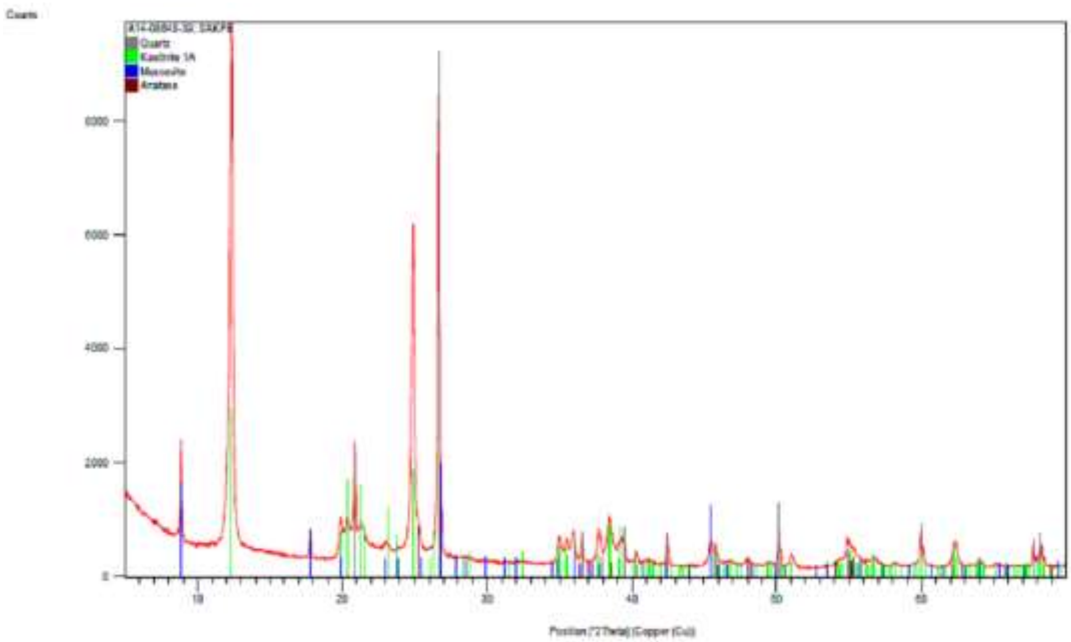
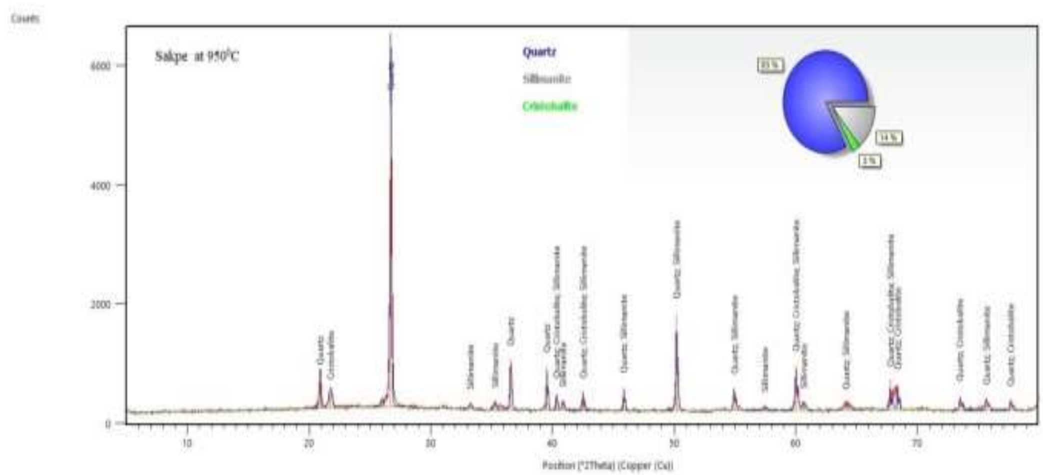


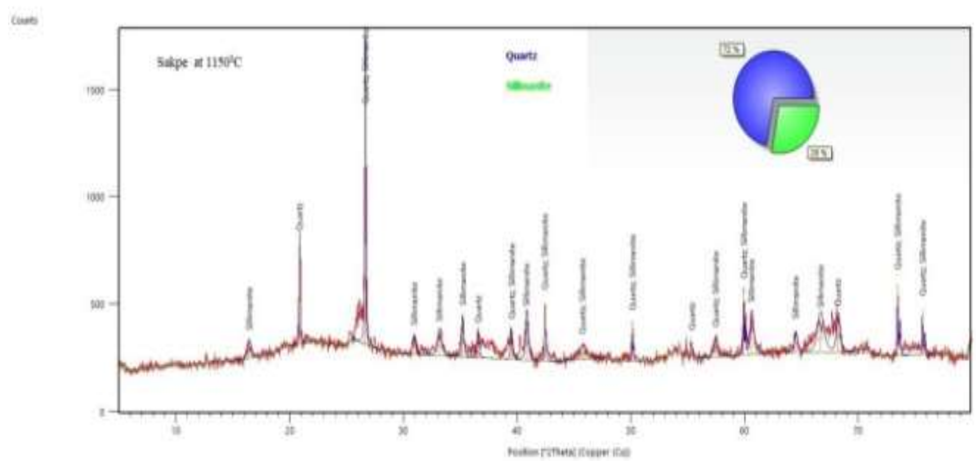
Figure 2: XRD Spectrum of unfired Sakpe Clay

The X-Ray Diffraction (XRD) analysis result of raw kaolin is presented in Table 2. The mineralogy of the clay is composed of quartz, Kaolinite $\{Al_2Si_2O_2(OH)_4\}$, muscovite $\{KAl_2(AlSi_3O_{10})\ (F,OH)_2\}$ and anatase (TiO_2) as the non-clay minerals components with percentage of each as shown in Table 2 and are comparable to clays from South Western Nigeria (Aramide *et al.*, 2014). The clay occurrence is dominated by kaolinite clay mineral with little concentration of muscovite. This confirms the studied clay to be kaolin.

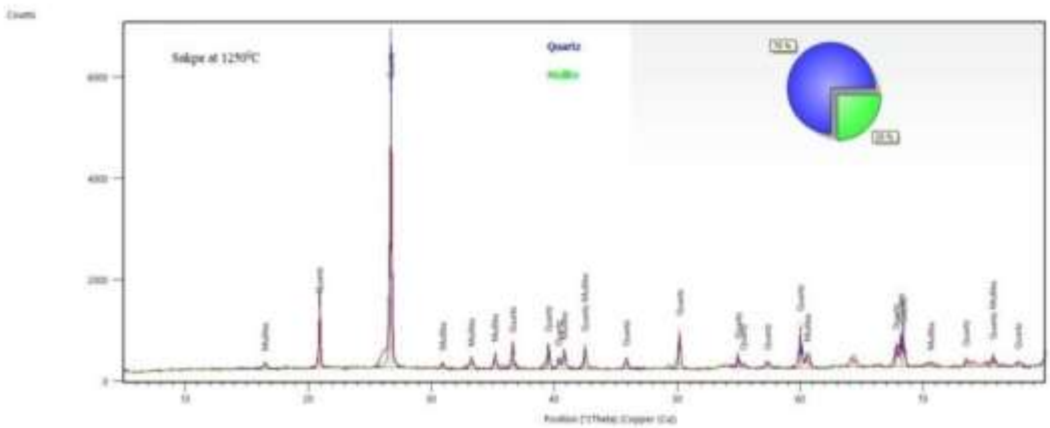
The fired samples were observed to undergo phase changes from the original phases of the initial raw kaolin. As the temperature increases towards 1250^{0}C, there was change in phase transformation to quartz-cristobalite-sillimanite phase at 950^{0}C; to quartz-sillimanite phase at 1150^{0}C and quartz-mullite phase at 1250^{0}C as revealed from the XRD patterns of various samples fired at different temperatures in Figure 3a-3c. This is also supported by the SEM photomicrograph in Figure 5, as mullite flakes are observed in quartz glassy phase (Abuh *et al.*, 2018).



a) XRD Spectrum Sintered Sample at 950^{0}C



b) XRD Spectrum Sintered Sample at 1150^{0}C



c) XRD Spectrum Sintered Sample at 1250^{0}C

Figure 3a-c: XRD Spectrum of Clay Fired/sintered at a) 950^{0}C b)1150^{0}C and c)1250^{0}C

3.3 Refractoriness and Thermal Shock Resistance

In terms of refractoriness, it was observed that all the investigated samples have high refractoriness and can withstand high temperatures above 1250^{0}C and below 1300^{0}C, hence, can only be used for low temperature applications like low temperature kilns, ovens and microwave compared to the others which can find application in moderate temperature environments such as heat treatment furnace for annealing and ladles. The clay tested did not meet the standard requirement of refractory materials. It has a thermal shock resistance of 12 cycles which are below the required cycles (of standard range of ≥ 20 cycles) for standard refractories as shown in Table 3, as supported by Shuaib-Babata, *et al.*, (2018).

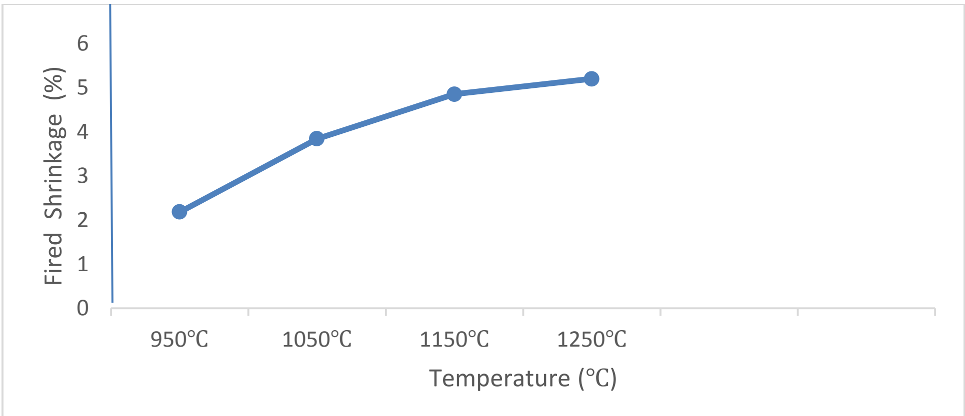
Table 3: Thermal Cycle and Refractoriness of the Clay

Thermal Shock Resistance	Refractoriness
12	≤1300^{0}C

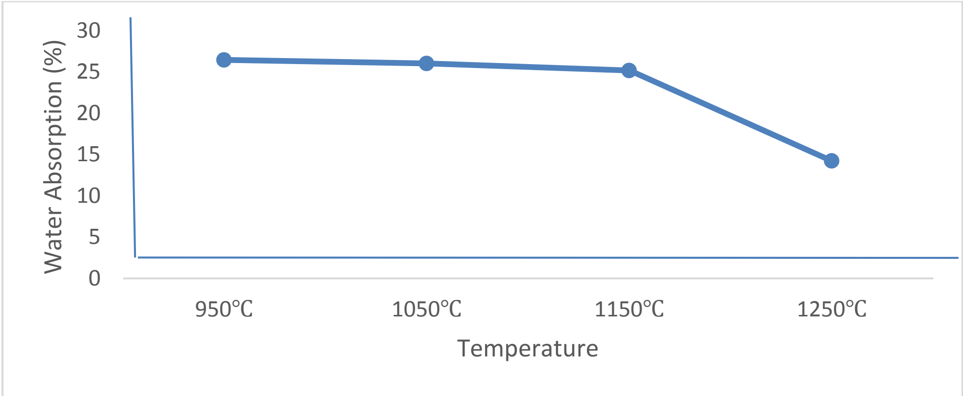
3.4 Physico-Mechanical Properties

Table 4: Physico-Mechanical Properties of the Clay

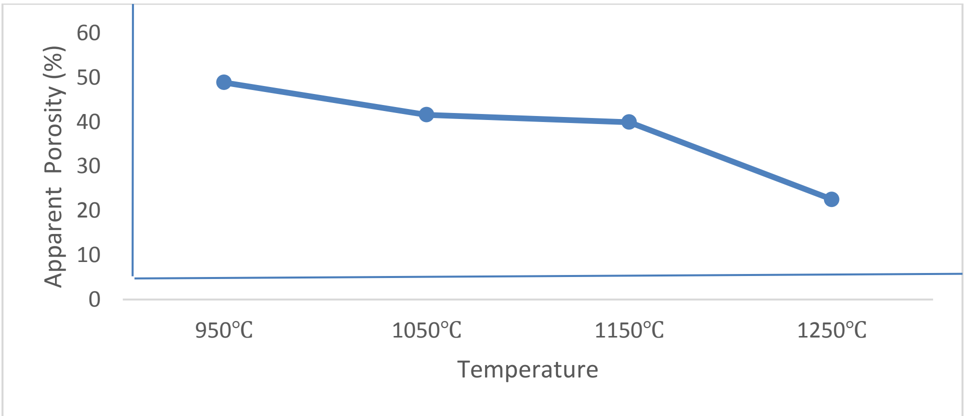
Property	At 950^{0}C	At 1050^{0}C	At 1150^{0}C	At 1250^{0}C
Bulk Density (g/cm^3)	1.62	1.60	1.59	1.59
Apparent Density (g/cm^3)	2.84	2.68	2.66	2.05
Water Absorption (%)	26.44	26.02	25.16	14.21
Apparent Porosity (%)	48.88	41.62	39.96	22.53
Linear Shrinkage (%)	2.18	3.84	4.85	5.20
Cold Crushing Strength (kg/cm^2)	47.62	72.6	90.04	135.62
Modulus of Rupture (kg/cm^2)	7.75	4.59	10.5	16.42
Modulus of Elasticity (kg/cm^2)	435.32	237.08	283.18	624.17



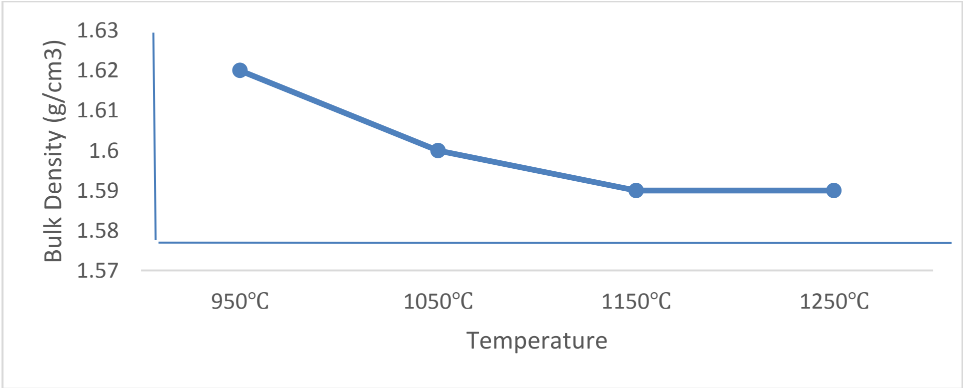
a) Effect of Sintering Temperature on Fired Shrinkage



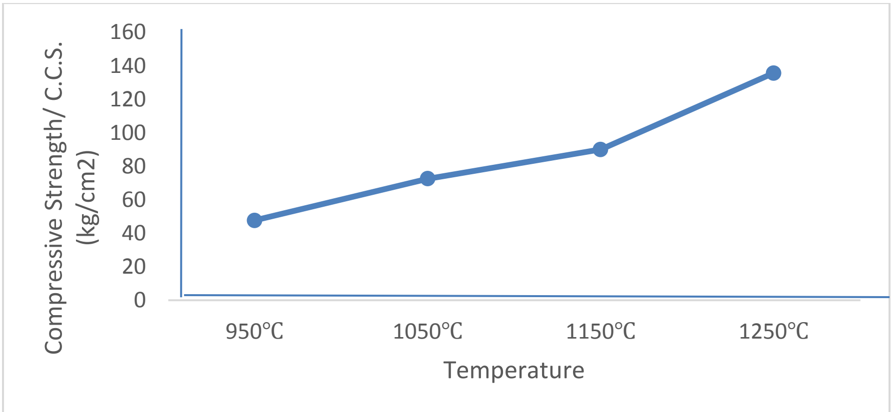
b) Effect of Sintering Temperature on Water Absorption



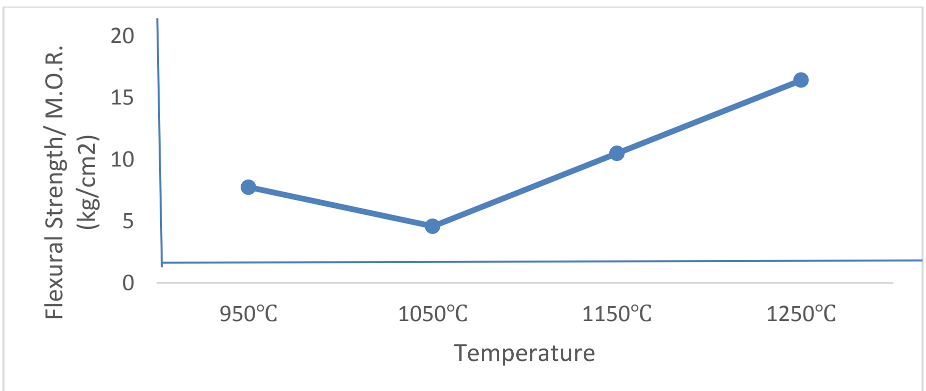
c) Effect of Sintering Temperature on Apparent Porosity



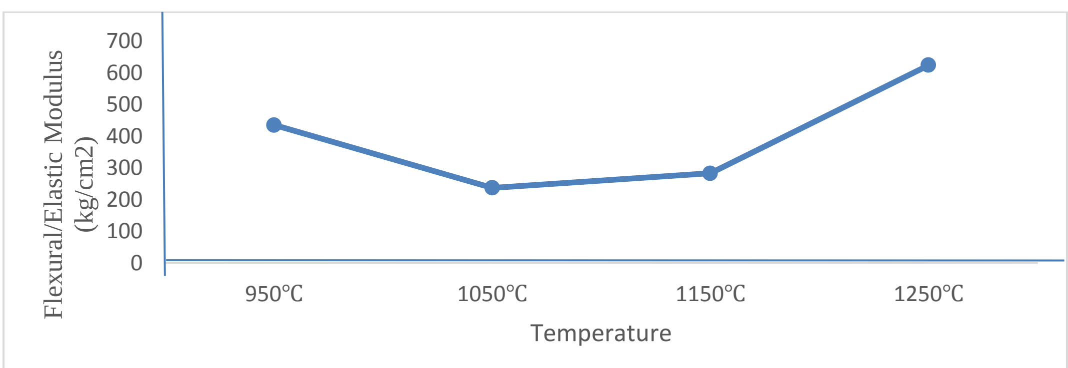
d) Effect of Sintering Temperature on Bulk Density



e) Effect of Sintering Temperature on Cold Crushing Strength (CCS)

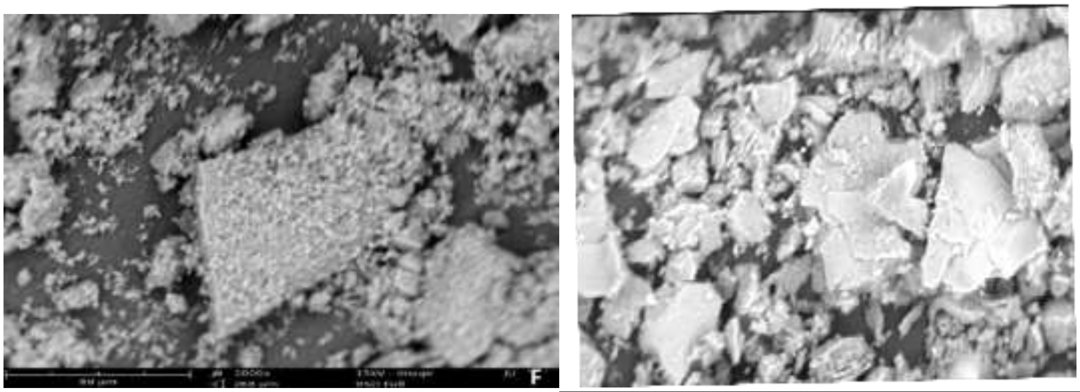


f) Effect of Sintering Temperature on Modulus of Rupture (MOR)



g) Effect of Sintering Temperature on Elastic Modulus

Figure 4a-g: Effect of Sintering Temperature on the Physico-Mechanical properties of Sakpe Clay



a) at 950^0C b) at 1250^0C

Figure 5: SEM Photomicrograph of fired Sakpe Clay.

The apparent porosity, water absorption rate decreases with increase in sintering temperature from 950^0C to 1250^0C. This could be attributed to decrease in pore space as a result of compaction or densification in the clay body and formation of glassy phase in the matrix (Aladesuyi *et al.*,2017). The effect of temperature on the physico-mechanical properties is as shown in Figure 4a-4g. Sakpe clay has porosity values of 48.88% at 950^0C and 22.53% at 1250^0C as observed in Table 4, high water absorption rate of between 14 and 26.44% with decreasing absorption rate as the temperature increases, while fired shrinkage, apparent density and bulk density increased as the temperature increases.

The Cold Crushing Strength (CCS) of the tested clay also increased as the firing temperature increased as a result of increase in compaction and decrease in porosities of the samples. The flexural strength and Elastic modulus were found to decrease (from 7.75 kg/cm^2 to 4.59 kg/cm^2 and 435.32 kg/cm^2 to 237.08 kg/cm^2 respectively) between 950^0C and 1050^0C, and then increased up to value of 16.42 kg/cm^2 and 624.17kg/cm^2, respectively, at 1250^0C as shown in Table 4 and Figure 4a to 4g.

4 CONCLUSION

The clay deposit was found to be kaolinitic and thermally stable at temperatures observed and refractoriness of $\leq 1300^0$C and good thermal shock resistance of 12 cycles were also observed and the samples were found to have good physical and mechanical properties values that meet the requirements for production of tiles, paints, filler in paper making, porcelain insulators, refractory lining of low temperature ovens, kilns and microwaves.

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A SYSTEMATIC REVIEW ON CORROSIVE WEAR OF LOAD BEARING IMPLANT BIOMATERIALS IN AGGRESSIVE BODY FLUIDS

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Abstract

Chemical stability, mechanical behaviour and biocompatibility of implants in the body fluids and tissues are the basic requirements for successful application of prostheses in bone repair and replacements. With the progress reported in novel biomaterials, various alloys, porous and gradient biomaterials are developed as substitutes for joint replacement to address the mismatch of implants modulus with host bone and also improved bone-tissue integration. However, there are limited researches on implants degradation caused by a foreign body reaction evoked by load-movement activities and electrochemical interaction of the body fluids with the prostheses especially on new tailored joint biomaterials. Prior to clinical investigation, it is very important to study the characteristic of implant surface, chemical composition, and electrolyte (body fluids) to achieve minimal releasing of toxic ions and premature failure of the prostheses. To design biocompatible implants, the research study required a suitable consideration of chemical, mechanical, and biological properties. Therefore, this article presents different aggressive body fluids properties (pH, dissolved oxygen and temperature) and their interaction with the surface of load bearing implant from relevant published journals. It also reviews the corrosion and wear properties of the load bearing implant biomaterials with body fluids. This review finally summarizes and suggests the future research areas yet to be conducted on the corrosion and wear behaviour of new tailored biomaterials (gradient and porous joint prostheses) in hostile living environments.

Keywords: Corrosion, Wear, Body fluids, Joint Implants, and Biomaterials

1. INTRODUCTION

According to the Food and Drug Administration [1], a medical implant is defined as “devices or tissues that are placed inside or on the surface of the body. Many implants are prosthetics, intended to replace missing body parts.

Load bearing implant biomaterials are bio inert materials to replace or repair damaged hip, shoulder, knee, ankle, and elbows. Due to the mechanical requirement in the area of applications, the implants are designed and manufactured by utilizing the polymers, metals, and ceramics biomaterials available either singly or in combination with the materials of these classes. These classes of materials offer various alternative applications in the body due to the different atomic arrangement formations with diversified structural, physical, chemical, and mechanical properties.

Initially, all devices need to meet the requirements of biocompatibility as indicated in ISO 10993 standards, depending on the specifications of the implant and the function in the body [2]. For instance, the evaluation differed according to the type of material, permanency in the body, composition, among others. The purpose with this normative is to improve the quality of the life of the patients with bone atrophy without expose them to future complications. The desirable characteristics of load bearing orthopedic implants such as excellent biocompatibility, high strength, osteointegration, comparable modulus with bones, good corrosion and wear resistance are significant qualities before being considered for clinical assessment. The improvements of the quality of the implants are needed to proffered solutions to the prevalence challenges with the use of the materials. Among the problems is the mismatch of the implant stiffness with the host bone, and degradation that resulted to loosening from stress shielding and inflammation effects. Loosening of joint implants is usually classified into aseptic loosening which is mainly considered to be caused by a foreign body reaction evoked by wear particle and corrosion products and septic loosening which is caused by living bacteria in deep implant-related infections [3].

Previous researches have focused on modification and formulation of new biomaterials with the high concentration on development of new alloys, composites, gradients, and porous biomaterials to minimize the modulus of the implants closer to host bone. However, biocompatibility of many of the new tailored biomaterials received limited attention in aqueous body fluid environments. The host reactions generated by the degradation of the implant in the physiological environment are two essential elements that determine a material's biocompatibility [4]. Implant degradation is triggered by mechanical wear of the components and electrochemical corrosive interactions with body fluids [5]. As a result of the electrochemical wear, the toxic debris release into the body and caused different allergies, inflammations and cancer dependent on the composition of the prosthesis implanted in the specific environment.

This article presents the details of body fluids, simulated body fluids properties and their elemental compositions that have been considered as electrolyte in the environments where implants are fixed. It also showed the details behaviour of wear and corrosion of the existing implants in the body fluids with respect to different implant biomaterials and finally suggests the research gaps on the used body fluids and tailored biomaterials.

2. PROPERTIES OF BODY FLUIDS

The human body is a aggressive environment for metals and alloys having an oxygenated saline solution with salt content of about 0.9 % at pH~7:4, and temperature of 37±1 ^oC (98.4 ^oF). It has been reported that water, complex compounds, dissolved oxygen, large amounts of sodium ($Na+$) and chloride ($Cl-$) ions, as well as other electrolytes such as bicarbonate and small amounts of potassium, calcium, magnesium, phosphate, sulphate, and amino acids, proteins, plasma, lymph, and so on, make up the body fluid [6]. Ionic species also have a variety of activities, including maintaining the body's pH and participating in electron transfer reactions.

Joint implants are load bearing materials that need to function in different biological fluids of different chemical composition depending on the area of their applications. Corrosion assessments of these biomaterials are often required before they are approved by regulatory organizations [6]. Corrosion and wear is an engineering testing procedure as shown in Figure 1. It is non-clinical test that is also called acellular test and described as one of the pre-clinical assessment tool of biomaterial to check the likely stability of a biomaterials in the aggressive body fluids. For a novel designed prosthesis to be developed and move from the lab to the clinic, it must pass through rigorous stages of experimental tests mentioned in Figure 1.

Therefore to assess corrosion and wear it requires body fluids electrolyte which can be either fluids extracted from humans or animals or using 'simulated' (synthetically produced from recipes) as shown in Table 1 for joint that are slightly alkaline with pH of 7.3-7.5. Many experimental researches utilized simulated body fluids such as Hank's Balanced Salt Solution (HBSS) and Phosphate Buffered Saline (PBS) which are mostly recommended as physiological solutions because of the constant pH its maintain throughout the in vitro experiments [4]. Some researchers considered Sodium chloride ($NaCl$) as the major compound of HBSS and PBS physiological simulated body fluid to investigate the corrosion effect on load bearing implants [7,8,9]. Their chemical composition varies significantly with regard to inorganic salts and biomolecules. Biomolecules are proteins and amino acids that can be adsorbed on the surface of metals.

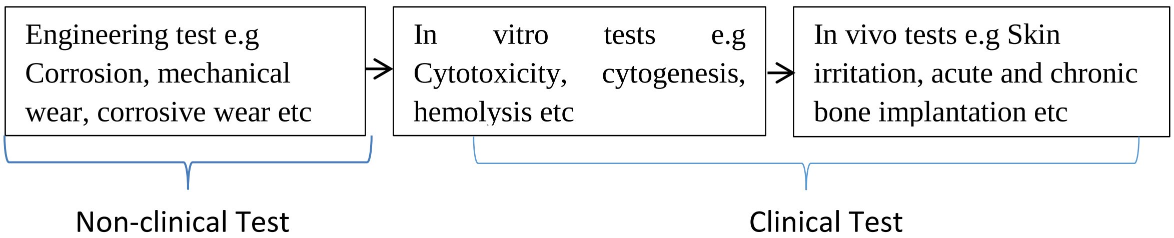

Figure 1: Steps for checking the Biocompatility of Joint Prosthesis

Table 1: Chemical Compositions of various Body fluids

Body Fluids	**Composition of Various Extracted Body Fluids**			**Composition of Various Simulated Body Fluids**		
Constituents	**Serum (mg/L)**	**Interstitial Fluid (mg/L)**	**Synovial Fluid (mg/L)**	**HBSS (g/L)**	**PBS (g/L)**	**Ringer's (g/L)**
K^+	156	156	156	-	-	-
Ca^{2+}	100	100	60	-	-	-
Cl^-	3581	4042	3811	-	-	-
Mg^{2+}	24	24	-	-	-	-
SO_4^{2-}	48	48	48	-	-	-
NaCl	-	-	-	8	8	8
KCl	-	-	-	0.40	0.20	0.30
$CaCl_2$	-	-	-	0.14	-	0.33
HCO_3^-	1648	1892	1880	-	-	-
HPO_4^{2-}	96	96	96	-	-	-
$NaHCO_3$	-	-	-	0.35	-	-
NaH_2PO_4	-	-	-	-	1.15	-
K_2HPO4	-	-	-	0.06	0.20	-
$MgCl_2.6H_2O$	-	-	-	0.10	-	-
$MgSO_4.7H_2O$	-	-	-	0.10	-	-
$Na_2HPO_4.12H_2O$	-	-	-	0.12	-	-
Protein	66,300	4144	15,000	-	-	-
Glucose	-	-	-	1.0	-	-
Phenol red	-	-	-	0.02	-	-
Organic acids	210	245	-	-	-	-
pH	7.35-7.45	7.35-7.45	-	6.9	7.3	6.4
Reference	[4]	[4]	[4]	[32]	[4]	[32]

Recently, Radovanovic *et al.* [10] studied the corrosion behaviour of Titanium metal in simulation body fluids with addition of different concentrations of adenine (AD), thymine (THY), and Lhistidine (HIS), biomolecules that are components of the compounds in the human body using electrochemical measurements. The biomolecules showed that the formation of film act as ligands and form metal complexes on the electrode surface and reduce corrosion processes. However, the inhibitive strength of biomolecules reactions in the body with joint implants reduced over time and resulted to degradation of the surface of implants. The body fluid reactions on the implants with the wear process due to the body joint operations drastically influence the surface of the implant and reduce the implants life spans.

3. WEAR AND COROSSIVE PROPERTIES OF IMPLANTS

Wear is a cumulative surface degradation phenomenon in which material is lost from a body as microscopic particles, primarily by mechanical processes [11]. Metal debris from total joint arthroplasty generated through wear and corrosion mechanisms can induce untoward effects in the peri-implant space [12]. Wear occurs when materials are mechanically removed from two or more contacting surfaces during relative motion. In the course of its usage, the implant device may simply wear out. This is mode of deformation that can mainly affect the performance of joint prostheses where it experiences either elastic or plastic contact in the body. Five mechanisms have been reported to initiate wear of prosthesis components and these include abrasive, adhesive, fatigue fretting and corrosive wear [13].

Corrosive wear is degradation of a material that involves both corrosion and wear mechanisms [14]. Corrosion is a major factor when choosing and designing metals and alloys for prosthetics. During corrosion processes, allergenic, toxic/cytotoxic, or carcinogenic species (e.g., Ni, Co, Cr, V, Al) may be released into the body [4]. Moreover, implant loosening and failure can be caused by a variety of corrosion mechanisms [15]. In the context of quality assurance and failure analysis, the corrosion behavior of load bearing biomaterials such as metallic implant materials have been extensively researched. The majority of corrosion-prevention techniques employed in industry are ineffective in the human body. This is because service in the body presents unique challenges due to the negative effects of proteins, enzymes, and other biological elements on corrosion processes, as well as the action of wear and high loads on load-bearing implants [4].

As a result, body system corrosion control is currently restricted to careful design (for example, to avoid galvanic couples or crevices), suitable material selection, and surface modification.

These brought about the development of tailored biomaterials like alloys, composite, gradient and porous materials. As a result, the techniques to surface modification have received a lot of attention.

Coatings, on the other hand, have a restricted application because many of them are susceptible to wear in the body. This emphasizes the importance of careful material selection during implant design. Several researches on the corrosion test of joint implants were conducted using electrochemical measurements (open circuit potential OCP, Cyclic polarizations CP, polarization 31 resistance Rp, potentiodynamic polarization curves PPC, electrochemical impedance spectroscopy EIS) test for corrosion process in the either extracted or simulated body fluids (SBF) [16].

In many non-clinical test of joint implants, corrosive properties were carried out on different implant and new developed implant biomaterials as shown in Table 2. However, Igual Munoz et al. [16] studied In vivo (clinical) electrochemical corrosion study of a CoCrMo biomedical alloy in 4 human synovial fluids. The findings demonstrated that the electrochemical properties of CoCrMo alloy in synovial fluids not only affected by material reactivity but also by synovial fluid reactive oxygen species.

Table 2: Corrosion Parameters for Selected Load Bearing Implant Biomaterials

Implant Materials	Corrosion Measurement	Corrosive Medium	Icorr (μAcm^{-2})	Ecorr (V)	Ipass ($mAcm^{-2}$)	Corrosion Rate (mm/yr)	Ref.
Cp- Ti	PPC	HBSS	0.33	-0.33	-	-	[17]
Cp- Ti	OCP/PPC	SBF	0.787	-0.53	0.112		[18]
Ti-7Zr-20Si-10B	OCP/PPC	SBF	0.275	-0.38	6.39	-	[18]
Ti-20%HA	PPC	Ringer	8.5X10-2	-0.55	-	0.003	[19]
Porous Ti-20%HA	PPC	Ringer	0.452	-0.66	-	-	[19]
Porous Ti-20%HA	PPC	HBSS	1.25	-1.10	-	-	[20]
Co-Cr-Mo	OCP	25% Serum	4.24± 0.28	-0.803	-	-	[21]
Co-Cr-Mo	OCP	25% PBS	11.82±0.28	-0.823			[21]
Co-Cr-Mo	OCP	0.9% NaCl	3.38± 0.41	-0.665			[21]
Ti-6Al-4V + 10% B4C		3.5 % NaCl	5.82	-	-	-	[22]
porous Ti-TiB-TiN	OCP/CP	PBS	-	−148±46	840±317.9	-	[23]
AISI 316L	PPC	0.9 % NaCl	0.10	-0.190	-	-	[24]
Porous AISI 316L	PPC	0.9 % NaCl	3.7	-0.143			. [24]
Ti15Mo	CP	HBSS	0.036	-0.369		0.5448	[25]
CoCrMo	CP	8 g/l NaCl solution	−14.5 ± 0.1	−0.342±0.02	-	-	[8]
CoCrMo-10HAP	CP	8 g/l NaCl solution	−84.5 ± 7.6	−0.336±0.01	-	-	[8]

Table 3: Corrosive Wear Parameters for Load Bearing Implant Biomaterials in Corrosive Medium

Implant Materials	Corrosive Medium	Load (N)	Wear Loss (10^2.mm^2)	Wear Rate (10^{-4}mm^3/(N.M)	Sliding speed (m/s), time (min)	Friction Coef.	Ref.
Ti-6Al-4V	3.5 NaCl	5	-	11.2	-	-	[9]
Ti-6Al-4V	Serum	3	10.75±0.19	-	0.04/3000	0.33±0.01	[26]
316L SS	HBSS	5		131	0.136/180	0.39 ± 1	[27]
Ti-7Si	Serum	*3*	8.63±2.05	-	0.04/3000	0.24±0.04	[26]
Ti-8Si	Serum	*3*	7.57±2.43	-	0.04/3000	0.23±0.03	[26]
Ti-6Si-18Zr	Serum	*3*	7.92±3.27	-	0.04/3000	0.26±0.03	[26]
Ti-6Si-18Nb	Serum	*3*	7.70±1.80	-	0.04/3000	0.26±0.01	[26]
Porous Ti-TiB-TiN*x*-30	150 mL PBS	3	-	-	25	0.52 ±0.04	[23]
Ti-6Al-4V/W-Mo	3.5 NaCl	5	-	0.895	-	-	[9]

Corrosion rates differed greatly amongst patients, ranging from 50 to 750 mg/dm^{-2}year^{-1}. Meanwhile, wear of the implants due to the operation (walking, jumping, dancing and climbing etc) it is subjected to in the body, resulted to releasing of metallic ions that are toxic to the body systems [28]. The methods used for the investigation of wear properties of implant biomaterial with pin-on-disc, ball on disc, pin on flat using CETR UMT−2 tribometer [8, 28, 29] and milling CNC turning process [30] under dry sliding in air and ambient or selected temperatures against the wear in living joint systems.

The corrosive wear of biomaterials was investigated in NaCl solution using a ball-on-disk wear tester in ambient air. The abrasive wear of Ti6Al4V was slightly higher in NaCl solution than in ambient air due to the considerable lubricating effect of the solution [9]. With non-clinical and clinical electrochemical corrosion and wear assessments of biomaterials, limited numbers of the researches were conducted on wear of the implants in body fluids environments shown in Table 3. These results indicated the process of involved combine effect of corrosive wear in aggressive body fluids is needed to simulate the actual implants behaviour in the body systems. The tribocorrosion behaviour of hot pressed CoCrMo-Hydroxyl appetite (HAP) biocomposites were studied by Doni et al. [8] confirmed the HAP particle addition increased the corrosion rate due to localized corrosion taking place on the pore sites near the matrix/reinforcement interface. However, with the tribological action, the composite samples relatively exhibited lower corrosion and coefficient of friction values.

However, the releasing toxic ions as of wear and corrosion products in the body revealed the importance of characterization of the load bearing biomaterials. The photographs from scanning electron microscope (SEM), x-ray diffractometry (XRD), energy dispersive spectroscopy EDS are essential tools for characterization of biomaterials to confirm damaged particles under sliding resulting in the loss of particles. Though, the effects of this mechnochemical process of the implanted prosthesises can also be identified through the clinical test such in vitro (cytotoxicity, cytogenesis) test with confirmation of the presence of toxic ions released in to the host body system. The adhering HAP particles on the joint implant surface were studied using SEM/EDS. are shown in Figure 2 and 3.

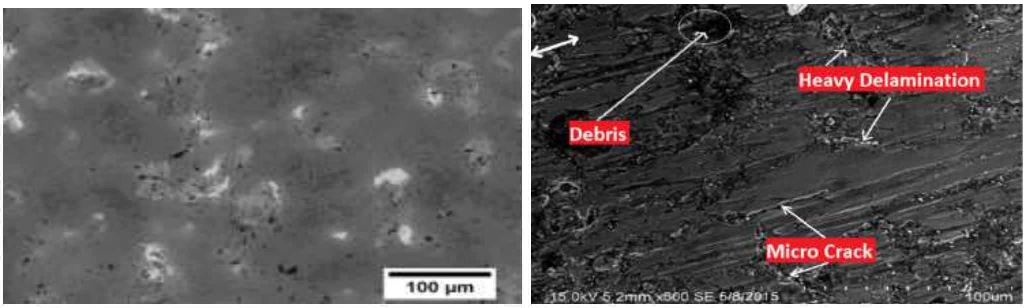

Figure 2: SEM micrograph of the Ti-6Al-4V and its worn surfaces composite [31]

Detached HAP debris has been reported to behave as a solid lubricant for sliding surfaces [8]. And this contributed to healing, and improves both mechanical and biological properties. In order to analyse the corrosion kinetics under sliding conditions, wearing and corrosion product of bio inert materials (Cp Titanium, HAP, Hafnium etc) in dynamic activities of body joints implants should be investigated under potentiostatic and potentiodynamic conditions.

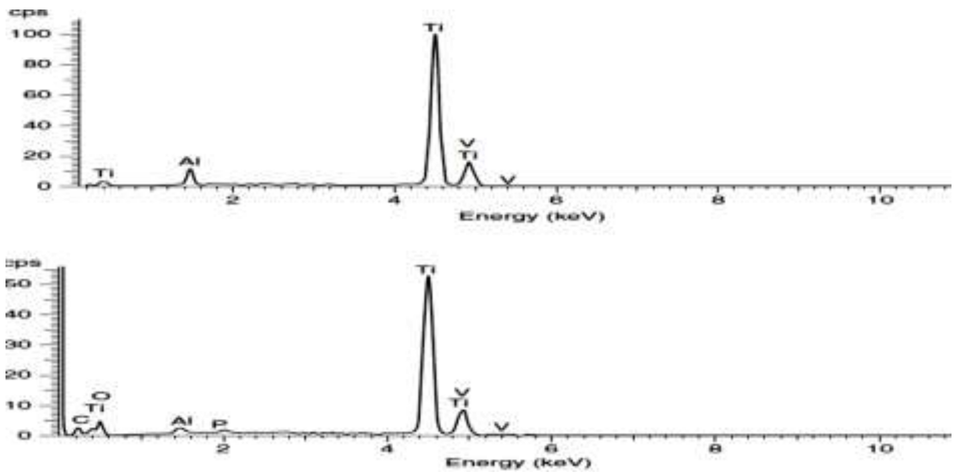

Figure 3: EDS analysis taken for Non Corroded and corroded Ti-6Al-4V, surfaces composite [3]

4. CONCLUSIONS AND FUTURE RESEARCH

The interaction of the body fluid and joint implants is a complex phenomenon that involved combine process of corrosion and wear mechanism. In particular, numerous chemical, physical, and biological elements requires balance assessment for body acceptable product. The complicated immunological response of the tissue must be taken into consideration while evaluating the efficacy of potential metals, alloys, and composite materials for innovative biomedical devices developed as prosthetics. Understanding the interactions between body fluids and materials can aid in the development of novel physiological acceptable device interfaces that can contribute to the healing and even mitigating the releasing of harmful ion in the body. This study however, suggesting the novel approach to utilise constituents in formulation of composite to enhance the wear and corrosion resistance through the mixture of particles with different size, shape and proportion to produce multiple porous and gradient materials. Most of the previous researches carried out on the corrosion and wear properties are not actual corrosive wear properties as it occurs in the human or animal joints. To gain a better understanding of the tribocorrosion behavior of joint implants, the variations in pH and metal ion content of the electrolyte after tribocorrosion tests should be considered in conjunction with the detailed characterisation of the wear debris generated during the tribocorrosion process. The study suggests the development of biotribocorrosion test rig to investigate the corrosive wear of implants rather than wear or corrosion influenced parameters. Further studies should address the corrosive wear challenge for quality checks and industrial standards for new tailored graded surfaces and porous biomaterials.

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ASSESSMENT OF CONTRIBUTION OF ILESHA GOLD MINING TO EMPLOYMENT CREATION AND REVENUE GENERATION IN OSUN STATE

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Abstract
Nigeria is a nation endowed with numerous mineral resources ranging from precious metal, stones, gypsum, kaolin, gold, barytes, and so on. Osun state is one of the states in Nigeria richly blessed with mineral resources such as gold, talc, granite, feldspar, kaolin, columbite and clay. This paper investigates the contribution of Ilesha gold deposit in Osun state to employment creation and revenue generation. Structure questionnaire was used to collect relevant data in addition to personal communications with selected skilled and unskilled labours within the gold mining sector and the residents of the host community. The study revealed that gold mining in Ilesha, Osun state, under the illegal miners and Artisanal and Small-scale Miners (ASM) has not had significant contribution to the state revenue. However, it has provided job opportunities for about 200 hundred mine workers and 150 indirect workers such as marketers, drivers and so on. The partnership of the state Government (under the Omoluabi mineral promotion company) with the mining companies (particularly the large-scale gold mining by Segilola gold project) will hopefully increase solid mineral growth domestic product (GDP) of Osun state and improve employment generation.

Keywords: Mineral, Ilesha Gold, Employment**,** Revenue

1.0 Introduction

Nigeria as a nation is a vast country embedded with considerable number of mineral resources as it is known as a country richly endowed with varieties of minerals ranging from precious metal, various stones, to some industrial minerals such as barytes, gypsum, kaoline, gold and so on. The country is also blessed with abundance of oil and gas reserves which have been driving the economy of the nation for a very long period of time (Adekoya, 2003).

The importance of mineral development in any nation cannot be overemphasized as it is one of the sources of industrial raw material supply, what must however, be emphasized is the manner in which the resources are developed. Nigeria is blessed with abundant mineral resources and human resources capable of tapping these resources for industrial growth, however, what is witnessed today is that most of the mineral development ,especially the exploration is done by informal and in most cases illegal miners using very crude techniques with no consideration for the environment or human health (Idowu, 2013).

A mineral is defined as a naturally occurring crystalline, inorganic substance that has a specific chemical formula and a crystal structure. Mineral resources are essential accumulation of natural occurring materials or commodity found on or in the earth, which can be extracted profitably.

These mineral resources are generally classified into three major categories;

1. Energy minerals; this includes

i. Nuclear fuels (such as uranium, zirconium) and,

ii. Fossil fuels (oil and gas), coal

iii. Bitumen

2. Metallic minerals resources which includes;

i. Ferrous metals (such as iron and iron-associates) and

ii. Non-ferrous metals such as light metals, Li, Bi, precious metals (platinum-group, Au, Ag, Sn) and Base metals (Cu, Zn, Pb, Ni, As, Cd)

3. Industrial minerals are minerals mined and processed (either from natural sources or synthetically processed) for the value of their non-metallurgical properties, it includes: clay, sand, talc, limestone potash and so on. (Alexander, 2014).

The mining of minerals in Nigeria accounts for only 0.3% of its GDP, due to the influence of its vast oil resources (Damulak, 2016). Nigeria is a country full of potentials, rich in human and natural resources many of which are hardly found anywhere else in the world, but unlike other countries endowed with as much resources, the management of our mineral resources is still an issue (Mallo, 2012). Gold in Nigeria is found in alluvial and eluvial placers, and primary veins from several parts in the northwest and southwest of Nigeria (Garba, 2003). The most important occurrences are found in the Maru, Anka and Malele areas of Zamfara State; Tsohon Birnin Gwari and Kwaga area in Kaduna; Gurmana area in Niger State; Bin Yauri in Kebbi; Okolom-Dogondaji in Kogi; and Iperindo area in Osun state (Garba, 2003). There are also a number of smaller occurrences beyond these major areas: for instance, Ajegunle-Awa area in Ogun State; Korobiri and Degeji area in Kwara State; Oban Massif area in Cross River State; and Ilasa.

The discovery of economic deposits of gold in the South East of Ilesha led to the discovery of other minerals in Osun State. (Ajeigbe et al, 2014). This paper therefore, investigates the contribution of Ilesha gold exploitation to employment generation.

2.0 Materials and Methods

This section presents the study area, the materials and methods used in this research.

The methods used include review of relevant literature, site visit for data collection; Data collected included:

i. Method of mining
ii. Biodata of mine workers and other job information
iii. Charge design and quantity of explosives used; and as built string file of levels access 1675 m to 1600 m,

Questionnaire and interview were administered for the collection of the above data. Interviews were undertaken at the study area, which involved verbal communication with the artisanal miners. The reason for adopting interview method is to know the positive and negative effect of gold mining in Osun State.

2.1 Study Area

Osun State is underlain by Precambrian rocks of the basement complex of Nigeria. Several varieties of these rocks possess appreciable degrees of economic mineralization (Tolulope *et al*., 2021). The study area is located in Atakumosa, Ilesha, Osun State (Figure 1). In Osun State deep weathering profiles, erosion surfaces and alluvial deposits have accumulated important mineral deposits such as laterites, talc and gold in stream sediments. In Osun State the mineral resources potentials found are Gold, Talc, Feldspars, Cassiterite, Columbite, Granite, Mica, Iron ore, Kaolin, Tourmaline, and Aquamarine and so on.

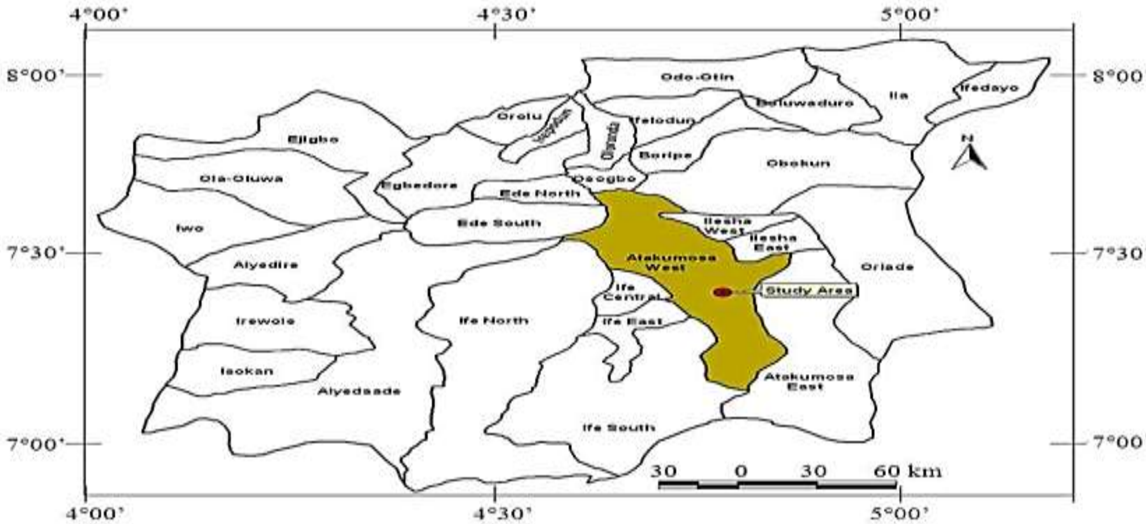

Figure 1: Map of Osun State showing studied area (Ayantobo *et al* 2014)

Mining Method

The type of mining method practised in the study area is between artisanal and small-scale mining. Some individuals mine gold illegally and left the ditches as death traps for animal and human beings. In artisanal mining, individuals engage in the mineral extraction that is not organised and no sophisticated equipment is used, whereas, in small scale mining, companies run the mines with machinery and has a higher revenue turnover.

Figure 2: Excavator loading the washing pan

The small-scale miners in the study area are mainly Chinese, which used manual labours, excavators for scooping the gold bearing sand. After the scooping, the sand is loaded into the washing pan (Figure 2). Excavator is being used in loading the washing pan with particles containing gold, the washing pan is designed in layers so that any gold particle that escape the first layer will be retained in the second or third. This is to ensure there is no loss or minimal in loss of gold particle during the process of washing. The particles are being washed through the layers of washing pan, due to the density of gold, which is higher than that of sand, gold settles while sand particles washed off the pan. Then gold retained is retrieved from the washing mats placed on the layers of the layers of washing machine.

It is noteworthy to mention that gold mining activities generates large amounts of highly soluble inorganic matter, some of which are considered toxic to the environment and aquatic and human life. Generation of chemical waste as a result of mining activities occurs world-wide and may severely affect natural resources such as vegetation, water bodies and the ecosystem in general (Haddaway *et al*, 2019). Unfortunately, the artisanal and small-scale gold miner pay lip service to environmental monitoring. This is evidence in the number of pits (Figure 3) that were left un-rehabilitated after mineral extraction; there are no control on the effluents that are released into the ecosystem.

Figure 3: Abandoned location on the site

Figure 4: Sample of raw mined gold

The recovered gold (Figure 4) is being exported raw according to the miners interviewed on the sites. The data collected via questionnaire was done in two categories; first is for the mine workers (artisanal/illegal/small scale/) and the other is for the community residents. This gives access to both parties opinion and enables the researcher to compare both for better conclusion.

The response of gold mine workers (artisanal)/owner in the studied area is presented in Table 1. Age distribution of the artisanal mine workers shows that they are largely young people as 88.2% falls under the age of 50. This implies that the mine workers are still very energetic hence expected to be more productive in the mining operations. The table also shows that a proportion of 82.4% of the respondents are males which means the mine is dominated of males due to the nature of the operation on the mine site, this could be more hazardous and dangerous for females.

Table 1: Frequency Table for Mine Workers/ Owner

Did you study mining engineering or any other related course?

		Frequency
Valid	Yes	4
	No	13
	Total	17

Did you pay royalty to the host community?

		Frequency
Valid	Yes	7
	No	10
	Total	17

Did you undergo mining related training or course before working on the site?

		Frequency
Valid	Yes	7
	No	10
	Total	17

Was reconnaissance survey carried out?

		Frequency
Valid	Yes	8
	No	9
	Total	17

Do government officials visit the site to inspect the activities?

		Frequency
Valid	Yes	12
	No	5
	Total	17

What is the expected life span of the mine?

		Frequency
Valid	1-2yrs	1
	3-5yrs	14
	above 5yrs	2
	Total	17

Does this mining operation add economic value to the state?

		Frequency
Valid	Yes	10
	No	7
	Total	17

How many years have you been working in Goldmine?

		Frequency
Valid	1-3yrs	15
	4-6yrs	2
	Total	17

Marital Status

		Frequency
Valid	Single	7
	Married	9
	Divorce	1
	Total	17

Table 4.18: ***Is government aware of the mining operation here?***

		Frequency
Valid	Yes	13
	No	4
	Total	17

Age

		Frequency
Valid	<18yrs	2
	18-25	4
	25-35	9
	above50	2
	Total	17

Sex

		Frequency
Valid	Male	14
	Female	3
	Total	17

Educational Level

		Frequency
Valid	PLSC	1
	JSS3	2
	SSCE	8
	ND Holders	5
	Graduate	1
	Total	17

Is mine gold processed here or exported raw?

		Frequency
Valid	Exported raw	17

Mineral endowment; a blessing or a curse?

		Frequency
Valid	A blessing	14
	Curse	3
	Total	17

It is noted from the table that 52.9% are married, while having verbal interaction with some illegal miners; majority gave excuse of what to feed their family as the reason behind them engaging in the illegal mining operations. The table also shows that a proportion of 88.2% has between 1-3years of working experience. This shows that most of the artisanal miners are not vast in the mining operations as they have limited experience in mining and hence could be dangerous to mining operations in term of mine accidents and the environment at large.

During the interaction with the miners (artisanal) it was discovered that some of them engage in other works which make them part-time workers on the mine site. Surprisingly, the table shows that only 5.9% of the respondents are graduates, while 29.4% are National Diploma holders and a larger percentage of 47.1 are Senior Secondary School Certificate holders and 5.9% has Primary leaving school certificate as educational background. It was also revealed that 23.5% of the respondents studied mining while out of 23.5%, about 17.7% are confirmed to be students on Industrial Training. So apparently, 5.9% are mining engineering graduates. According to the table, 41.2% of the respondents have undergone mining course/training while larger percentages of 58.8% are unskilled; this definitely have negative effect on the mining operation.

It was noted that a proportion of 47.1% of the respondents said reconnaissance survey was done before the commencement of mining operation in the location while larger proportion of 52.9% said there was nothing like reconnaissance survey before operations commenced. However, the experience during the site visitation suggests that reconnaissance survey was not properly carried out in the location. The reconnaissance survey is regarded as extensive study of an entire area that might be used for a road or airfield. Its purpose is to eliminate those routes or sites, which are unfeasible, and to identify the more promising routes or sites. Existing maps and aerial photographs may be of great help. The importance of this survey cannot be overemphasized as far as mining operation is concerned but sadly, artisanal miners who have dominated mine sites today fail to carry out reconnaissance survey, hence result in damaging of land surface unnecessarily.

A proportion of 82.4% respondents said the mine life span is 3-5 years while 52.9% claimed they have been involved in mining operations on the site for the past 2years. Reclamation is the combined processes by which adverse environmental effects of surface mining are minimized and mined out areas are returned to a beneficial end use. A proportion of 76.5% of respondents justifies that reclamation was done. Although during the site visitation, it was observed that the reclamation was not properly done due to the nature of the operation. Land is not being returned to formal shape after the mining operations, this is attested to in figure 3. It was also noted that the mined gold is being exported raw; this justifies the claim of 58% of the respondents who opined that gold mining in the state has no positive economic impact on the state. A total percentage of 41.2% claimed that royalty is being paid to the host communities, while 78.5% respondents claimed that government is aware of the mining operations in the state.

During the visit to Omoluabi mineral Promotion Company in Osun state government house, it was confirmed that Osun state government is not officially aware of mining operations going on in the state. The second questionnaire covers the community residents as presented in Table 2.

Table 2: Frequency Table for Community Residents

Age

		Frequency
Valid	*<18yrs*	*1*
	18-25yrs	*6*
	25-35yrs	*14*
	35-50yrs	*10*
	above 50	*3*
	Total	*34*

Sex

		Frequency
Valid	*0*	*1*
	Male	*18*
	Female	*15*
	Total	*34*

Marital Status

		Frequency
Valid	*Single*	*11*
	Married	*17*
	Divorced	*6*
	Total	*34*

Employment Status

		Frequency
Valid	*Self-employment*	*19*
	Employed	*9*
	Part-time	*3*
	Full-time	*3*
	Total	*34*

Are you aware of gold mining operation in your community?

		Frequency
Valid	*Yes*	*29*
	No	*5*
	Total	*34*

Has gold mining generated any revenue to your community?

		Frequency
Valid	*Yes*	*12*
	No	*22*
	Total	*34*

Is Mineral endowment beneficial to your community?

		Frequency
Valid	*Yes*	*15*
	No	*19*
	Total	*34*

Has Gold mining positively impacted the community?

		Frequency
Valid	*Yes*	*16*
	No	*18*
	Total	*34*

Has gold mining negatively impacted the community?

		Frequency
Valid	*Yes*	*17*
	No	*17*
	Total	*34*

Do you have any conflict?

		Frequency
Valid	*Yes*	*11*
	No	*23*
	Total	*34*

Has Gold mining brought any development to your community?

		Frequency
Valid	*Yes*	*13*
	No	*21*
	Total	*34*

Is Gold mineral a blessing for the community economic development?

		Frequency
Valid	*Yes*	*17*
	No	*17*
	Total	*34*

Have you benefitted so far in the mining of Gold here?

		Frequency
Valid	*Yes*	*9*
	No	*25*
	Total	*34*

Is Gold mining operations hazardous to your community?

		Frequency
Valid	*Yes*	*22*
	No	*12*
	Total	*34*

Do you wish the mining activities continue in your community?

		Frequency
Valid	*0*	*1*
	Yes	*17*
	No	*16*
	Total	*34*

Table 2 shows that 41.2% of the respondents are within the age range of 25-35years and 52.9% are males. According to the table, 50% from the respondents are married. 44.1% of the residents have been living in the community for over 10years while 35.3% and 20.6% of the residents have been there between 6-10years and 1-5years respectively. These means larger percentages of the respondents are familiar with the environment and are expected to be knowledgeable of happenings in their community. A proportion of 55.9% of the respondents who are self-employed are mostly farmers, this shows that farming is the major source of income in the community. According to the table, 85.3% the respondents are aware of what is going on around them as they claimed to be aware of gold mining in their community.

From the review of the questionnaire, it was noted that 55.9% proportion of the respondents agreed that mining of gold in their communities is not beneficial them, while 44.1% and 47.1% respectively said the mining operation in their communities is beneficial and impact positively on them. The table revealed that 67.6% of the respondents stated that there is no conflict as regards the mining operations. 47.1% of the respondents stated that mineral endowment of gold is a curse to their communities due to environmental damages being experienced, which has terribly affected the farming processes , which is known as their major means of livelihood in the community. Gold mining caused some environment challenges such as deforestation, river siltation, soil erosion and water pollution. According to Table 2, only 26.5% has so far benefited from the mining operations in their communities.

3.0 CONCLUSION

This study reveals that illegal miners, who are not skilled in mining operations, have taken over mining operations in Nigeria; this does not exclude the gold mines in Osun State. During the course of research, it was noted that mined gold is being exported raw out of the country. Hence, this makes gold mining in the state and the country of no economic value. It was also observed that lands used are being deformed as reclamation was not properly done, farmlands are destroyed and waters are polluted.

Government should be involved and invest in mining operations in Nigeria to curtain those enriching themselves with mining of resources and leaving the majority at disadvantage positions. This will make the resources at best use and blessing to the nation. The Ministry of Mines and Steel Development with the assistance of the security agents should intensify efforts in nipping the activities of illegal miners in the bud. Only licensed personnel should be allowed to carry out mining operations; this will make every miner accountable and help government in generating expected revenue from mining operations, which will in turn affect the nation's economy positively.

The partnership of the state Government (under the Omoluabi mineral promotion company) with the mining companies (particularly the large-scale gold mining by Segilola gold project) will hopefully increase mineral growth domestic product (GDP) and improve employment generation.

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LIBERATION OF NIGER STATE MANGANESE DEPOSIT

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ABSTRACT

Characterization and liberation of low-grade manganese deposit located in Niger State was carried out. The chemical and mineralogical characterization of the ore were assessed. The chemical analysis using the X-ray Fluorescence (XRF) spectroscopy revealed that the ore contains an average of 34.38% of manganese. The mineralogical analysis using X-ray Diffraction (XRD) spectroscopy showed that the ore samples contained spessartine ($Mn_3\ Al_2\ (Si\ O_4)_3$) and iron rich ilmenite and quartz. The SEM and EDX also revealed that iron, silicon and aluminum are the major constituent elements in the ore. The work index using bond's equations was calculated to be 2.4 kwh/ton. The degree of liberation was calculated and the ore ground to 75 µm sieve size showed a better liberation of manganese. The degree of liberation was modelled on MATLAB and the plot of the result was obtained.

Keywords: Liberation**,** Characterization, Mineralogical, Manganese, Spessartine, Ore

INTRODUCTION

Manganese is a vital resource required for production of steel. Increased consumption of manganese ores is due to the rise in steel demand, making the steel industry the major consumer of manganese (Singh, Chakrabortay & Tripathy 2019). Manganese finds other use in making batteries cells (Yi, Huang, Jiang, Zhao, Zhong &Liang, 2017), and artificial photo reduction and a carrier of oxygen in chemical combustion processes (Singh *et al*., 2019). Manganese also finds use in desulphurization (Cheraghia, 2020; Zwarah, 2020) and de-oxidation during steel making and production of Ferro alloys. Emphasis on the importance of manganese is appreciated in the textile and ceramic industries, it also finds application in making of battery cells, dyes and paint and is key in the production of Aluminum alloy (Baba, 2018; Li *et al*., 2020, Gbadamosi *et al*., 2021). Manganese deposit have been found in Adamawa, Bauchi, Benue, Cross River, Kastina, Kebbi, Nasarawa, and Plateau states (Nigerian Ministry of Mines and Steel, 2020). Therefore, the data as regards the chemical and mineralogical characteristics needs to be made available to metallurgist and metallurgical industries for further exploitation, justifying this research.

MATERIALS AND METHOD

The manganese ore studied was obtained from Niger state, Middle belt of Nigeria. Collected from three different pits dug by artisanal miners. The ore was crushed and grinded to +1400 µm and + 63 µm. the grinded ore was subjected to sieve analysis using screen size of 425 µm, 300 µm, 150 µm, 75 µm, and -75 µm. the mesh size of 425 µm was used for the SEM and XRD analysis and five screen sizes were subjected to XRF analysis the sample ore was labelled B.

Chemical Analysis

The XRD was done at the National Steel and Raw Material and Exploration Agency (NSRMEA) Kaduna. The samples were prepared using back loading method and the emerging peak was revealed alongside the phases present in the ore. Also, the XRF was investigated at NSRMEA and the elemental composition for different mesh sizes were obtained.

Determination of Specific Gravity

The specific gravity of the ore sample was determined from the density using a 250ml pycnometer. This test was carried out at Brighter School Minna, Niger State. And the calculations made using the formula;

$$Density = \frac{(W_1 - W)}{(W_3 - W) - (W_2 - W_1)} \times 1000 \quad (1)$$

$$Specific\ gravity = \frac{Density\ of\ Ore}{Density\ of\ Water} \quad (2)$$

RESULT AND DISCUSSION

Work Index

The tables 1 and 2 show respectively the cumulative weight retained and passing of the reference ore (graphite) and table 3 and 4 shows that of the Niger State manganese ore. Whereas, the figure 1 and 2 show the graph of the sieve size plotted against the cumulative passing and retained of the reference ore while Figure 3 and 4 is that of the Niger State manganese ore. The work index was calculated using Bond's equation. And the work index was determined to be 2.4 kwh/t. Bond's equation:

$$W_t = \frac{W_r\left[\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{F_r}}\right]}{\left[\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}\right]} \quad (3)$$

Where; W_r= Work index of reference ore; W_t= Work index of test ore; P_r= Product of reference ore diameter, 80% passing through the sieve aperture; P_t= Product of Test ore diameter, 80% passing through the sieve aperture; F_r= Feed of reference ore diameter, 80% passing through the sieve aperture; F_t= Feed of Test ore diameter, 80% passing through the sieve aperture.

Table 1: Sieve Size of particle (reference ore) feed to ball mill

Sieve Size(μm)	Weight (g)	Weight Retained (%)	Cumulative Weight Retained (%)	Cumulative Weight Passing (%)
+1400	11.53	11.54	11.54	88.46
+1000	12.22	12.23	23.77	76.23
+710	13.88	13.89	37.66	62.34
+500	13.94	13.96	51.62	48.38
+355	12. 36	12.37	63.99	36.01
+250	10.66	10.67	74.66	25.34
+180	9.97	9.98	84.64	15.36
+125	4.64	4.65	89.29	10.71
+90	3.96	3.96	93.25	6.75
+63	2.98	2.98	96.23	3.77
-63	3.75	3.75	99.98	0.02

If 1400 μm=88.64

X μm=80%

Then, $\text{X}\ \mu\text{m} = \frac{1400 \times 80}{88.64} = 1263.54\mu m - F_r$

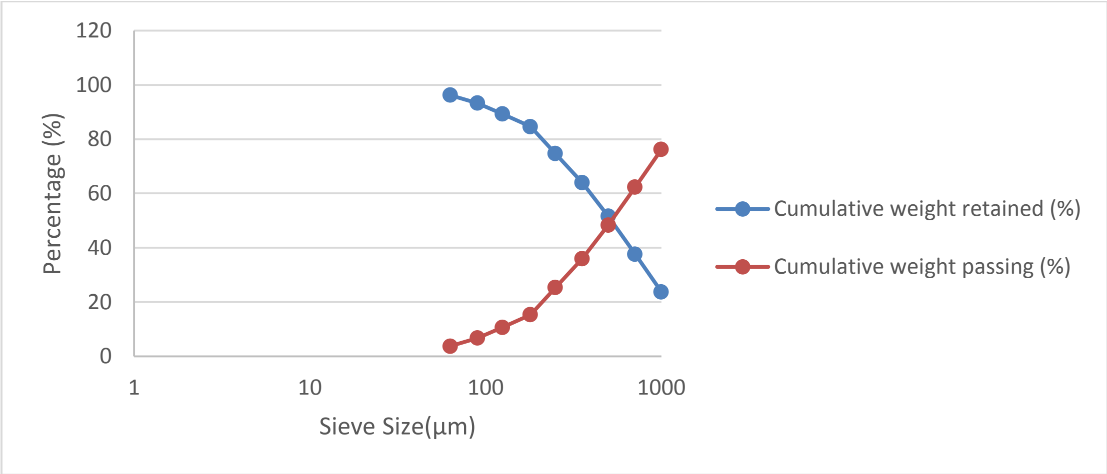

Figure 1: Logarithmic graph of reference ore Feed to Ball mill

Table 2: Reference ore particle size discharged from the ball mill

Sieve Size(µm)	Weight (g)	Weight Retained (%)	Cumulative Weight Retained (%)	Cumulative weight Passing (%)
+710	21.09	21.11	21.11	78.89
+500	16.94	16.96	38.07	61.93
+355	22. 56	22.59	60.66	39.34
+250	16.52	16.54	77.2	22.8
+180	7.97	7.98	85.18	14.82
+125	5.97	5.98	91.16	8.84
+90	4.29	4.30	95.46	4.54
+63	2.97	2.97	98.43	1.57
-63	1.57	1.57	100	0.00

If 710 µm=78.89

X µm=80%

Then, X µm $= \frac{710\times80}{78.89} = 719.99\mu m - P_r$

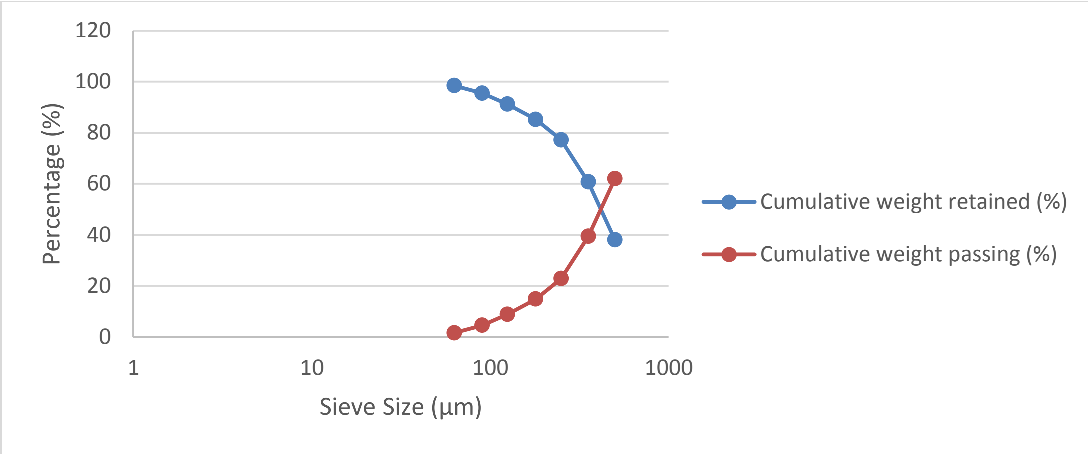

Figure 2: Logarithmic graph of product (Reference Ore) from ball mill

Table 3: Sieve Size of particle (Test ore Sample B) feed to ball mill

Sieve Size(µm)	Weight (g)	Weight Retained (%)	Cumulative Weight Retained (%)	Cumulative Passing (%)
+710	20.40	20.43	20.43	79.57
+500	25.74	25.78	46.21	53.79
+355	9.56	9.58	55.79	44.21
+250	12.54	12.56	68.35	31.65
+180	16.88	16.91	85.26	14.74
+125	5.82	5.83	91.09	8.91
+90	4.96	4.96	96.05	3.95
+63	2.42	2.42	98.47	1.53
-63	1.52	1.52	99.99	0.01

If 710 µm=79.57

X µm=80%

Then, $\text{X µm} = \frac{710\times 80}{79.57} = 713.84\mu m - F_t$

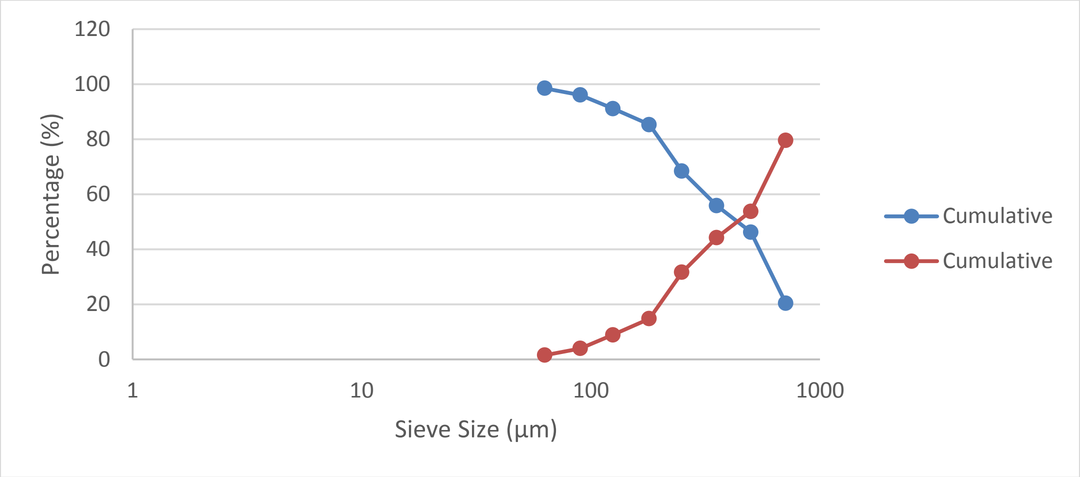

Figure 3: Logarithmic graph of sample B feed to ball mill

Table 4: Test ore particle size discharged from the ball mill sample B

Sieve size	weight retained (g)	Weight retained (%)	Cumulative weight retain (%)	Cumulative weight passing (%)
+710	11.93	11.94	11.94	88.06
+500	14.56	14.58	26.52	73.48
+355	10.72	10.73	37.25	62.25
+250	25.23	25.25	62.50	37.5
+180	17.44	17.46	79.96	20.04
+125	6.82	6.83	86.79	13.21
+90	7.09	7.10	93.89	6.11
+63	3.55	3.55	97.44	2.56
-63	2.55	2.55	99.99	0.01

If 500 µm=88.60

X µm=80%

Then, X µm $= \frac{500\times 80}{73.48} = 544.37\mu m - P_t$

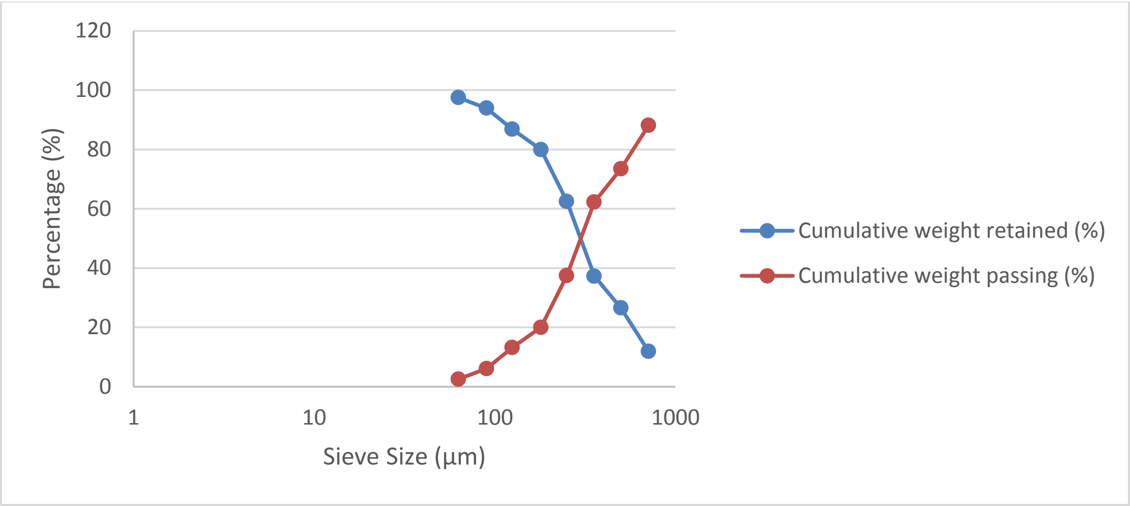

Figure 4: Logarithmic graph of sample B product from ball mill

Then, the work index,

$$W_r = 14.39\left[\frac{\frac{10}{\sqrt{719.99}}-\frac{10}{\sqrt{1263.54}}}{\frac{10}{\sqrt{544.37}}-\frac{10}{\sqrt{713.84}}}\right] = 2.4 \text{ kwh/t}$$

The specific gravity of the ore is 7.7 which is higher than similar ores found in literature (Yaro, 2020)

Sieve Analysis

The assessment of ore size is key in the determination of liberation through communition (Ismail 2016). The commuted ore was passed through different sieve sizes and the percentage undersize and oversize is presented in the table 5 and figure 5 below.

Table 5: Screen Size Analysis

Sieve Size (µm)	425	300	150	75	-75
Cumulative undersize	85.65	85.76	85.95	86.05	99.71
Cumulative oversize	14.35	14.24	14.05	13.95	0.29

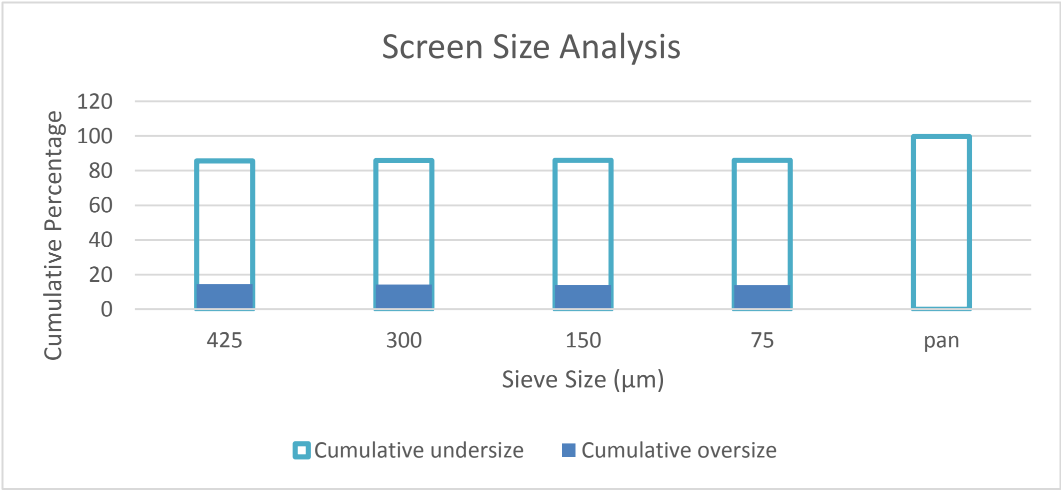

Figure 5: Graph of Cumulative Percentage plotted against Sieve Size

SCAN ELECTRON MICROSCOPY (SEM)

The SEM analysis was investigated at NSRMEA, using the Phenom Pro X Model machine, the figure 6 shows the SEM result which reveal, the dark zone as the manganese rich and low iron zone, while the white granular zone reveals richness in iron and the gray area shows the presence of silicon and aluminum as depicted by the EDX, in table 6, showing aluminum, silicon, iron and manganese as the major constituent of the ore.

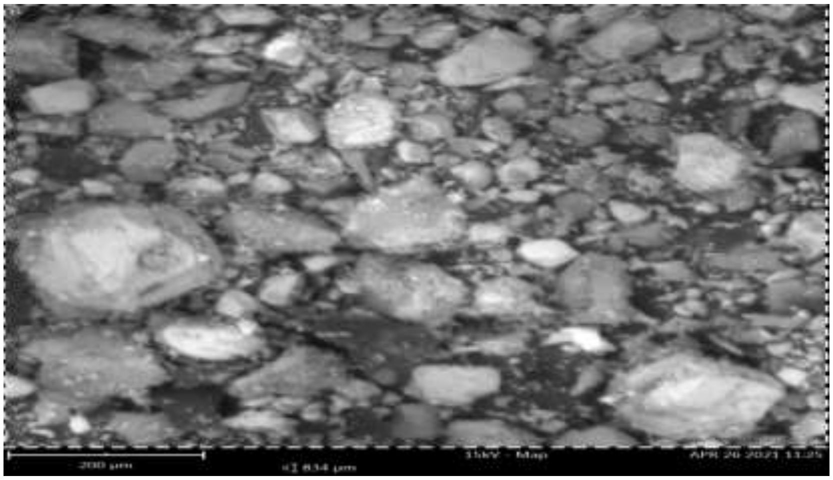

Figure 6: Scan Electron Microscopic view of Niger State Manganese ore

FOV: 834 µm, Mode: 15kV - Map, Detector: BSD Full, Time: APR 26 2021 11:25

Table 6: EDX Elemental Assay

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
25	Mn	Manganese	31.85	38.91
26	Fe	Iron	23.92	29.71
14	Si	Silicon	21.19	13.23
13	Al	Aluminium	13.20	7.92
20	Ca	Calcium	2.02	1.80
47	Ag	Silver	0.69	1.65
22	Ti	Titanium	1.42	1.52
19	K	Potassium	1.23	1.07
41	Nb	Niobium	0.38	0.78
16	S	Sulfur	0.94	0.67
23	V	Vanadium	0.48	0.55
17	Cl	Chlorine	0.69	0.55
15	P	Phosphorus	0.73	0.50
39	Y	Yttrium	0.22	0.43
24	Cr	Chromium	0.29	0.34
11	Na	Sodium	0.42	0.22
12	Mg	Magnesium	0.34	0.18

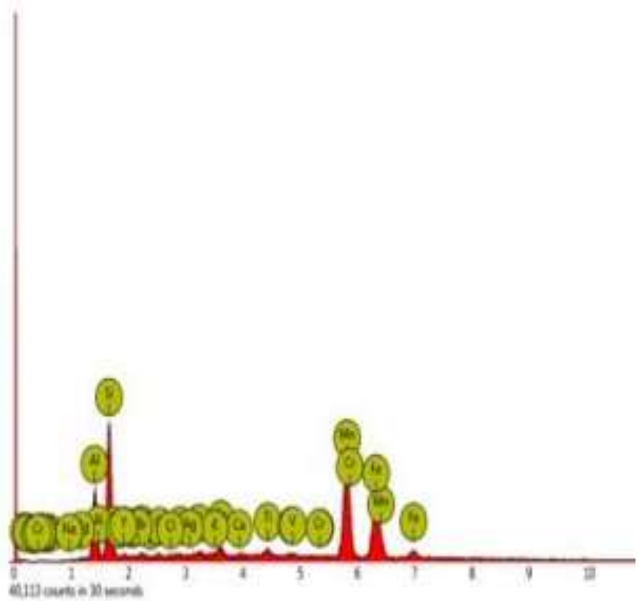

Figure 7: EDX Analysis Spectrum

X-ray Fluorescence (XRF) Spectroscopy

Five different mesh size were subjected to XRF analysis and the result is presented in the table 7, the label B1, B2, B3, B4, B5 represent respectively the mesh sizes 75 µm, 150 µm, 300 µm, 425 µm and -75 µm. The heavy presence of Al, Si and other element like Ca, Ba although in trace amount poses complexity in recovering the Manganese Mineral (Ali, 2019).

Table 7: Sample B XRF result showing constituent elements

Sample	Al_2O_3 (%)	SiO_2 (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	TiO_2 (%)	MnO (%)	Fe_2O_3 (%)	Na_2O (%)	Sb_2O_5 (%)	BaO (%)
B1	23.5664	32.0687	0.1417	0.3592	3.8520	0.0000	35.8720	3.2149	0.0233	0.0043	0.8974
B2	22.9529	33.8407	0.1474	0.4469	3.8302	0.0000	35.0250	2.7300	0.0302	0.0069	0.9896
B3	23.2066	35.1130	0.1646	0.4705	3.3825	0.0000	33.1231	3.7087	0.0260	0.0209	0.7842
B4	23.2066	35.2130	0.1646	0.4705	3.3825	0.0000	33.0231	3.7087	0.0260	0.0209	0.7842
B5	26.3653	28.8374	0.1737	0.5060	4.7179	0.1580	34.8338	3.6079	0.0344	0.0264	0.7393

X-ray Diffraction (XRD) Spectroscopy

The XRD result as shown in the figure 8 and 9 indicates spessartite ($Mn_3Al_2(SiO_4)_3$) as the predominant manganese ore which is similar to that to that at Wasugu (Yaro, 2020) and is associated with quarts, ilmenite, Albite and Chlorite as gangue. This corresponds with the EDX analysis.

Phase name	Formula	Figure of merit	Phase reg. detail	Space Group	DB Card Number
Ilmenite	Fe1.04 Ti0.96 O3	3.294	Import(PDF-4 Minerals 2020...	148 : R-3H	01-073-1255
Spessartine, syn	Mn3 Al2 (Si O4)3	2.859	Import(PDF-4 Minerals 2020...	230 : Ia-3d	01-078-2943
Albite	Na Al Si3 O8	2.994	Import(PDF-4 Minerals 2020...	2 : C-1	00-001-0739
Chlorite (NR)	Al - Fe - Si O2 - O	2.850	Import(PDF-4 Minerals 2020...		00-002-0023
Quartz	Si O2	0.856	S/M(PDF-4 Minerals 2020 R...	154 : P3221	01-075-8320

Figure 8: Table showing XRD mineralogical identification

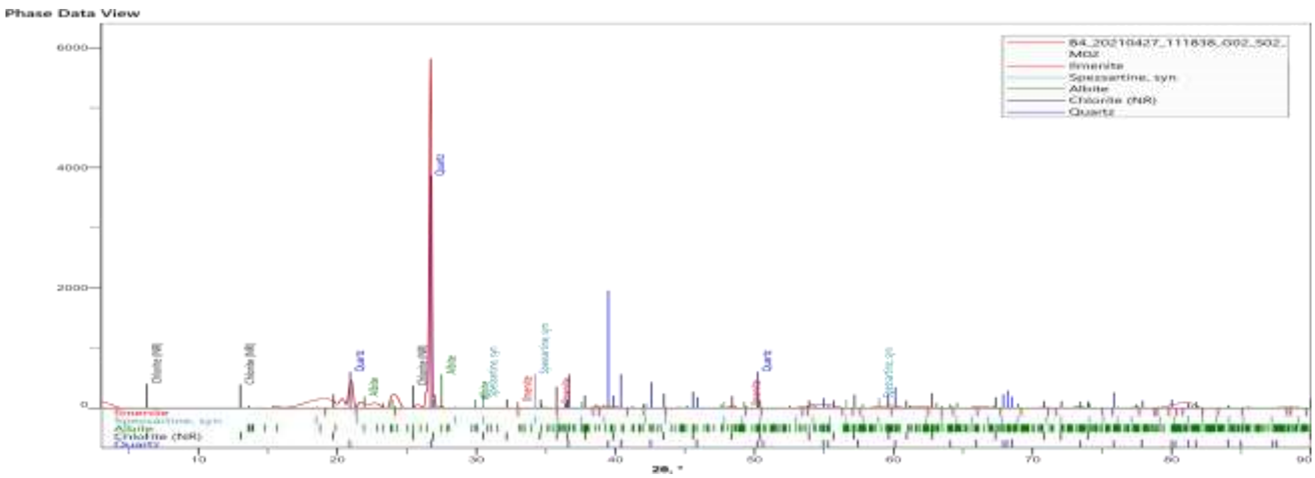

Figure 9: XRD Peak matching of Manganese Ore

Liberation Analysis

The liberation analysis was ascertained using the formula;

$$Degree\ of\ Liberation = \frac{Total\ number\ of\ Free\ Particle}{Total\ Number\ of\ Free\ Particles + Locked\ Particles} \times 100$$

The liberation of the manganese ore were calculated and presented in figure 10, the liberation of the ore would be attained when the ore is ground to 75µm, above this size, liberation would not be maximized. This shows Niger State manganese as a potential deposit, which when upgraded would serve as a resource site.

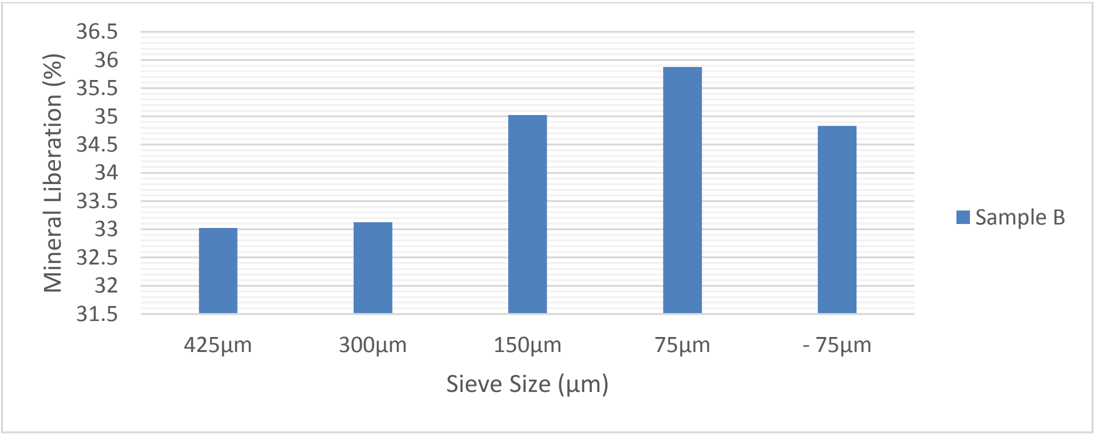

Figure 10: Degree of Liberation of Niger State Manganese ore

MATLAB MODEL

The model of the measure of liberation of manganese was measured for the ore sample using statistical approach to produce a plot of the degree of liberation using the quantitative analysis, the percentage of manganese per sieve was obtained. The formula used for this was:

Degree of liberation using Quantitative analysis $Y = \frac{(\sum T_i - \sum G_i) \times 1oo}{\sum T_i}$ (4)

Where $\sum T_i$= Sum total of the constituent of the mineral ore, $\sum G_i$= the sum total of the gangue, Y= Degree of liberation, i= Test sieve size.

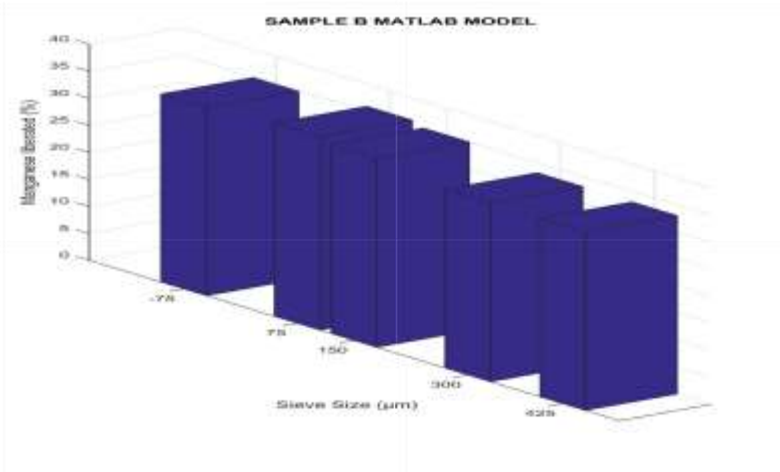

Figure 11: Result from MATLAB simulation for Manganese sample

CONCLUSION

The work index of the manganese ore was calculated to be 2.4 kwh/t. the chemical and mineralogical characterization was investigated and the chemical analysis revealed that the ore contains 34.38% manganese on the average, while the mineralogical characterization revealed that the ore is chiefly spessartine and quarts, ilmenite, Albite and Chlorite are gangues. The liberation was better achieved when the ore was ground to the 75µm sieve size. The characterization also shows the need for beneficiation in the extraction of manganese from its tailing.

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EVALUATION OF THE PROPERTIES OF GADABIU AND KWALI NATURAL SAND DEPOSITS FOR FOUNDRY APPLICATIONS

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Abstract
Sand deposits of Kwali and its environs have been widely used for pottery works. There is need to investigate the suitability of Kwali sands for Foundry applications. Therefore, this study investigated the foundry properties of Kwali natural sand deposits from two selected areas, Gadabiu (sample A) and Kwali town (sample B). The sand samples were mixed by varying the moisture content: Sample A (8-10 %); Sample B (2-6 %). Properties of the sand samples were tested in accordance with American Foundry Society standard guidelines. In addition, sand samples from the two areas were used to prepare moulds for casting aluminium. Moisture content of these sand moulds influenced the properties evaluated. The grain fineness numbers and clay contents obtained from the analyses of sample A (fine particles) were 73.49 and 55.6%, and sample B (coarse-grained) were 87.78 and 35.7 %, respectively. Results of the properties investigated for sample A at 9 % moisture content include green compression strength (127.55 kN/m^2), green shear strength (48.26 kN/m^2) and permeability of 4.9, while sample B at 4% moisture content were green compression strength (84.81 kN/m^2), green shear strength (58.61 kN/m^2) and permeability of 6.0, which agree with the standards. Better aluminium casting was achieved from sample B at 4% moisture-mould compared to that of 6% moisture-mould. Sample A was suitable as facing sand because of its grains roundness and high fineness, although high plasticity prevented it from forming moulds. Therefore, Kwali sands can be used for foundry applications.

Keyword: Aluminium alloys, moulding sand, casting, foundry properties, Kwali natural sand

1.0 INTRODUCTION

Kwali natural sands have been employed variously for pottery works, bricks making, landfilling and farming but has not been characterized for foundry application, even though the deposits are close to centres of artisanal works and large metal ore deposits. The deposits are of sedimentary origin (Osemenam, *et al.*, 2018). The selected areas of study: Gadabiu (for Sample A) and Kwali town (for Sample B), flushed by tributaries of Rivers Niger and Benue, and situated in the Patti formation that is noted for clay, are both in Kwali Area Council of Nigeria's Federal Capital.

Sands are classified as synthetic or natural (Montgomery, 2011) composing about 90% SiO_2, which impacts high thermal stability, refractoriness and chemical resistivity while undergoing polymorphism. Hence, apart from being abundant, silica sand has amenable qualities for foundry applications. But presence of high clay and moisture contents makes natural sands poor for foundry works (Asuquo, 2015). Oblivious of the challenges, many founders use them. Shuaib-Babata, *et al.*, (2017) argued that because of availability they hardly resort to suitability. However, to consistently produce better results, necessary specifications (Table 1) for moulding (AFS, 2009), which many natural sands lack, should be met. The parameters that decide suitability and improved performance are size, shape of the sand grains, content and nature of the clay, moisture, additives, efficiency of moulding and mulling (Ihom, *et al.*, 2011; Olaiya, *et al.*, 2019; Shauib-Babata, *et al.*, 2017; Acharya, *et al.*, 2017; Edoziuno, *et al.*, 2017; Kandpal, *et al.*, 2021). Oakland (2003) asserted that performance reliability of any raw material that gives it acceptance depends on its ability to function satisfactorily over time. Unfortunately, obtaining quality sands or the synthetic types is very costly. Guma & Ogboi (2019) suggested that making quality materials with the available was down to proper research aimed at minimizing defects by optimizing control variables. Hence, the application of water to control all properties. Although, this appears narrow, Ihom, *et al.* (2011) stressed that if mulling of sand was critical in deciding the behaviour of sand moulds, then controlling water addition influences the whole process, and determines their properties.

Characterized sands provide the founder latitudes for variability. It is imperative, due to the economic advantages of sand casting, to supply foundry with suitable raw materials. Thus, the objectives are to evaluate Kwali sands and apply their moulds to casting for quality assessment.

Table 1: Satisfactory Sand Mould Properties for Castings

Metal	Clay	Moisture	Green Comp.	Dry Comp.	Permeability
Heavy Steel	10-12	4-5	70-85	1000-2000	130-300
Light Steel	7-12	6-8	70-85	400-1000	125-200
Heavy Grey Steel	10-19	6-8	70-105	50-800	70-120
Aluminium	8-10	6.5-8.5	50-70	200-550	10-30
Brass/Bronze	10-15	5-7.5	55-85	200-800	15-40
Light Grey Iron	8-13	4-6	50-85	200-550	20-50
Malleable Iron	8-14	5-7	45-55	210-550	20-60
Medium Grey	11-15	5-8	70-105	350-800	40-50

Source: Shuaib-Babata, *et al.* (2017); AFS (2009).

2.0 Materials and Methods

Materials and Equipment

Sand samples were collected from Gadabiu clay site (sample A) and Kwali town (sample B). Material for casting was Aluminium scraps. The main equipment for testing, casting and inspection were a set of sieves with aperture sizes of 1.400 to 0.063 mm, sieve shaker, digital balance, moisture teller, wash bottles, laboratory muller, permeability tester, oven, universal strength testing machine (USTM), mould boxes, rammer, charcoal-fired pit furnace, crucible ladle, magnifying glass.

Methods

Procedures of sand testing and analyses were carried out in the laboratory of the National Metallurgical Development Centre, Jos according to standard specifications (AFS, 2009).

Physical Examination

Morphology of samples, including shapes, sizes, colours, and nature, was observed and recorded.

Sieve Analyses

Sample A and sample B, each weighing 100 g, were put into the sieve set from the topmost sieve of 1.400 mm aperture (Plate I), shaken for 15 minutes to screen them onto different sieves to the 0.063 mm aperture and pan. Grain fineness numbers were deduced from their respective results.

Plate I: Sieves arrangement on sieves shaker

Determination of clay contents

Dried 50 g weight each of samples A and B were put into wash bottles containing a solution of 475 ml distilled water and 25 ml of 3% sodium hydroxide. Each mixture was washed for 5 minutes by means of Rapid Stirrer (60 rev/min) to separate their clayey matters. The clay suspension formed, after 10 minutes, was decanted off each wash bottle. At 5 minutes' interval, the procedure was repeated until water was clear. The remnant was dried at 300°C, weighed and average clay content of each determined by taking half the difference of initial and final weights.

Preparation of Standard specimens

With clean water (8, 9 and 10 vol. % each) three homogeneous mixtures of sample A (2 kg each) were made with muller (Ridsdale model: SM 845). Specimens, of dimension 50 mm × Ø 50 mm, were made and stripped after ramming each rammed with a 6.40 kg compaction blow 3 times from a 50 mm height. The procedure was done for sample B (2, 4 and 6 vol. % of water each).

Green compression strength test

Three sample A specimens of mass 920, 910 and 900 g were each mounted on compression head accessories of the universal strength testing machine (USTM) (Ridsdale model: M8415), and compressed. At rupture, results were read off the USTM lever and recorded. The procedure was done for all specimens of sample B weighing 980, 960 and 940 g respectively.

Dry compression strength test

Three specimens of sample A were oven-dried (Gallenkamp model: GL 026) at 160°C for 30 minutes, cooled at room temperature, and mounted on the compression head accessory of the USTM. Compression strength at rupture point, upon axial load application was recorded. Same procedure was carried out for all sample B specimens.

Green shear strength test

Sample A specimens were mounted on the shear head accessory of the USTM (Ridsdale model: M8415). Uniform applied load ruptured the specimens. The shear strength was recorded. Same procedure was carried out for all sample B specimens.

Dry shear strength test

Three sample A specimens were oven-dried at 160 °C for 30 minutes, cooled at room temperature before mounting on shear head accessory of the USTM. After rupture, the dry shear strength was recorded. Same procedure was done for sample B specimens.

Permeability test

Standard specimens of sample A were mounted on permeability tester (Ridsdale model: PE 872) and a standard pressure of 9.8×10^2 N/m^2 applied. Rate of flow of air was 2000 cm^3 for 270 seconds through a small orifice air nozzle since the grain size of both samples is in the medium to fine particle range (Nakayama Co., 2012). The permeability number was recorded. The same procedures were carried out for all sample B specimens.

Sand casting

None of the three sample A mixtures formed moulds due to high plasticity. Similarly, three 40 kg of sample B were each mixed with 2, 4 and 6 vol. % of water in the ratio of 9.8:0.2, 9.6:0.4 and 9.4:0.6 according to ASTM D7765-18a to cast 5 kg of aluminium scraps. The scraps were melted in a charcoal-fired pit furnace at 700°C. Resultant castings were knocked out after solidification.

Plate II: Mould cavity and the Gating System

Visual Inspection

The castings were inspected with physical eyes aided by a magnifying glass (Kaushish, 2013).

3.0 Results and Discussion

Grain Distribution and Grain Fineness Number (GFN)

Sample A is a round-shaped, reddish clay-laden fine particle, while sample B is an angular-grained, coarse grey sand. Results indicated that with 31.33% fines and 68.67% coarse particles, the grains distribution of sample B could impact good permeability and strengths as voids are formed. Asuquo, 2015; Acharya *et al*. 2017; Ihom *et al.*, 2011; Shuaib-Babata *et al.*, 2017 posited that both fine, medium and coarse grains were required to make good moulds, such that portions of the voids are filled during compaction to aid permeability of the mould. Sample A has a high percentage of finer grains. Table 3.1 showed from percent Passing Finer that sample A was in the 0.50-0.355 mm range, while sample B (Table 3.2) was in 1.40-1.00 mm range. Their GFNs of 73.49 and 87.78 respectively met standard ranges of 35-90, which Acharya *et al*. (2017) stated was critical; they improve strengths and impact quality to castings (Plate III). Sample B grains were evenly distributed unlike those of sample A. Thus, sample B met moulding sand selection criteria (Ihom *et al.*, 2011; Kandpal *et al.*, 2021).

Controlling moisture distinguished the quality of both samples. Increasing water precipitated coarse grains in the cavity during ramming due to high relative density leading to poor defects in the 6 % moisture-mould of sample B.

Table II: Sieve Analysis/Calculation of Grain Fineness Number of Sample A

ISO Sieve size	Weight (wt) Retained	% Passing	Cum. %	Multiplier	Product
1.400	5.42	100.00	–	12	65.16
1.000	6.04	94.57	5.43	16	96.80
0.710	11.01	88.52	11.48	22	242.66
0.500	18.43	77.49	22.51	30	554.10
0.355	23.10	59.02	40.98	44	1018.60
0.250	14.05	35.87	64.13	60	844.80
0.180	4.95	21.79	78.21	85	421.60
0.125	4.32	16.83	83.17	120	519.60
0.090	3.94	12.50	87.50	170	671.50
0.063	0.88	8.55	91.45	240	211.20
Pan	7.66	7.67	92.33	350	2688.00
TOTAL	99.80	-0.01	100.1		7334.02

$$AFS\ GFN = \frac{\Sigma[Product]}{\Sigma[Weight\ (\%)\ Retained]} = \frac{7334.02}{99.8} = 73.49$$

Table III: Sieve Analysis/Calculation of Grain Fineness Number of Sample B

ISO Sieve size (mm)	Weight Ret. (g)	% Passing Finer	Cum. % Ret.	Multiplier	Product
1.400	15.64	100.00	–	12	187.92
1.000	9.88	84.34	15.66	16	158.24
0.710	8.83	74.45	25.55	22	194.48
0.500	9.38	65.61	34.39	30	281.70
0.355	12.65	56.22	43.78	44	557.48
0.250	8.30	43.55	56.45	60	498.60
0.180	8.70	35.24	64.76	85	740.35
0.125	8.93	26.53	73.47	120	1072.80
0.090	5.40	17.59	82.41	170	919.70
0.063	0.97	12.18	87.82	240	232.80
Pan	11.20	11.21	88.79	350	3923.50
TOTAL	99.88	0.00	100.00		8767.57

$$AFS\ GFN = \frac{\Sigma[Product]}{\Sigma[Weight\ (\%)\ Retained]} = \frac{8767.57}{99.88} = 87.78$$

Clay Content

The clay content of samples A and B are 55.6% and 35.7% respectively. Asuquo (2015) confirmed that at more than 50%, sample A is clay. High clay content results to high plasticity and low permeability. The characteristic swelling actions of clay and high moisture absorption, for which spaces for gaseous exchange were blocked will damage any castings made (Kandpal *et al.*, 2021). Thus, sample A could not form moulds. Sample B with 2 % moisture also could not form a mould due to insufficient moisture to initiate binding.

Clay content of sample A

$$Clay\ content = \frac{50.0 - 22.2}{50.0} \times 100 = 55.6\%$$

Clay content of sample B

$$Clay\ content = \frac{50.0 - 32.15}{50.0} \times 100 = 35.7\%$$

Green Compression Strengths

Increasing moisture increased the compression strength of sample A but decreased that of sample B (Tables 3.3 & 3.4). Wide variation in strengths of sample B specimens was affected by the geometric addition of water and the wide mass variation (from 940 to 980 g). The behaviour, nonetheless, followed standard trends (Kaushish, 2013; Shuaib-Babata *et al.*, 2017; Ihom *et al.*, 2011). At its optimum moisture, the green compression strength was 84.81 kN/m^2. High bonding capacity of clay and high degree of ramming influenced the low values in the 6% specimen. Thence, if higher compression strengths are required, 2 % water of sample B could be used.

Dry Compression Strength

Tables 3 and 4 present the effect of moisture on dry compression strengths. Increase in water increased dry compression strengths of sample B by influencing high compaction and cohesiveness. But the values are comparatively smaller than standard results. Sample B with 6% moisture will suit dry moulding, if drying time is increased to thoroughly remove trapped vapour in the mould. High dry compression strengths reduce mould collapse during pouring. Sample A could not break for dry compression beyond 8% moisture content due to high plasticity.

Green Shear Strengths

From Tables 3.3 & 3.4, it could be seen that the green shear strength of sample A decreased as water is increased, and was vague beyond 9%, while that of sample B increased. This is due to high plasticity of sample A. For sample B, moisture activated high bonding with clay such that a greater resistance existed between grains to prevent shear when molten metal was poured (Kaushish, 2013). Green shear strength is needed upon removal of pattern from moulds.

Dry Shear Strengths

Adding water impacted high strengths up to 189.61 kN/m^2 in Sample A and 155.13 kN/m^2 in Sample B, but beyond which, although high, the values depreciated because of the high clay. Thus, both samples can adapt to shapes change upon applied shear forces at elevated temperatures (Asuquo (2015); Kaushish, 2013).

Permeability

From Table 3.3, increasing water decreased the permeability of sample A from 5.7 to 4.0 because interstices blocked by clayey-matter swelled upon water addition, and pushed particles apart while making room for air entrapment (Rundman, 2000). The specimens became saturated having high density but reduced permeability. For sample B (Table 3.4), adding water increased permeability up to 4% before decreasing, following foundry sand standards (Kaushish, 2013).

Table IV: Results of Mechanical Properties of Sample A

Specimen (g)	Water	Green Comp.	Green Shear	Dry Comp.	Dry Shear	Permeability
920	8	112.39	51.71	99.97	142.03	5.7
910	9	127.55	48.26	No Break	189.61	4.9
900	10	N/A	N/A	No Break	120.66	4.0

Table V: Results of Mechanical Properties of Sample B

Specimen (g)	Water	Green Comp.	Green Shear	Dry Comp.	Dry Shear	Permeability
980	2	126.86	34.47	113.76	103.42	5.5
960	4	84.81	58.61	117.21	155.13	6.0
940	6	35.16	103.42	118.59	120.66	5.8

Visual Inspection

Visual inspection showed that the casting made with 4% moisture-mould had surface integrity compared to that of 6% moisture-mould.

(a). Finished Product of 4% Moisture-mould

(b). Finished Product of 6% Moisture-mould

Plate III: The Cast/Finished Products

4.0 Conclusion

Requisite foundry properties of Kwali sands have been evaluated and it can be concluded that:

i. Sample A with round, fine particles and 73.49 GFN was good for facing sand but failed moulding tests. Sample B with angular, coarse grains and 87.78 GFN is good for moulding;

ii. Moulds made from sample B at 4% and 6% water volumes were good (Plate II). 2% moisture-mould was friable. Thus, moisture strongly influenced foundry properties of the sands;

iii. Sample B with 4% moisture content produced casting with good surface finish, compared to that of 6% moisture-mould (saturation point), verifiable by visual inspection (Plate III).

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A REVIEW OF PIPELINE MONITORING DEVICES

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Abstract
Defect detection in transportation pipelines is important for their safe operation and environmental protection. These defects can be in form of cracks, corrosion, or leakages which poses a great risk to human life and the environment due to the hazardous substances being transported. Oil spillage, fire incidents, air pollution, and loss of aquatic life are some of the consequences of delayed detection of defects in pipelines. In order to reduce the possibility of defects and avert the ugly consequences that accompany it, pipeline monitoring devices are utilized. This paper presents a review of pipeline monitoring devices and the principles applied in detecting defects.

Keywords: Oil**,** Pipeline monitoring, Defect detection, Sensor

1.0 INTRODUCTION

Pipelines offer a fast, economic, and safe way of conveying oil and gas products from production wells through processing sites to the consumption points [1,2,3]. They traverse crooked landscapes, mountain ranges, water bodies, or in some cases, are buried underground or underwater at very deep depths over 1 kilometer. Nowadays, pipelines carry varying kinds of substances such as oil, natural gas, crude oil, biofuels, and sewage, in addition to salt and fresh water. There exist over 1.9 million kilometers of transport pipelines around the world which when placed end to end could surpass the circumference of the earth in terms of length about 50 times over [4,5].

Although pipelines are the safest and most reliable means of petroleum product transportation when compared to other modes of transportation, accidents and thefts are possibilities [4]. Accidents result from material and construction defects, maintenance or third-party excavation (TPE), incorrect operation, and creep and cracking mechanisms [6]. In Nigeria, theft occurs in the form of oil pipeline vandalism (bunkering) and militancy. The Amnesty offer of 2009 has helped to reduce the incidences of militancy but oil pipeline vandalism is still increasing due to poverty and illiteracy [7].

According to [8], of the 16,083 cases of pipeline bursts found in the past 10 years, 398 were due to natural rupture which constitutes 2.4% of the total number, while 15,685 cases were as a result of pipeline bunkering activities representing 97.5% of the overall cases. Due to the enormous length and remote nature of pipeline structures, physical inspection has become limited; therefore, improved ways of monitoring these pipelines for cracks and leaks are being sought after in recent times. To effectively detect and localize accidental leaks, there is need for more intelligent detection systems.

2.0 PIPELINE REGULATIONS

Due to the hazardous nature of the petroleum materials being transported by pipelines, many countries of the world have dimmed it necessary to adopt specific official requirements in order to ensure the safety of pipelines [4]. In Nigeria, the construction, operation and maintenance of pipelines is regulated by the Oil Pipelines Act of 1956. Some international requirements as observed in Germany, USA, and Canada are:

1. "Germany - TRFL the Technical Rule for Pipelines" [4]

2. "USA – American Petroleum Institute (API) requirements
   i. API 1130, which handles computational pipeline monitoring for liquids;
   ii. API 1149, which handles unstable uncertainties in pipelines and their effects on leak detection performance;
   iii. The former API 1155, which contains performance criteria for leak detection systems, which has since been replaced by API 1130;
   iv. American Code of Federal Regulations (CFR): 49 CFR 195, which regulates the transport of hazardous liquids via pipelines" [4].

3. "Canada – CSA Z662, regarding oil and gas pipelines" [4].

A good leak detection system must be sensitive, reliable, accurate, and robust [4].

2.0.1 SENSITIVITY

The sensitivity of a Leak Detection System (LDS) is defined as a measure of the minimum detectable discharge or leak rate and the time taken until a leak is detected [4].

2.0.2 RELIABILITY

The reliability of an LDS implies its ability to detect only actual leaks while totally avoiding false alarms [4].

2.0.3 ACCURACY

The main reference here is leaks localization, that is, how exactly the location of leaks is determined. Leak location is represented as a unit of length while accuracy information is indicated in percent of the entire length of the pipeline, or instrumented segment [4].

2.0.4 ROBUSTNESS

The robustness of an LDS is a measure of its operability under less than ideal situations. In the event of a sensor failure for example, the LDS should still be able to detect failures and at least continue to work despite reduction in its sensitivity [4].

Table 1 shows a description of performance criteria according to API 1155 requirements.

Table 1: API 1155 Performance Criteria [4].

Label	Description
Sensitivity	Minimum detectable leak rate; Detection time
Reliability	Avoid false alarms; Reliably detect leaks
Accuracy	Accurate localization of leaks
Robustness	Detect failing sensors; Fall-back strategies in the event of sensor failure

2.1 PIPELINE LEAK DETECTION SYSTEMS

Numerous methods of leak detection, applying different working principles are in existence, such as: inspection by helicopter, smart pigging, tracking dogs, fibre optic cable, acoustic systems, sensor hoses, video monitoring, pressure point analysis [9,10], mass balance method [11], statistical systems, Real Time Transient Model (RTTM) based systems and Extended RTTM (E-RTTM) based systems. [12,13] have classified them based on their technicalities into three categories: continuous and non-continuous methods. Figure 1 shows a summary of the classifications.

Figure 1: Summary of Leak Detection Systems [4]

2.1.1 INSPECTION BY HELICOPTER

In this system, outflowing gas from the pipeline is detected by the helicopter which flies along the pipeline. This is achieved by the use of radars, infrared cameras, or leak sniffers [4].

2.1.1.1 CHARM (CH_4 Airborne Remote Monitoring) system

An Infrared Differential Absorption Lidar (DIAL) technique was used by [14] to develop a CHARM (CH_4 Airborne Remote Monitoring) system for an efficient transmission of natural gas pipelines. Optical Parametric Oscillators (OPOs) were used to generate infrared radiation for methane DIAL; these all-solid-state light sources are usable in airborne systems. Injection seeding technique at the OPO's signal wavelength was used to achieve single longitudinal mode operation. The beam on the ground is scanned by a specially designed rotating tilted-mirror in a way that its tilt angle can be continuously adjusted. A fast infrared photodiode is used to detect the ground returns and the signals are digitized and interfaced with the data logger. Figure 2 shows the assembly attached to the helicopter's fuselage.

Figure 2: CHARM system attached to the Helicopter [14].

2.1.1.2 Unmanned Airborne Vehicle (UAV)

A quadcopter Unmanned Airborne Vehicle (UAV) system was developed by [15] which is a developing extension of the helicopter inspection method. Two Liquefied Petroleum Gas (LPG) sensors were used as the Leak Detection Unit (LDU) in the design while the flight control, tracking, and 3D simulation of the UAV was done by the use of the Multiwii software. The data captured by the LPG sensors were then analyzed using Matrix Laboratory (MATLAB) software. The UAV device is as shown in Figure 3.

Figure 3: Unmanned Aerial Vehicle [15]

Two experiments were conducted by [15]; the first test was used to simulate an oil and gas pipeline without any leakage while the second one simulated a pipeline with three leakage points is the control experiment as shown in figures 4 and 5 respectively.

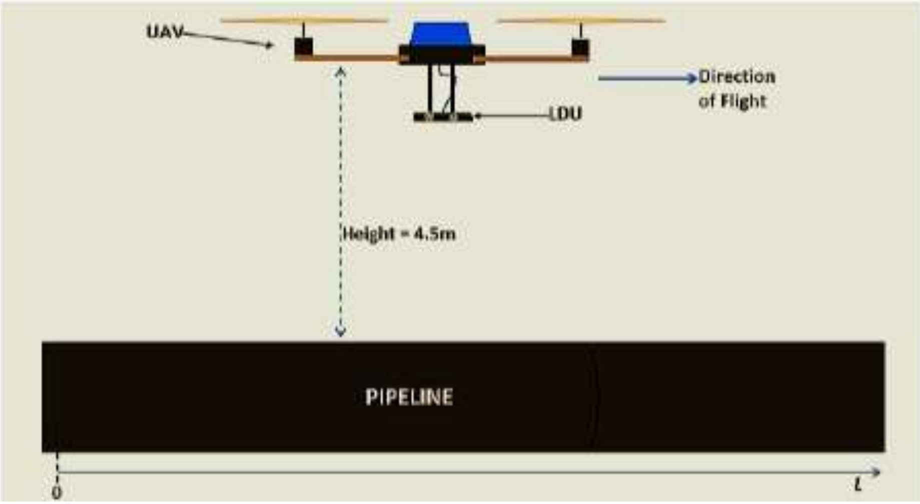

Figure 4: Experiment without Leakage [15]

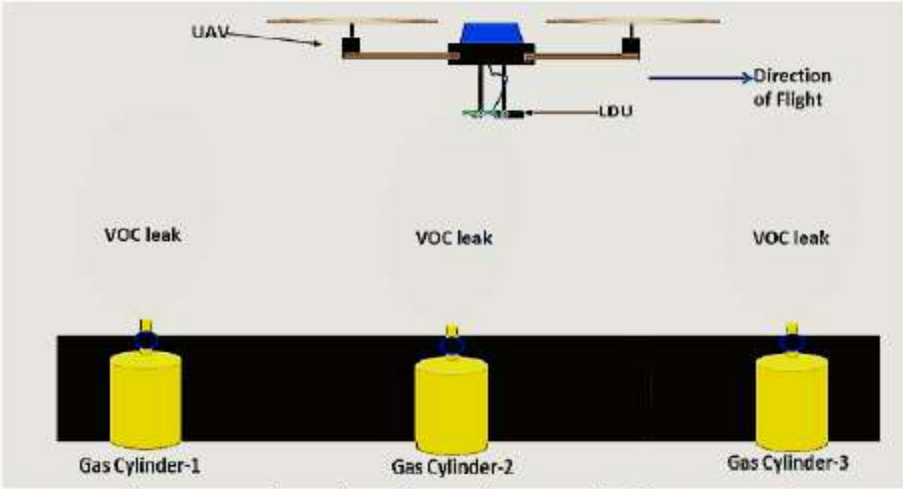

Figure 5: Control Experiment with Three Leakage Points [15]

The Variation of Concentration (VOC) represented as C_g with the length of the pipeline was measured as the device moved along it. Three leaking LPG cylinders were used to depict the leakage points in the control experiment. From the results, the concentration of gas C_g in the pipeline without leakage was relatively constant throughout the length of the pipeline. However, this was likened to the influence of ambient smoke, heat, and volatile gases from other sources. Furthermore, a significant increase in LPG concentration was detected around three points which coincided with the positions of the LPG cylinders in the control experiment as seen in figure 6.

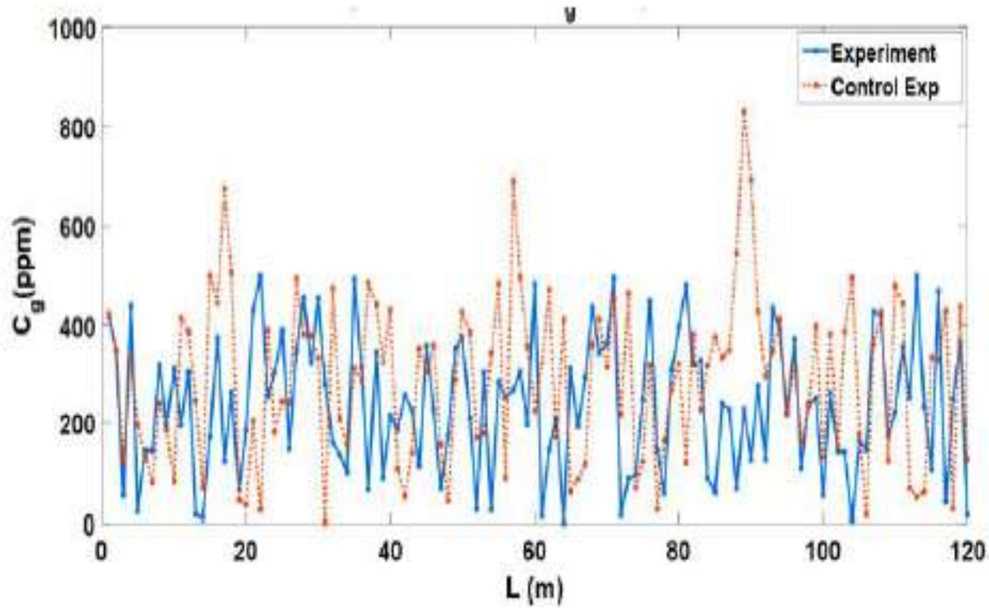

Figure 6: Graph of Cg vs L, the length of the pipeline [15]

2.1.2 SMART PIGGING SYSTEM

Pipeline PIGs (Pipeline Inspection Gauges) are used in pipeline cleaning, and in monitoring pipeline condition. A PIG launcher is used to insert the PIG into the pipeline and is propelled by the medium being transported by the pipeline, useful data about corrosion, cracks, wall thickness and leakage is captured as it moves along the pipeline. A receiver is then used to guide the PIG out of the pipeline and the captured data is analyzed to determine the condition of the pipeline [4]. Two main techniques employed in pigging are: (a) Magnetic Flux Leakage and (b) Ultrasonic Principle.

2.1.2.1 Magnetic Flux Leakage (MFL) Method

In this method, the pipeline is magnetized using a strong permanent magnet and changes in the pipeline wall such as crack and corrosion will change the magnetic flux lines which are captured by magnetic sensors attached to the PIG. The captured signals are then analyzed against reference signals to determine the presence of defects [4]. Figure 6 shows an MFL PIG with a drive section at the front, a magnetizer section at the centre, and a data logging section at the left end.

Figure 7: An MFL PIG [2]

Figure 8 demonstrates the signals felt on a pipe under the application of a magnetic flux, figure 8a shows the pipe without any defect or metal loss while figure 8b shows the pipe with defect (metal loss).

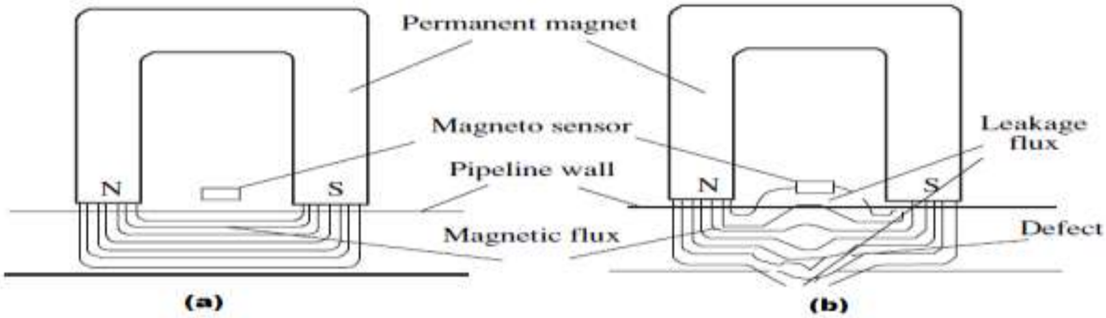

Figure 8: Demonstration of MFL Method [2]

According to [16], in the smart pigging of a pipeline using the MFL method, the orientation of the crack and the direction of the magnetic field lines affect the detectability of the crack defect. It was concluded that for a magnetic field direction parallel to the shape of the defect, the PIG sensor may not detect the anomaly because the magnetic field may not be deflected adequately enough towards the sensor. Figure 9 describes the phenomenon.

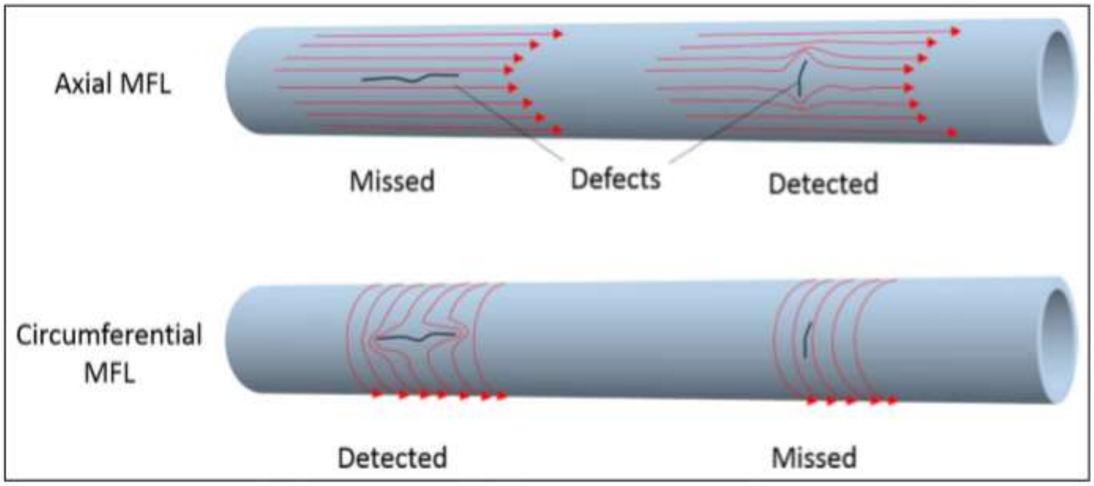

Figure 9: Orientation of Magnetic Field Lines for Proper Detection of Cracks Depending on Crack Orientation. [16]

2.1.3 Ultrasonic Method

A Structural Health Monitoring (SHM) system called iPerm was produced by [17], which uses guided ultrasonic wave technology. IPerm was designed to be permanently mounted on the outside of the pipeline; it is equipped with a robust ultrasonic sensor system which uses piezoelectric transducers to generate consistent axisymmetric Ultrasonic Guided Waves (UGW). The sensor system excites UGW at low frequencies below 200 KHz, these UGW provide complete cross-sectional area coverage of the pipeline as they transmit along the pipeline. Internal and external corrosion defects can be detected and located from information collected by an attached portable data collection device. The hardware components of the iPerm system are shown in Figure 9.

Figure 9: iPerm System Hardware Components [17]

3.0 CONCLUSION

Pipeline defect monitoring and localization is a rigorous testing and validation process. Performance of environmental assessment is necessary to determine whether environmental conditions such as air, water, land, and energy can affect the functionality of the device before its application. From the review, the detectability of defects in pipelines using MFL devices is dependent on the orientation of the defect and the direction of the magnetic field lines.

FUTURE WORK

This review is a preliminary study of the different monitoring devices and systems currently used in the industries. The next stage is to develop a portable low cost device for pipeline structure monitoring using a combination of ultrasonic and magnetic sensors.

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COMPARATIVE ANALYSIS OF KWARA NORTH SILICA SANDS FOR MOULDING IN FOUNDRY WORK

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Abstract
Previous studies have established that the quality of silica sand is one of the important variables that determine the soundness of mould for metal casting. This study focused on analysis of Bacita and Tsonga silica sands, located in Kwara North area of Kwara state, Nigeria, in order to determine the suitability of these sands for casting purposes. Thus, important properties of silica sand that are required during casting processes such as green compressive strength, green shear strength, permeability, clay content and moisture content were determined. The results showed that the silica sands at Bacita and Tsonga are relatively fine and can be used for zinc casting, or any non-ferrous metals. It can also be employed for small and medium light weight iron castings.

Keywords: Foundry, Silica Sand, Casting and Metal

INTRODUCTION

According to Bcira, (1985), for a quality production to be ascertained in a foundry, all aspects of green sand mould technology, from the basic raw materials, their properties and control, as well as the principles involved must be adequately understood. The success of any green sand system depends to a large extent on the continual re-use of the moulding sand and the necessity to maintain its properties, together with information on the normal and special tests which may be necessary. The need for sand cooling and the means for carrying it out should be adequately reviewed, as the methods for mould handling on mechanized plants, the requirements for sand storage and for the handling and removal of cast mould prior to re-circulation.

All materials used for the manufacturing of sand mould and cores are termed mould materials (Mikhailov, 1989). Sand is the principal basic moulding materials used by the foundry-man, whether it is for iron, steel, non-ferrous or light-alloy castings. The study of foundry sand constitutes one of the main sections of foundry technology and sand testing has becomes an essential part of the day-to-day control of foundry operation. In the early years of last century, foundry work and preparation of moulding core sands mixtures were still a craftsman's art. Particular sand was used because of custom or renew for a certain class of work. The experienced moulder, often a highly skill craftsman, could produce results with his limited equipment and favourably compares to those of the best modern sand plant based on his long experience and rule of thumb methods. His sand mixes were a closely guarded secret and endless varieties of such mixes were in use.

Moulding sand can be defined as raw material used in the making of mould which contain a bonding material usually in the form of clay and occasionally with a small proportion of an organic compound, the whole being suitable moistened with water for moulding purposes. Though, there are many known deposits of silica sand, clay and the availability of additive in the country, the determination of foundry properties of these materials when used as a foundry sand has not been methodically carried out, also the composition of the sand mixture that gives the optimum water content cannot be evaluated. These have become important in order to establish the best properties that can be derived from a particular sand deposit in the country in order to eliminate most casting defects.

The need for systematic evaluation of working properties of qualities of moulding materials under foundry condition has led to the development of a wide range of tests. Some of these tests are concerned with basic chemical and physical characteristics but the majorities are designed to measure bulk properties. The bulk properties of an aggregate are sensitive to small variation in mixing condition and specimen preparation so that rigid standardization in needed at all stages. The reproduceability of tests has been shown to be optimal permeability and least in dry strength determination (Morey and Ackerlind, 1947). The properties of the sand will vary according to the type of work being carried out, for example, for light or heavy casting, plain carbon or high-alloyed steel used in a mechanized or jobbing foundry.

MATERIALS AND METHOD

The silica sands used for this work were obtained from the vast deposits at Bacita and Tsonga, in Kwara State. The silica sands were washed, scrubbed and sieved through an Endecott sieve to remove exceptionally coarse or fine material and dried under the Sun for 5 days. All calcaceous matters such as crab shells and snail shells were removed.

Preparation of the standard test specimens

The AFS cylindrical test specimens was prepared using the metric standard rammer. The AFS cylindrical test piece of 50.8mm diameter x 2mm is made by dropping 6.356kg weight three times through a height 50.8mm onto the measured quantity of sand. 150g of the prepared sand was weighed and placed in a 127mm height special tube with an internal diameter of 50.8mm, the base of which had been sealed by a suitable metal cup. The weight on the rammer was raised by means of the handle provided on the side of the equipment. The specimen tube and the cup were then placed under the ramming head with the centralizing peg on the metal plug located in the hole of the base plate. The rammer head and weight were then lowered until they were supported by the sand in the container.

Rotating handle attached to the apparatus was allowed to fall freely through a 50.8mm height determined by the cam on the equipment which raised the rammer weight. This operation was repeated twice to ram three times for the silica sands. The specimen was removed from the rammer by raising the weight.

METHOD

Green compressive and green shear strength

The compressive strength was performed on the universal sand strength tester, which first requires shaping the sample in the AFS standard tube. The AFS cylindrical test specimen was stripped from the tube on a suitable striping post. The prepared stripped specimens were carefully set on the universal sand tester. A manually operated rotating device applied to the load to move the components were then operated and the components were moved along the semi-circular graduated scale until they fractured. A small moving magnet placed on the accessory indicated the reading.

The green shear strength was similarly determined by placing the necessary accessories for the shear strength.

Permeability

The permeability was determined while the rammed samples were still retained in the ramming tube by simply inverting the tube and fixing the open end over an orifice in a large permeability meter. These were made air tighten and then released. The permeability values were then read directly through the pointer.

Moisture content

The hot air methods were employed to determine the moisture content. The apparatus was switch on and allow to heat up for some minutes. 150g of the prepared sands were measured and they were placed in the pan provided at the base of the instrument. The thermostat on the equipment was set to 110°C and the drier was set in operation by means of a timer switch. The dried samples of the sands were then allowed to cool and they were reweighed. So the moisture contents of the sands were then determined.

Sieve analysis

The size and distribution of the sand grains were determined with sieve analysis test. A dried 150 grammes of the silica sands were measured on a weighing balance. The weight sand was then placed on top of a series of sieve that ranges from l400µm to 45µm or rather a set of sieves of decreasing aperture size contained on a shaker.

The shaker was switched on for a period of 15 minutes. Then the sands retained in each sieve and the bottom pan were weighed and recorded against the sieve aperture size and their percentages as a measure of the total samples were determined.

Clay content

750ml of distilled water containing 5ml of ammonia was boiled gently in an evaporating basin of 254mm diameter. 50g samples of silica sands, which was previously dried, was weighed and added to the boiling water, and then allowed to boil for a period of 10 minutes. The sand and water mixture were allowed to cool and then transferred to a straight-sided glass cylinder. The cylinder has a mark suitably inscribed which was 152.4mm above the inside base of the cylinder. Extra water was added to the cylinder to adjust the level to this 152.4mm mark. The sand and water mixture were stirred with a metal rod and then allowed to settle for a period of 10 minutes. The water was siphoned off and the cylinder was then refilled to the 152.4mm mark and it was stirred again and was allowed to settle for 10 minutes. The procedure was repeated until 5 minutes settling period gives perfectly clear water in the upper 127mm. After siphoning, the remaining sand water was returned to the original evaporating dish and allowed to settle for 2 minutes before excess water was poured away carefully without losing any granular particles. The residues were then dried to constant weight at temperature of 100°C - 105°C. The loss in weight of the sample was determined by re-weighing and expressed as a percentage of the original weight of the samples.

RESULTS AND DISCUSSION

DATA AND RESULTS

The results obtained during the sands test were recorded and were as subsequently presented in the tables 4.1 and 4.2 which represents the result of the sieve analysis while tables 4.3, 4.4, 4.5, 4.6, 4.7 and 4.8 reveals the effect of varying additive with constant volume of water on the green compressive strength, green shear strength and moisture content.

Table 4.1: Sieve Analysis of Bacita silica sand

S/N	Mech (₦)	Sieve diameter (micron)	Wt of sieve pan (g)	Wt of pan and retained sand (g)	Wt of retained sand (g)	% wt of retained sand (g)	Product (g) [% Wt of retained sand x sieve No]	Cumulative (g)
1	12	1400	312.881	313.028	0.1470	0.047	-	-
2	16	1000	299.931	300.015	0.0840	0.028	0.336	0.075
3	22	710	287.070	287.443	0.3730	0.130	2.080	0.205
4	30	500	259.858	266.046	6.1880	2.381	52.382	2.586
5	44	355	241.321	259.083	17.7620	7.360	220.800	9.946
6	60	250	233.595	253.175	19.5800	8.382	368.808	18.328
7	85	180	225.282	249.970	24.6880	10.959	657.540	29.287
8	120	125	213.470	241.188	27.7180	12.984	1103.640	42.271
9	170	90	211.693	220.355	8.6620	4.092	491.040	46.363
10	240	63	208.904	211.446	2.5420	1.217	206.890	47.580
11	350	45	210.610	211.353	0.7430	0.353	84.720	47.933
12	350	-	196.147	196.653	0.5061	0.258	90.300	48.191
						48.191	**3278.536**	

$$AFS = \frac{Total\ \ product}{Total\ retained\ sand\ (\%)}$$

$$AFS = \frac{3278.536}{48.191} = 68.032$$

$\therefore$ AFS grain fineness number is 68.03

Table 4.2: Sieve Analysis of Tsonga silica sand

S/N	Mech (₦)	Sieve diameter (micron)	Wt of sieve pan (g)	Wt of pan and retained sand (g)	Wt of retained sand (g)	% wt of retained sand (g)	Product (g) [% Wt of retained sand x sieve No]	Cumulative (g)
1	12	1400	312.881	313.062	0.1810	0.058	-	-
2	16	1000	299.931	300.039	0.1080	0.036	0.432	0.094
3	22	710	287.070	287.463	0.3930	0.137	2.192	0.231
4	30	500	259.858	267.347	7.4890	2.882	63.404	3.113
5	44	355	241.321	259.625	18.3040	7.585	227.550	10.698
6	60	250	233.595	253.182	19.5870	8.385	368.940	19.083
7	85	180	225.282	249.601	24.3190	10.795	647.700	29.878
8	120	125	213.470	240.768	27.2980	12.788	1086.980	42.666
9	170	90	211.693	220.377	8.6840	4.102	492.240	46.768
10	240	63	208.904	211.812	2.9080	1.392	236.640	48.160
11	350	45	210.610	211.370	0.7603	0.361	86.640	48.521
12	350	-	196.147	196.684	0.5374	0.274	95.900	48.795
						48.795	**3308.618**	

$$\text{AFS} = \frac{Total \quad product}{Total \ retained \ sand \ (\%)}$$

$$\text{AFS} = \frac{3308.618}{48.795} = 67.806$$

$\therefore$ AFS grain fineness number is 67.81

Table 4.3: Moulding properties of prepared Bacita moulding sand (8% bentonite, 6% coal dust)

Properties	1st reading	2nd reading	3rd reading	Average
Green compressive strength (KN/M^2)	55.60	55.40	55.50	55.50
Shear strength (KN/M^2)	24.20	24.40	24.20	24.27
Moisture content	3.10	2.90	3.20	3.07

Table 4.4: Moulding properties of prepared Tsonga moulding sand (8% bentonite, 6% coal dust)

Properties	1st reading	2nd reading	3rd reading	Average
Green compressive strength (KN/M^2)	55.30	55.20	55.10	55.20
Shear strength (KN/M^2)	23.70	23.50	23.60	23.60
Moisture content	2.90	2.80	3.00	2.90

Table 4.5: Moulding properties of prepared Bacita moulding sand (8.5% bentonite, 6.5% coal dust)

Properties	1st reading	2nd reading	3rd reading	Average
Green compressive strength (KN/M^2)	74.00	73.50	72.50	73.33
Shear strength (KN/M^2)	25.00	24.50	25.50	25.00
Moisture content	2.80	2.90	2.85	2.85

Table 4.6: Moulding properties of prepared Tsonga moulding sand (8.5% bentonite, 6.5% coal dust)

Properties	1st reading	2nd reading	3rd reading	Average
Green compressive strength (KN/M^2)	73.50	73.00	73.25	73.25
Shear strength (KN/M^2)	24.50	24.00	24.30	24.27
Moisture content	2.75	2.70	2.65	2.70

Table 4.7: Moulding properties of prepared Bacita moulding sand (9% bentonite, 7% coal dust)

Properties	1st reading	2nd reading	3rd reading	Average
Green compressive strength (KN/M^2)	93.00	92.50	93.50	93.00
Shear strength (KN/M^2)	26.50	26.70	26.30	26.50
Moisture content	2.70	2.80	2.60	2.70

Table 4.8: Moulding properties of prepared Tsonga moulding sand (9% bentonite, 7% coal dust)

Properties	1st reading	2nd reading	3rd reading	Average
Green compressive strength (KN/M^2)	92.00	91.80	92.40	92.07
Shear strength (KN/M^2)	25.40	25.80	26.00	25.73
Moisture content	2.65	2.60	2.58	2.61

DISCUSSION OF RESULTS

Green compressive strength

There was general increase in the green compressive strength with increase in the additive to the silica sand as can be seen from the table 4.3 to 4.8. This increase in green compressive strength was due to the combined bonding and hardening effect offered by the added bentonite and coal dust with the passage of time. Coal dust is used in green sand mould for protecting mould surfaces against the action of molten metal and improves the surface finish of the castings. When the molten metal comes in contact with mould surface containing coal dust, a gaseous envelope is formed which resists the fusion of the sand to metal, the use of coal dust increases green strength, green shear strength and dry strength, reduces tendency to scabbing and metal penetration. Bentonite was used with high silica sand as a green sand binder to increase the bonding action and impart plasticity, so it increases both green compressive strength and green shear strength. The addition of water is what generates the bond. Bentonite resists erosion of moulds and its volumetric contraction helps in compensating the expansion of silica grains.

Moisture content

It was observed that the moisture content decreases as the added additives increases. This was an indication that so far the temper water is not increased; the additive will definitely reduce the water content, so the moisture content will be lowered. Moisture content in moulding sands is the major requirement for ensuring ease of moulding, good quality mould and good casting.

Grain size

The washed sand grains range from sub-angular to rounded. It has a well-defined grading with 70 percent and above of the sand grains retained by three adjacent sieves. The AFS reveals that the sand grains are relatively fine.

Surface finish of the casting using Bacita moulding sand

The casting produced by the use of Bacita moulding sand was with fine surface finish with little or no defect. There were little defect of blow holes or gas holes caused due to entrapped air or gas. They were generally rounded cavities spherical, flattened or elongated air or gas. These were generally found inside the casting. This could be remedied by creating more vent holes on mould and allowing melt to settle before pouring.

Surface finish of the casting using Tsonga moulding sand

The casting produced by the use of Tsonga moulding sand was also with fine surface finish with little or no defect. There was observed a little defect of cold shuts caused by non- uniform of metal stream resulting in discontinuity due to imperfect fusion where two streams of metal have converged. This could be remedied by skin-drying of the mould and fsater pouring rate.

Surface finish of the casting using Bacita and Tsonga moulding sands in equal Proportions

The casting produced by the use of the two moulding sands in equal proportion was of good surface finish with little defect of shrinkage cavity or depression also caused by a large or small depression on the casting that results from varying rates of contractions while the metal is changing from liquid to solid. This could be improved upon by providing feeder heads on the casting.

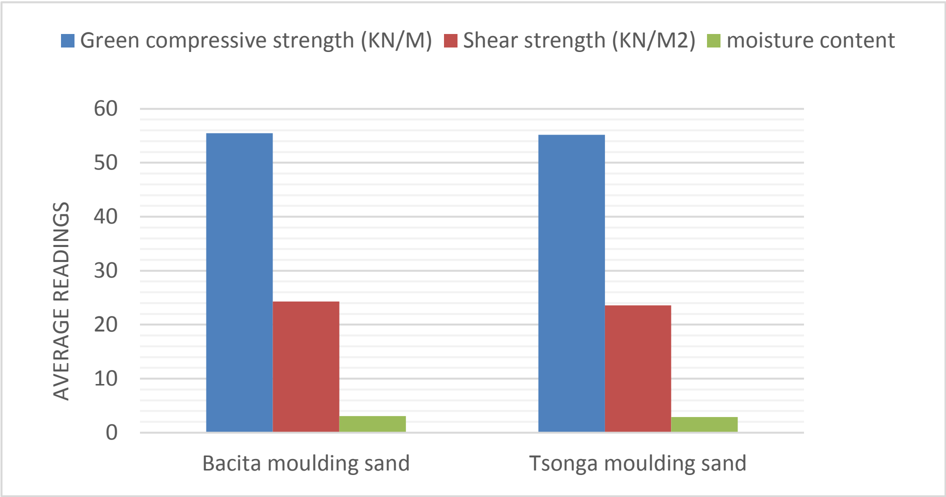

FIG. 1: Moulding properties of prepared Bacita and Tsonga moulding sand (8% bentonite, 6% coal dust)

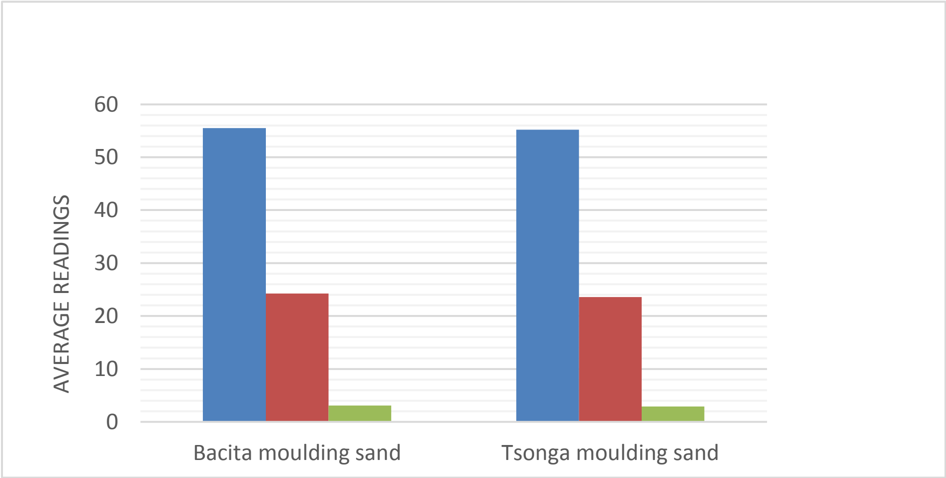

FIG. 2: Moulding properties of prepared bacita and tsonga moulding sand 8.5% bentonite, 6.5% coal dust)

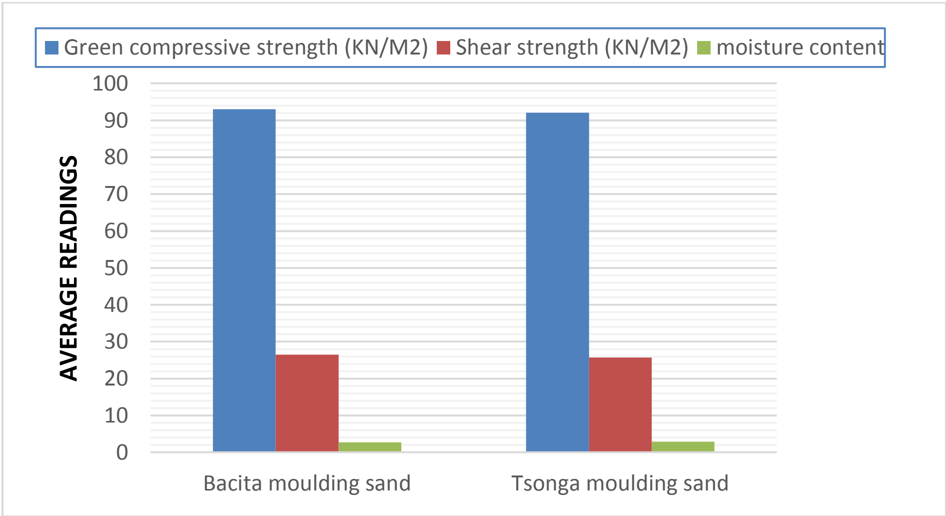

FIG. 3: Moulding Properties of Prepared Bacita and Tsonga Moulding Sands (9% Bentonite, 7% Coal Dust)

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ASSESSMENT AND COMPARISON OF SAFETY AND ENVIRONMENTAL CONTROL LEVEL IN THREE DIFFERENT QUARRIES

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Abstract
The safety of the workers and equipment should be of importance to the operators and the entire community. The study was carried out to investigate the level of safety control in each of the quarries. Three functional quarries were selected. Structured questionnaire was drafted, it asks questions about the profile of the respondents and relevant safety matters, the questionnaires were distributed to the workers in each of the quarries, retrieved and analyzed using SPSS statistics. The result shows that the safety of the activities i.e., drilling, blasting in each of the quarries can be rated 'fair' while the overall safety rating in each of the quarries is also just 'fair'. This is not good for quarries. Useful recommendations were made which are believed to be helpful if implemented.

Keywords: safety, quarry, statistics, fair, activities, control

Introduction

Large scale extraction of mineral resources from the earth's crust is closely associated with deleterious environmental degradation and positive/negative socio-economic implications which have attracted the attention of governments, experts and host communities where they are harnessed worldwide in space and time (Taylor and Kesler, 2008).

In Nigeria, the mining of solid minerals, have negatively affected the morphology of the land surface, soils, vegetation, typology, socio-economy, socio-culture, ethnic composition, agriculture, population and even politics of the nation. The positive impact is mainly on the generation of revenue and foreign exchange, but the negative effects are threatening the sustainability of Nigeria's hitherto qualitative environment (FEPA, 1990).

Mining plays a very crucial role in the development of Nigeria. The sector plays a key role in terms of foreign exchange, gross domestic product (GDP), government revenue, and capital formation. It also serves as a source of employment opportunity for the citizenry.

Besides the direct economic importance of the mining industry to Nigeria, the sector has also been influential in the infrastructural development of the country which formed importance centers of commercial activity and eventually developed into permanent communities with basic infrastructure such as water, communication, health, education, electricity and ultimately local government.

Despite the remarkable contributions that mining has made towards the development of Nigeria and other parts of the world, its history is married by a legacy of negative impacts. Among the negative impacts of mining include the destruction of the natural landscape, pollution of surface and groundwater resources, contamination of soils, erosion and disturbance of ecosystems and displacement of local wildlife, creation of ghost towns, and impingement human health and safety including extreme cases of death of mine workers through accidents at work (Eaton, 1996). Improvements in mining methods (e.g., long wall mining), hazardous gas monitoring (such as safety-lamps or more modern electronic gas monitors), gas drainage, electrical equipment, and ventilation have reduced many of the risks of rock falls, explosions, and unhealthy air quality. Statistical analyses performance by the U.S Department of Labor's Mine Safety and Health Administration (MSHA) show that between 1990 and 2004, the industry cut the rate of injuries by more than half and fatalities by two-thirds. However, according to the Bureau of Labour statistics, mining remains the second most dangerous occupation (Wilson, 2010).

The goal of this study is to assess the state of safety and environmental practices in Ladson Quarry, Ibadan, Abule Quarry, Shao and Complete Construction Company, Ilorin; and make useful comparison.

Methodology.

Description of study Areas.

Ladson quarry is in Akinyele District of Akinyele Local Government in Ibadan. Abule quarry is in Sao of Moro Local Government while Complete Construction Solid Concentrates is located in Ilorin South Local Government, both in Kwara state. Ladson quarry covers about 140 acres of land while the other two quarries cover approximately 60 acres of land each. The resource consists of granite derivative developed within the small granite batholiths of carboniferous age (approximately 350 million years old). Granite practically devoid of dark minerals, comprising principally of quartz, alkali feldspar and mica. The granite nature of the rock extends for considerable depth very close to the ground surface averagely i.e., at least 500m.

Fig. 1 shows the map of Nigeria showing the locations of the quarries studied.

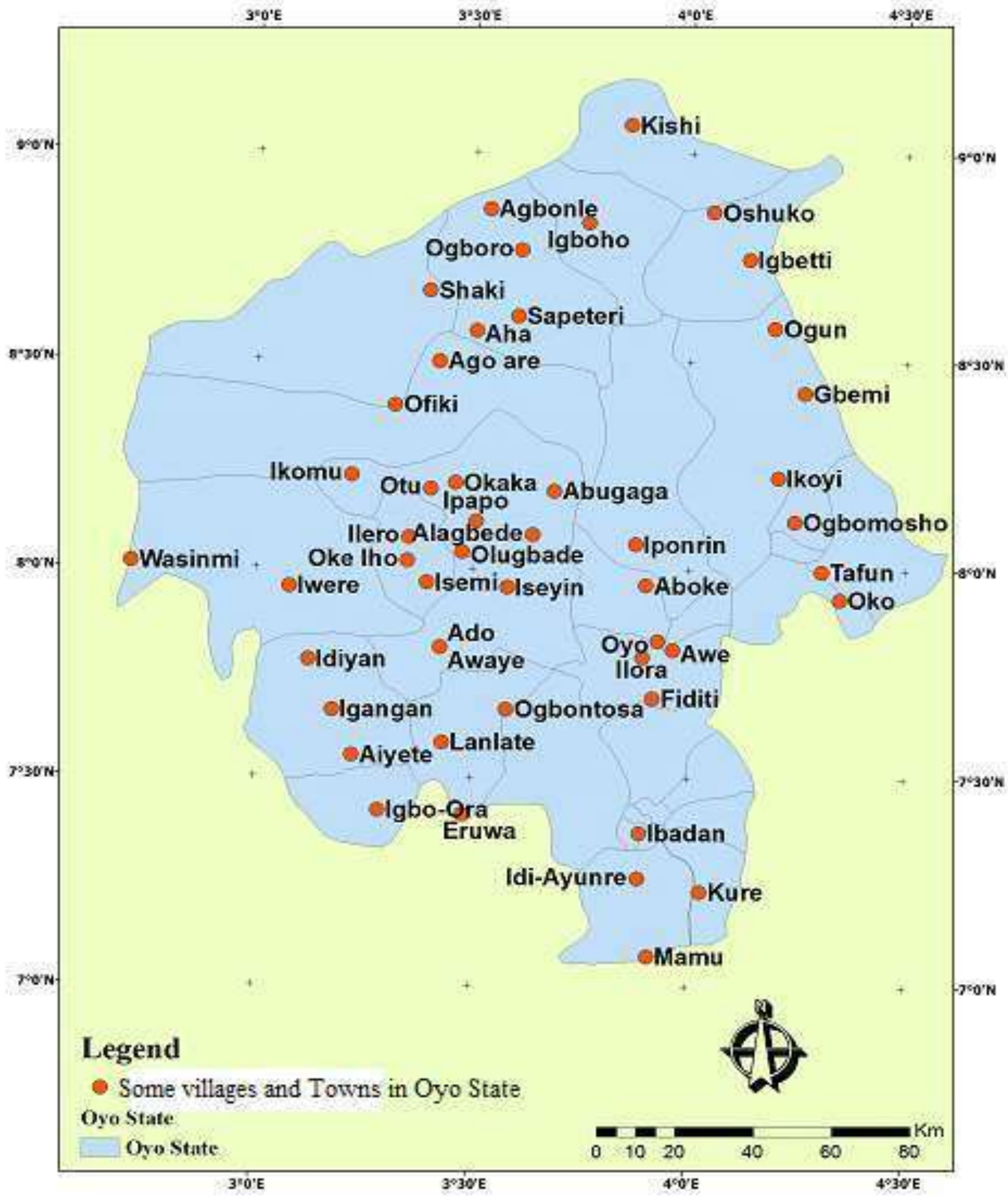

Fig.1: Map of Nigeria showing the locations of the studied quarries.

The landscape of the mining site and prospecting area in general is comprised of low rounded hills and rolling plains, which contrast the jagged peaks of limestone that flank the granite formation of the region. Surface soils on these plains chiefly of low agricultural value sandy loams derived from the weathering of granite to quartz sand, intermittent remnants of which persist as isolated 10 – 20 tonnes of boulders of hard granite strewn across the soil surface showing magniferrous staining from weathering. Together, soils and weathered overburden at the quarry extend from 3 – 5m depth over the hard-fresh granite basement rock.

Data acquisition

This study was conducted over a period of four months between April and July. A questionnaire was designed for the workers in the quarry site. The copies of the questionnaire were administered by the researcher. Out of the workforce of approximately 120 workers employed by the quarry, a total of 50 workers, constituting 41 percent of the workforces were sampled.

Information sought included, level of education, job description, working conditions, department, and years of experience, including workplace health and safety and marital status. The questionnaire was inquired for five sections. These include drilling operations, blasting, and material handling, hauling (transportation) and crushing. The crushing section is further sub-divided into primary crushers, secondary crushers, screening plants and material handling. Responses to the questionnaires and checklist were analyzed using ratings on the questionnaire/checklist. The researcher spent one week with the company to fill his checklist for further confirmation of the result and the results were compared.

Analysis of Questionnaire and Checklist of Safety and Environmental Control in Surface Mines

The questionnaire is rated into four categories: regularly, occasionally, rarely and never.

Table 1: Rating of the questionnaires.

S/No	Category	Rating
1.	Never	0
2.	Rarely	1
3.	Occasionally	2
4.	Regularly	3

There are nine questions asked under drilling operations, blasting section has six questions; material handling has four questions, hauling (transportation) has four questions while crushing section which is sub-divided into primary crushers (having five questions) secondary crushers (having three questions). The result is also computed for each section and its rating according to the interval given was then used to interpret degree of the safety and environmental control which the three quarries had taken so far.

Statistical Package for Social Science (SPSS) 2018 version was used to analyze the results obtained from the questionnaire. This produced the average scores of individual and overall activities in each of the quarries, and their comparisons

Results and Discussion

The results of the study areas are provided in the table below:

Table 2: Scoring description of ratings

Score	Description
3	Good
2.5-2.9	Fair
1.5-2.4	Poor
0-1.4	Dangerous

Table 3: Safety Scores in selected quarries.

	Drilling	Blasting	Material handling	Hauling (Transportation)	Primary Crusher	Secondary Crusher	Screening Plant	Material Handling for Crusher
LADSON quarry Ibadan	2.6	2.58	2.53	2.6	2.56	2.63	2.53	2.58
CCC quarry Sango, Ilorin	2.57	2.57	2.58	2.6	2.52	2.6	2.57	2.55
ABULE quarry Sao, Ilorin	2.58	2.52	2.58	2.6	2.52	2.6	2.7	2.48

The scores are ‘fair’

Table 4: Description of Safetyscores for sum of each of the Activities in the studied quarries.

a.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean
					Lower Bound
Drilling	3	2.5833	.01528	.00882	2.5454
Blasting	3	2.5567	.03215	.01856	2.4768
Material Handling	3	2.5633	.02887	.01667	2.4916
Hauling	3	2.6000	.00000	.00000	2.6000
Primary crusher	3	2.5333	.02309	.01333	2.4760
Screening	3	2.6100	.01732	.01000	2.5670
Material Handling for crushers	3	2.6000	.08888	.05132	2.3792
8.00	3	2.5267	.04509	.02603	2.4147
Total	24	2.5717	.04508	.00920	2.5526

All the scores is 'fair'

b.

	95% Confidence Interval for Mean	Minimum	Maximum
	Upper Bound		
Drilling	2.6213	2.57	2.60
Blasting	2.6365	2.52	2.58
Material Handling	2.6350	2.53	2.58
Hauling	2.6000	2.60	2.60
Primary crusher	2.5907	2.52	2.56
Screening	2.6530	2.60	2.63
Material Handling for crushers	2.8208	2.53	2.70
8.00	2.6387	2.48	2.57
Total	2.5907	2.48	2.70

Table 5: ANOVA of the safety scores of activities

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.021	7	.003	1.865	.143
Within Groups	.026	16	.002		
Total	.047	23			

The ANOVA scores shows that the mean score for each of the activities combined in the studied quarries are not significantly different from each other statistically.

Table 6: Post Hoc Tests for Multiple Comparisons of the Safety scores of the Dependent Variable Activities.

Tukey HSD

(I) Activity	(J) Activity	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Drilling	Blasting	.02667	.03274	.990	-.0867	.1400
	Material Handling	.02000	.03274	.998	-.0934	.1334
	Hauling	-.01667	.03274	.999	-.1300	.0967
	Primary crusher	.05000	.03274	.783	-.0634	.1634
	Screening	-.02667	.03274	.990	-.1400	.0867
	Material Handling for crushers	-.01667	.03274	.999	-.1300	.0967
	8.00	.05667	.03274	.670	-.0567	.1700
Blasting	Drilling	-.02667	.03274	.990	-.1400	.0867
	Material Handling	-.00667	.03274	1.000	-.1200	.1067
	Hauling	-.04333	.03274	.877	-.1567	.0700
	Primary crusher	.02333	.03274	.995	-.0900	.1367
	Screening	-.05333	.03274	.728	-.1667	.0600
	Material Handling for crushers	-.04333	.03274	.877	-.1567	.0700
	8.00	.03000	.03274	.980	-.0834	.1434
Material Handling	Drilling	-.02000	.03274	.998	-.1334	.0934
	Blasting	.00667	.03274	1.000	-.1067	.1200
	Hauling	-.03667	.03274	.943	-.1500	.0767
	Primary crusher	.03000	.03274	.980	-.0834	.1434
	Screening	-.04667	.03274	.833	-.1600	.0667
	Material Handling for crushers	-.03667	.03274	.943	-.1500	.0767
	8.00	.03667	.03274	.943	-.0767	.1500
Hauling	Drilling	.01667	.03274	.999	-.0967	.1300
	Blasting	.04333	.03274	.877	-.0700	.1567
	Material Handling	.03667	.03274	.943	-.0767	.1500
	Primary crusher	.06667	.03274	.490	-.0467	.1800
	Screening	-.01000	.03274	1.000	-.1234	.1034
	Material Handling for crushers	.00000	.03274	1.000	-.1134	.1134
	8.00	.07333	.03274	.380	-.0400	.1867
Primary crusher	Drilling	-.05000	.03274	.783	-.1634	.0634
	Blasting	-.02333	.03274	.995	-.1367	.0900
	Material Handling	-.03000	.03274	.980	-.1434	.0834
	Hauling	-.06667	.03274	.490	-.1800	.0467
	Screening	-.07667	.03274	.331	-.1900	.0367
	Material Handling for crushers	-.06667	.03274	.490	-.1800	.0467
	8.00	.00667	.03274	1.000	-.1067	.1200
Screening	Drilling	.02667	.03274	.990	-.0867	.1400
	Blasting	.05333	.03274	.728	-.0600	.1667
	Material Handling	.04667	.03274	.833	-.0667	.1600
	Hauling	.01000	.03274	1.000	-.1034	.1234
	Primary crusher	.07667	.03274	.331	-.0367	.1900
	Material Handling for crushers	.01000	.03274	1.000	-.1034	.1234
	8.00	.08333	.03274	.245	-.0300	.1967
Material Handling for crushers	Drilling	.01667	.03274	.999	-.0967	.1300
	Blasting	.04333	.03274	.877	-.0700	.1567
	Material Handling	.03667	.03274	.943	-.0767	.1500
	Hauling	.00000	.03274	1.000	-.1134	.1134
	Primary crusher	.06667	.03274	.490	-.0467	.1800
	Screening	-.01000	.03274	1.000	-.1234	.1034
	8.00	.07333	.03274	.380	-.0400	.1867
8.00	Drilling	-.05667	.03274	.670	-.1700	.0567
	Blasting	-.03000	.03274	.980	-.1434	.0834
	Material Handling	-.03667	.03274	.943	-.1500	.0767
	Hauling	-.07333	.03274	.380	-.1867	.0400
	Primary crusher	-.00667	.03274	1.000	-.1200	.1067
	Screening	-.08333	.03274	.245	-.1967	.0300
	Material Handling for crushers	-.07333	.03274	.380	-.1867	.0400

Table 6 shows that the scores in each of the activities is not significantly different from each other statistically and that there is no evidence of dependence among them.

Means Plots

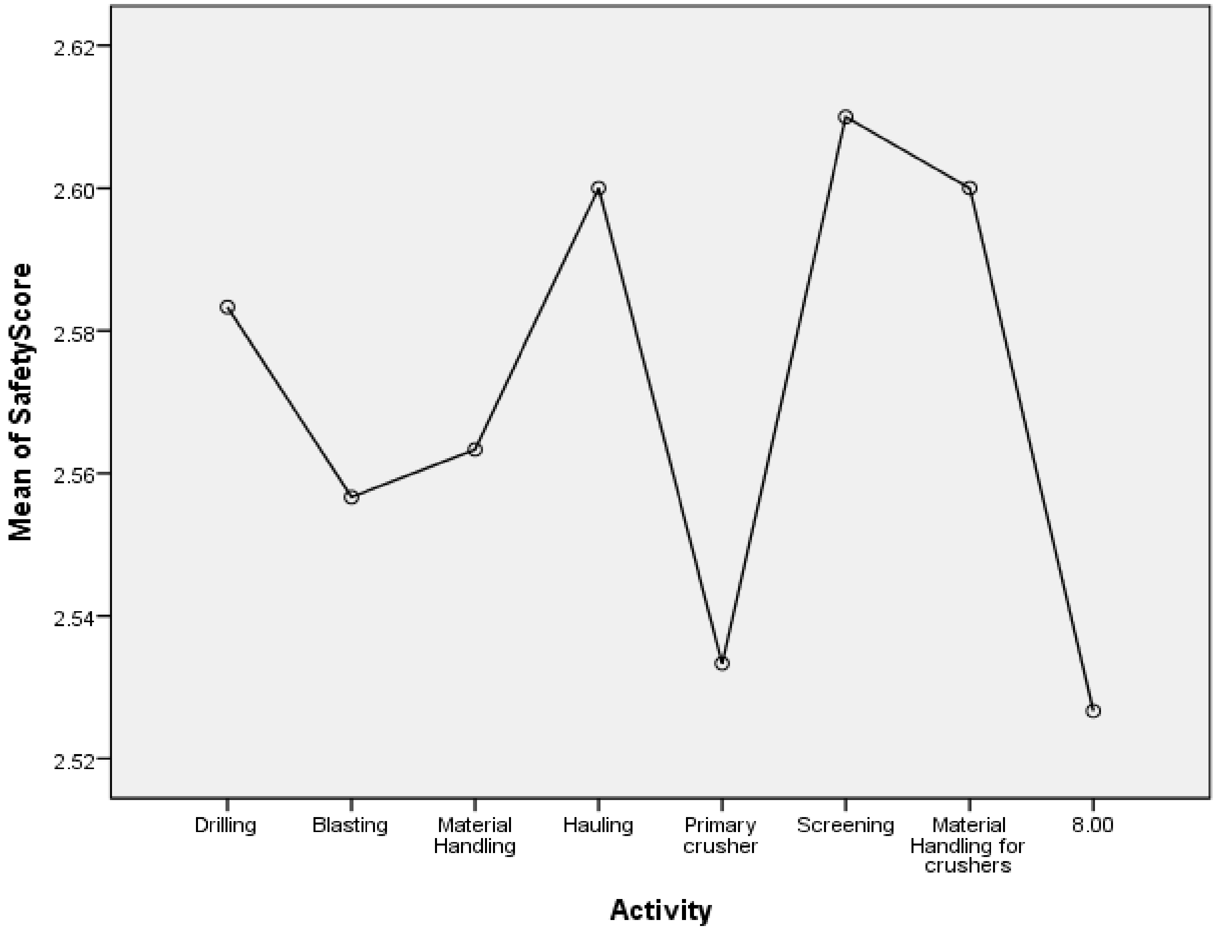

Fig.2: Means Plots

The mean plots show that the activity with the highest safety scores is ‘screening’ while the one with the least score is ‘primary crusher’. The further statistical analysis of the safe scores in each of the quarries is described below.

Table 7: Overall Rating of **Descriptive** Safetyscore in each of the studied quarries.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Ladson	8	2.5763	.03503	.01238	2.5470	2.6055
CCC	8	2.5700	.02619	.00926	2.5481	2.5919
Abule	8	2.5725	.06756	.02389	2.5160	2.6290
Total	24	2.5729	.04448	.00908	2.5541	2.5917

The overall safety rating in each of the quarries is between 2.5700 and 2.5763

Table 8: The Description of the overall safety scores in each of the quarries.

	Minimum	Maximum
Ladson	2.53	2.63
CCC	2.52	2.60
Abule	2.48	2.70
Total	2.48	2.70

This shows that the overall rating of the safety in each of the quarries is 'fair'

Table 9: ANOVA table of the overall Safety scores in the quarry.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	.037	.964
Within Groups	.045	21	.002		
Total	.045	23			

The ANOVA table shows that there is no statistically significance dependence among the scores for each quarry.

Table 10: Post Hoc Tests for Comparison of the overall safety scores in each of the quarries.

Tukey HSD

(I) Quarry	(J) Quarry	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Ladson	CCC	.00625	.02323	.961	-.0523	.0648
	Abule	.00375	.02323	.986	-.0548	.0623
CCC	Ladson	-.00625	.02323	.961	-.0648	.0523
	Abule	-.00250	.02323	.994	-.0611	.0561
Abule	Ladson	-.00375	.02323	.986	-.0623	.0548
	CCC	.00250	.02323	.994	-.0561	.0611

Table 10 shows that there is no statistical dependence among the safety scores of each of the studied quarries.

Means Plots

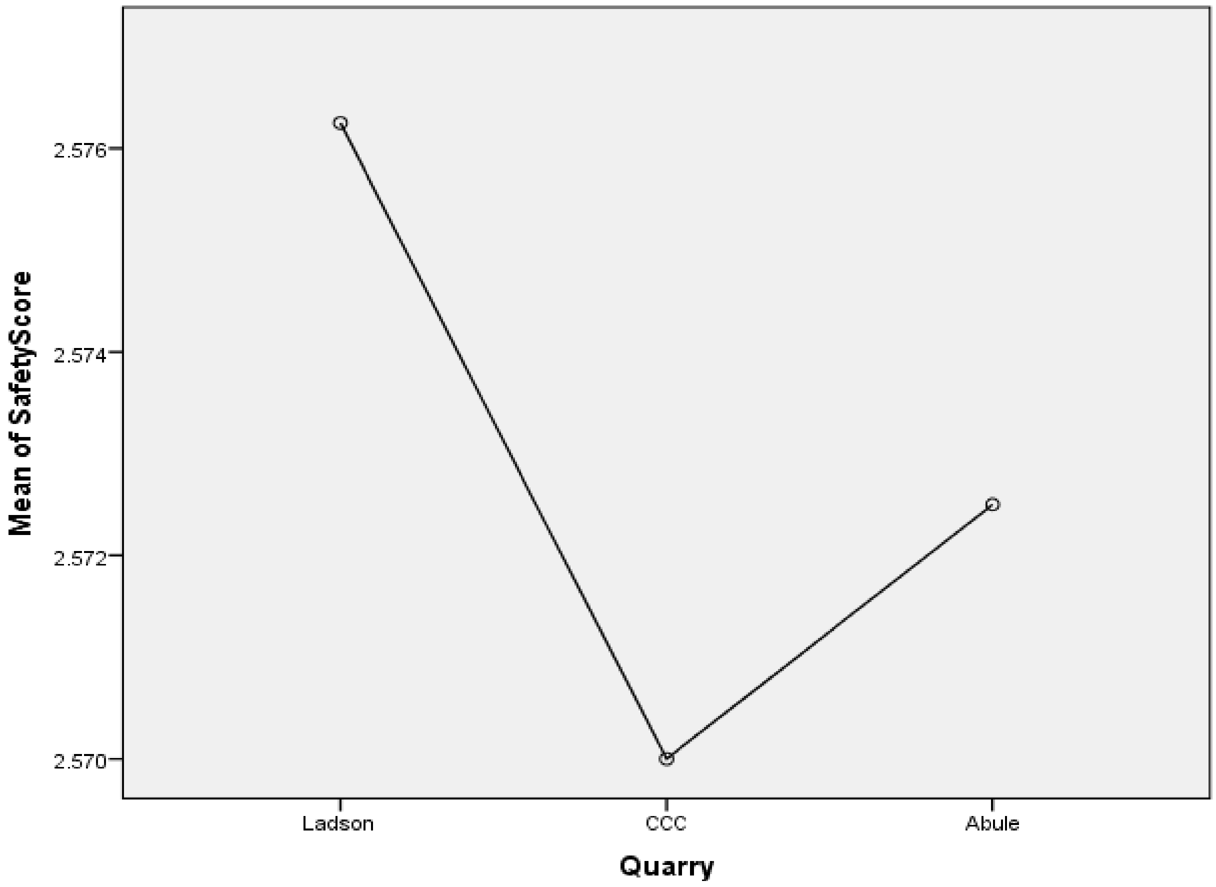

Fig.3: Means Plots

Fig. 3 shows that CCC Quarry has the lowest score while Ladson Quarry has the highest safety score.

Drilling, which can be defined as an act of boring holes into the earth surface (rock) is the major operation that cannot be neglected in a quarry site. This can be in the form of rotary, percussive, rotary percussive or pneumatic drilling. The principles behind drilling include assembling of drill screen, replacement of worn-out tools, installation of the drill at a given elevation and addition of lengths of drilling operation for the three sites (LADSON, CCC, ABULE Quarries) is compared in the table shown above i.e., Tables 4. The score ranges from 2.5 to 2.8 which shows 'fair' condition.

The remark shows that drilling operation here is towards danger in safety. It means that a lot of safety measures are not put in place. The workers use less dust collection system that fit in drilling equipment while there is low use of dust mask. There is also no proper maintenance of her drilling and ancillary equipment while hydraulic breakers for reducing size of large rock boulders is not in use at all. This is contrary to recommendation of Chigonda (2008) that all drilling operators and supervising staff must adopt proper safety measures during drilling operations including wearing dust mask and ear plugs.

Blasting is the act of fragmentation of rocks using low or high explosives such as ANFO, dynamite, gelatin etc. It is the process that follows drilling operation in a quarry. During this operation, charging or loading, stemming, or temping and initiation are the major contribution to its effectiveness. It is one of the most dangerous operations that need proper safety measures. The remark from Table 4 is fair i.e., there is a lot of work to be done. The company does not take proper monitoring of ground vibrations and air pressure which was stated from the guideline given by Rashid (2010). Ground vibrations and air pressure should be monitored regularly during the blasting operations. The recommended limit is that measurements should be taken from 800m from the blasting face towards the nearest residential area. If the residential area is located less than 800m from the blasting face, then the measurements should be taken close to the foundation of the nearest building (Rashid, 2010).

Materials such as explosives, cortex fuse, detonators, fuel, and equipment need proper handling by an expert to prevent damages and even loss of lives. Table 4 shows that Ladson quarry have poor safety measures while both CCC and Abule quarries have fairly controlled safety in material handling. Ladson quarry result is responsible for her lack of expertise/trained operators to operate some of the equipment used. This shows that the company is liable to record any of the unsafe act or unsafe conditions described by Cole (1997). Such acts include operating equipment at improper speeds, operating equipment with authority, improper use of equipment, using defective equipment, failure to wear personal protective equipment, taking and improper working position, servicing equipment in motion, poor illumination, poor housekeeping etc.

Hauling involves transportation of fragmented rocks within the site to the crushing plants and processed rocks to the consumers. During this operation, there are some safety measures that had to be taken into consideration. The results in Table 4 show that safety measures are controlled, it is evident that none of the quarries have symbols like speed limits, road conditions and directions along their roads. They received lesser complaints from their residents about how dump truck travels, but they do not normally pave or spray water on their hauling road regularly. This can cause high dust diseases such as silicosis, silicotubercolis (complication of tuberculosis by silica), silicatosis (by other silicates), siderosis (by iron) etc.

All these are respiratory ailments or diseases. In its least harmful effect, an air-borne dust may cause pigmentation of the lungs and shortness of breath. In addition, exposure to excessive concentrations of all dusts increases the frequency of mild respiratory ailments (colds, influenza) and can worsen existing respiratory diseases (asthma, tuberculosis) (Aso et al., 1999). Another improper measure not taken into consideration is that there are no visible symbols along the hauling road that will direct the vehicles and trucks at the site.

Crushing is the process of reducing the size of solid bodies by breaking them with the aid of external forces, because of which internal adhesion forces joining the separate particles of the solid body are overcome and new surface are exposed. During this operation, a lot of dusts are generated most especially during the dry season. Therefore, adequate safety and control measures had to be taken during operation. Table 4 shows that safety measures are only fair in Ladson quarry while those of CCC and Abule quarries are poor. This is due to inefficient control system for primary feeder installed and lack of encapsulation of primary feeder. This means that there is low maintenance of primary crusher and inadequate prevention of dust, noise emissions and other problems. Secondary crusher is not well sealed with rubber curtains. It is also not well encapsulated. The screening plants are poor in the carrying out of proper maintenance of the screens. Some of the screens are almost rusting because they are not protected with rubber curtains. It was because the conveyor that would transport the materials does not have proper chutes that mode some of the material to fall sideways. There is also no proper maintenance of the material used in handling the products. Finally, there is no spraying of their stockpiles of graded fine material with water as recommended by Glendon *et al*., (1997).

Contrary to the laid down standard of measures by the Nigerian Minerals and Mining Act (2007) 111 and 123 which states that ‘the holder of mineral title shall, in exercise of his rights under the mineral title, have regard to the effect of the mining operations on the environment and take such steps as may be necessary to prevent pollution of the environment resulting from the mining operation’ and ‘No person shall, in the course of mining or exploration for minerals pollute or case to be polluted any water or watercourse in the area within the mining lease or beyond that area’. Some of the necessary rules were not put into consideration by the three quarries.

Table shows that each of the activities is ‘fair’. It is important for the managers to identify risks associated with the equipment, access workers’ hazard, and define prevention skills to fully address potential hazards in safety programs (Bae *et al*., 2021).

Conclusions and Recommendations

It was observed that safety control in LADSON quarry is totally poor in the drilling operation. This is due to low use of filters to dispose fine dust and improper maintenance of the drilling equipment. Further observation is that there is a proper safety measure for blasting operation except that ground vibrations and air over pressure were not controlled.

In addition, it was observed that good measures are taken in the handling of materials and transportation of blasted rocks to the crushing plant except that no symbols to direct the path of the trucks were made. The result also shows that dusts generated in the crushing plants are not properly controlled. CCC Quarry has the lowest score while Ladson Quarry has the highest safety score.

It must not be construed that environment is secondary, but what is implied is that a balance approach between the two; environment and mineral exploitation should be evolved.

The following recommendations are hereby made:

The major activities in a quarry site had shown that noise, flying fragments, vibration, fractures, dust and noxious gases are caused by mining operations. Therefore, it is important for mining companies to ensure that proper safety measures are being taken during and after operations.

There should be prevention of long-term environmental side effects by “mitigative measures” so that remedies do not become unmanageable and, expensive in the long run. This could be achieved by proper environmental management in the operative mines and quarries and impact assessment programs in the case of new mineral projects should be made mandatory by the government.

There should also be environment audit-monitoring of the effectiveness of the environmental safeguards and corrective measures from time to time.

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EFFECT OF SAFETY LEVEL ON PRODUCTIVITY IN SELECTED GRANITE QUARRIES IN KWARA STATE, NIGERIA

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Abstract

Safety among the workers in the mineral industry has been of importance over the years. Goal of reducing the injury rates and eradicate fatalities are of concern to stakeholders in the industry. It has been discovered that a good safety rating of industry gives good public image and will likely influence the morale of the workers thereby affecting the productivity. Granite quarries in Kwara state contributes to the economic productivity of the state and employment generation. It is importance to investigate how the safety indices there influences the productivity. Ten quarries were used as case study, structured questionnaire with Likert scale questions was drafted, evaluated, and distributed to workers in the quarries. The completed questionnaires were retrieved, analyzed using nonparametric analysis on SPSS software. The result shows negative correlation between the safety levels and productivity in the studied sites. This implies that though there may be a relationship between the productivity and safety, other factors also influence the productivity, which mask the relationship. It is hereby recommended that more studies be carried out to reveal more of the factors which influence the productivity in the quarries, this will help in proper planning and design of more effective granite quarries especially in the state.

Keywords: Safety, Productivity, , quarry, ,correlation, planning

1.0 Introduction

It has been observed that workers become more productive when they are satisfied with working conditions and feel safe from injuries (Geldart *et al.*. 2010, Hola, 2012 and Hall et al.,2016). Individual performance of workers is affected by various factors in the working environment i.e., communication, motivation, ergonomics, and automation in addition to organizational factors (Narayan 2012). Resnick and Zanotti (1997) reported that comfortable environment helps operators to perform their task productively, and the confidence of the workers is increased by a safe working environment. These reduce the occurrence of injuries. Nwachuckwu in (2001) reported that occupational health is the summation of every activity and programs which are employed to attain and maintain the highest level of health and safety for everyone engaged in any kind of work.

Mine accident (inclusive of quarry) is an occupational injury which occurs to any person as a result of quarrying or mining for which medical treatment is administered or which leads to loss of consciousness or death (Manfred and Norman, 2001). Schimtz (2005) says competition and change in work practices influence productivity. The Health and Safety Act of 1969 in US, the law, which specified health and safety regulations in coal mines, was cited as the cause of the decline in productivity per shift experienced since 1970. Schimtz, (2005); Zimmerman, (1977) also said that the impact of health and safety regulations is analogous to a negative rate of technological change.

The use of diesel-powered equipment in mines increases productivity as well as safety risks. It is not known whether adjustments in work practices to accommodate hot environments will reduce productivity and whether increases in coal mining employment which would bring into the work force persons who are not acclimatized and unaware of heat and cold hazards will significantly increase these adverse health effects (Occupational Safety and Health Implications of Increased Coal Utilization (Bridbord et al. ,1979). Bridbord et al (1979) reported that the review of occupational health and safety aspects of increased coal production supports the conclusion that without strong preventive health and safety measures, increasing coal production cannot be obtained without incurring additional costs in occupationally induced disease job related disabling injuries, and accidental deaths.

Economic insecurity, falling accident rates and industrial peace all contributed to the rapid productivity growth of the 1950s (Naples, 1998). Through being proactive in seeking safer and healthier coal mines, the 1969 Act of US should help improve miner morale and thereby productivity but because the Act instituted new inspection and enforcement procedures which took time to learn, it might initially hinder productivity growth. It has also been argued to hamper management flexibility, thereby depressing productivity (Naples, 1998).

A summary of a few preliminary findings of the committee appointed by American Engineering Council in 1926 to investigate accident and productivity relationship in industries showed that there was a positive indirect relationship between accidents and production. It was conclusively displayed by unquestionable evidence that a steadily increasing productivity over a period of years is accompanied by simultaneous reduction in the frequency and severity of accidents. There was also considerable indication that maximum productivity is dependent upon the reduction of accidents to an irreducible (Monthly Labor Review, 1927).

This study was carried out to provide information about how the safety practice is faring in selected mineral industries in Kwara State, Nigeria and how the safety level influences the productivity of workers in those establishments.

Materials and Methods

Survey tools

A questionnaire survey was used for this study. The questionnaire has a mixture of questions presented in random order to each of the participants a way of minimizing the bias of the respondents, and it was divided into sections. The topics in the sections are about different aspects of operations in quarry i.e., drilling, blasting, material handling, processing, equipment, and facilities. A four-point likert scale was employed so that residents can provide either 'degree of answers from 1-4' . Each of the likert responses 'regularly' 'occasionally' 'rarely' and 'never' was assigned a score, with '4' '3' '2' and '1' respectively.

Sample

The production data of each of the establishments for 8-hour shifts were collected by the management of each of the establishments. The installed and operating capacities of each of the plants were received in the same manner.

The paper based questionnaire was administered to workers of ten (10) quarries; Yassa Quarry, Ilorin, Kamwire Quarry, Ilorin, Bulletine Quarry, Ilorin, Dasofunjo Quarry, Ilorin, Omega Quarry, Ilorin, As-Salam Ltd., Ilorin, Abule Quarry, Shao, Harbin Engineering Ltd., Ilorin, IBBL Quarry, Ilorin, and Ibrosalam Quarry, Bode Saadu.

The questionnaire was anonymous to minimize the effect of social desirability and avoid identification of the participants. It was administered to all employees of target population over a period of two weeks, the participation in the survey was voluntary. The filled questionnaires were retrieved for analysis. Analysis of the data was carried out using SPSS version 22 software package (IBM, IBM SPSS Statistics for Windows, version 22.0. Armonk NY US, 2013). The nonparametric statistics procedure was used with median value calculations, with the significance level for all statistical tests set to '0.5'

Spearman's bivariate was carried out on the mean score of each of the establishments and the productivity level to explore possible relationship between the safety level and productivity level for the mineral industries studied.

Results and Discussion

Results

The average of relative productivity of eight (8) hours shift in each of the establishments is shown in Table 1.

Table 1: The relative productivity of the plants

S/No	Establishment	Relative productivity
1.	Harbin Engineering Ltd.	0.3
2.	Yassat Quarry	0.1
3.	Ibrosalam Construction Company	0.1
4.	Dasofunjo Quarry Nig. Ltd	0.4
5.	Bulletine Construction Company	0.2
6.	Omega Rocks and Minerals Nig. Ltd	0.4
7.	Abule Quarry	0.3
8.	Assalam Quarry	0.8
9.	Kamwire Quarry	0.2
10.	IBBL Quarry	0.3

Table 1 shows that the relative productivity of each of the plant varies between 0.1 to 0.8, this shows that the mineral plants studied operate below their installed capacity. This is not good economically especially because of the fixed cost of running the industry.

Table 2 shows rating of scores of evaluation of safety practice in the study area.

Table 2: The safety scores of each of the plants of the study area

S/No	Establishment	Score
1.	Harbin Engineering Ltd.	2.3
2.	Yassat Quarry	2.1
3.	Ibrosalam Construction Company	2.2
4.	Dasofunjo Quarry Nig. Ltd	2.3
5.	Bulletine Construction Company	2.2
6.	Omega Rocks and Minerals Nig. Ltd	2.0
7.	Abule Quarry	2.6
8.	Assalam Quarry	2.0
9.	Kamwire Quarry	2.3
10.	IBBL Quarry	2.4

Table 3: The rating of scores of evaluation of safety practice in the study area

S/No	Rating	Occurrence	Score (Numerical)
1.	Good	Regularly	3
2.	Fair	Occasionally	2
3.	Poor	Rarely	1
4.	Very poor	Never	0

When the safety practice is practiced regularly, it's rated 'Good' and scored 3, occasionally practiced was scored 2, rated 'Fair' rarely is scored 1 and rated 'poor' and 'Very Poor' rating for never, and scored 0.

Table 4 shows the evaluation of the level of safety practice in each of the establishments.

Table 4 shows that the study reveals that Abule Quarry has the highest score of safety of 2.6/3.0 while Omega Rocks and Minerals Nig. Ltd has a score of 2.0/3.0, the lowest of all the plants.

Table 4: The correlation of productivity with safety practice in the study areas

S/No	Average Safety Score (x)	Relative Productivity (y)
1.	2.3	0.3
2.	2.1	0.1
3.	2.2	0.1
4.	2.3	0.4
5.	2.2	0.2
6.	2.0	0.4
7.	2.6	0.3
8.	2.0	0.8
9.	2.3	0.2
10.	2.3	0.4
r = -0.3		

The negative correlation of -0.3 shows that there is no meaningful correlation, in any way between the productivity rate and safety indices of the plants studied. This result aligns with the observation that other factors influence the productivity (Narayan, 2012; Schimtz, 2005).

Nonetheless, the fact that the plants with high safety scores i.e., 2.6, 2.3 and 2.3 has relative productivity of 0.3, 0.4 and 0.4 respectively shows that there is an evidence of a positive indirect relationship between accidents and production, and that there is a considerable indication that maximum productivity is dependent upon the reduction of accidents to an irreducible (Monthly Labor Review, 1927).

Conclusion

It can be inferred from the study that there are other factors which influence productivities in Kwara State, Nigeria, other than safety practices i.e., managerial skills, maintenance of equipment etc. Further studies to carried out to determine other factors which influence the productivities and their weights.

Since the rating of the safety practice in the quarry is 'fair' there is need to improve on safety practices by the quarries managements.

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