Geochemistry and Socioeconomic Importance of Gypsum in Fune and Fika LGA, Yobe, North Eastern Nigeria.

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DOI : https://dx.doi.org/10.47772/IJRISS.2024.803152S

Received: 19 May 2024; Accepted: 15 June 2024; Accepted: 21 June 2024; Publication: 27 July 2024

ABSTRACT

Artisanal mining have being taking place for decades in the study area. It serves as source of income and employment to the miners as well as revenue generation to both Yobe state and Fika and Fune LGAs. 15 representative gypsum samples were collected at Alangafe, Turmi and Mamunji active mining sites from a depth of 3m — 5.7m. X-ray fluorescence was used to determine the geochemistry of the samples. The result revealed that Turmi (TG) has the highest purity with 88.30%, Alangafe (AG) with 87.44% and Mamunji with lowest purity 83.92%. Percentage purity of gypsum were determined by calculating the percentage of Calcium Sulfate dehydrate ($CaS0_4.H_20$) or by heating the mineral and quantify change in mass. When compared with imported gypsum from Morocco and Spain, it was found that the crystalline gypsum of the study area is of low grade but Turmi (TG) and Alangafe (AG) meet the required limit of 84 — 100% purity for industrial application while Mamunji (MG) falls below the American Society for Testing and Materials (ASTM) limit with 83.92%. The order of purity is Turmi>Alangafe>Mamunji.For Socioeconomic analysis, six locations were considered and monitored for the period of eight (8) weeks and gypsum outputs were measured with head pan and sold per ton at the rate of ₦60, 000. It can be deduced that Ganguwale yielded 30% gypsum output, Garin Ari 19%, Bulaburin 15%, Mamunji 14%, Gawara 12% and Turmi 10% respectively. This implies income for the artisanal miners as well as State and local government. Another socioeconomic importance is that the gypsum serve as raw materials for certain industries such as cement, chalk paints etc. Proper monitoring is required to reduce environmental degradation, surface and groundwater pollution.

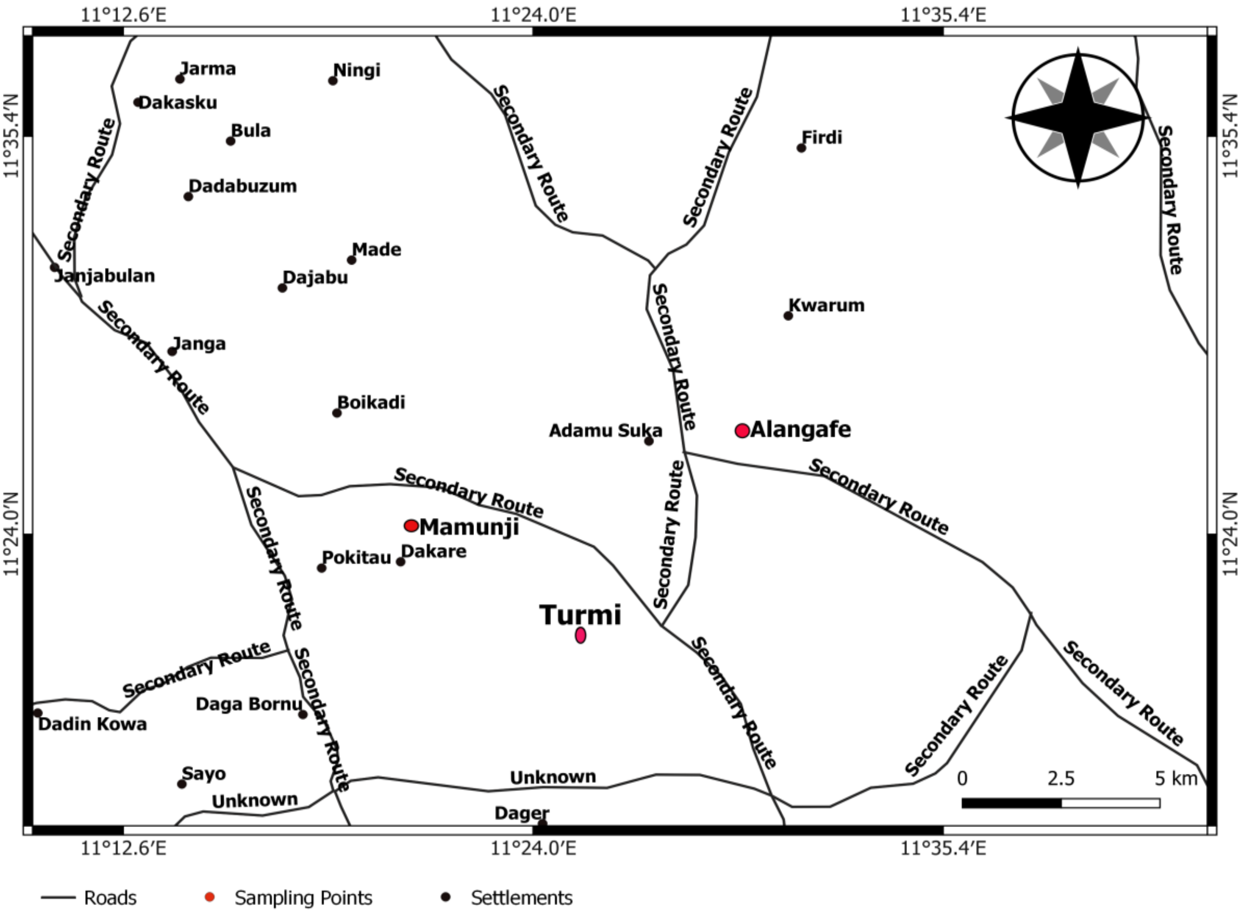
Keywords: Gypsum, Geochemistry, Socioeconomic, Mining, Artisanal.

INTRODUCTION

Every State and Local Government in Nigeria is blessed with various minerals and metals in commercial quantities which are distributed by nature. Its mind blowing to see a country like Nigeria wallowing in abject poverty and having a comatose industrial sector due to inadequate attention and political will to transform the abundant minerals and metals across the Country. Minerals are the foundation for economic and industrial development of any nation. The study of the geological history of our planet requires the knowledge of minerals and their sources (Aigbedion and Iyayi, 2007). In fact, all aspect of human is affected by minerals. Donatus, 2002 opined that minerals are needed mainly for three reasons; life support, energy generation and industrial constructions. Gypsum is a hydrous calcium sulphate with the chemical formula $CaSO_4.2H_2O$ (Klein et al., 1985) which may be interpreted as calcium united with sulphuric acid and holding water of crystallization. Its natural form when pure is usually white and massive, pearly or glistening when crystalized and the crystalline mineral looks transparent to a remarkable degree. Gypsum occurs naturally as a soft rock in association with limestone, silica, clays and a variety of soluble salts and impurities. Gypsum is not frequently impure due to other substances present during its formation or incorporated subsequently over time and the impurities are usually organic matter, iron compounds, clay and carbonates of lime and magnesia. Gypsum is often fresh-red, honey-yellow, ocher — yellow or blue due to gang minerals, it may be brown, red, or reddish-brown and sometimes black. When gypsum is reduced to powder, its colour is commonly white (Hamza et al., 2018; Iraboret al., 2013). Gypsum occurrence within Fika shale of the Upper Benue trough was first reported by Carter et al., 1963 and later confirmed by Rayment, 1965; Bala and Ashiru 2021. Gypsum occurrence was also found in Chad Basin around Gadaka, Potiskum, Fika , Fune, and Bularafa areas in Yobe State. It has been locally mined in Fika town for many decades without knowing more of its uses talk less of it quality and different forms by the artisanal miners (Bukaret al., 2009; RMDC, 19996; Baba et al., 1995). Deposits are known to occur in layers as far back as the Archaean eon (Cockellet al., 2007). And the largest known gypsum deposits in Nigeria are mainly in north-eastern part of the country located in Nafada, Gombe and Fika in Yobe State (El-Nafaty and Baba, 1995; Orazurike and Haruna, 1997; Anigbogu and Ogezi 1998). This serve as a great opportunity for the two States and establish industries and companies that will improve socioeconomic lives of its people. Gypsum mining is usually done in Nigeria by open cast method which involve the removal of the overburden and tapping the mineral of interest or tunneling (underground) method mostly employed by artisanal miners in rural areas which is dangerous due to lack of adequate pillars to support the walls during exploitation (Sneha et al., 2012). Wastes are created and require space for dumping and trigger a number of environmental problems (Ravicandran et al., 2009). However, since the discovery of easily accessible gypsum deposit in Yobe state joined with high demand for industrial minerals in the globe, exploitation of gypsum has become widespread due to its high quality (Bala and Ashiru, 2021). Gypsum can produce different products such as Chalk, Paint, Cement, plaster of Paris (POP) and highly recommended as soil amendment. Environmental monitoring is required to protect the environment for future generation.

STUDY AREA AND METHODOLOGY

The study area comprised of Fika and Fune Local Government Areas in Yobe State, Nigeria. Mamunji and Turmi sampling points are located in Fika LGA while Alangafe is in Fune LGA. Fika lies on latitudes 11˚00 N and longitudes 11˚ 18E while Fune LGA lies on latitudes 11˚40'N and longitudes 11˚ 33E. All the study locations fall within the Sudan Savanna zone of Nigeria with mean rainfall of about 800mm per annum and temperature of 39 - 42˚C.



Source: GIS Expert extracted from goggle earth (2024)
Fig 1: Location Map of Study area showing sampling points

The materials and methods listed below were used for the analysis: Gypsum samples, Stearic acid, X-ray fluorescence spectrophotometer, polythene bags, hand anger, hammer, pestle and mortar, spatula, oven, pH meter, analytical balance, weighing bottle, hot plate and beakers. Field work was carried out in two phases. Phase 1 involved the reconnaissance survey which was done before sampling. It was necessary in order to examine the general characteristics of the area, determine the most feasible routes for sampling collection and identify active mining sites and mining methods used. The three (3) locations were selected because it the most dominant mining sites with high gypsum outputs.Communities identified for the sampling were Alangafe in Fune LGA, Mamuji and Turmi in Fika LGA. Phase 2 was the detailed work which involved collection of samples from different lithological units within the formation and taking coordinates of the sampling sites using a Global positioning Device (GPS) in order to generate a map of the points where the samples were taken. The mining method observed is pitting and underground with many old abandoned pits connected underneath by various tunnels. Underground mining has led to dead of the many miners due to collapsing of overburden during exploitation of the mineral.Most artisanal miners work in difficult and often dangerous conditions in the absence of standard and safe mining regulations to safeguard the mining operations. 15 representative samples were systematically collected from approved sites ranging in depth from 3m to 5.7m due to financial constraint**.** The samples were well labelled, packed and taken to Ashaka Cement Laboratory for X-ray fluorescence (XRF) analysis. The representative samples were cleaned, crushed, sieved and weighted. 10g of the powdered sample was mixed with 1g of stearic acid (binder) and thoroughly homogenized in to a 40mm diameter hardened steel disc and pressed in to a pellet. Each pellet was then used for X-ray fluorescence (XRF) analysis of the elements in their oxide form, combine water and purity. For XRF analysis to be done, samples of the rock are radiated with X-rays of sufficient energy and electrons are dislodged at different wavelengths and intensities specific for the elemental composition of different samples. XRF is based on measurement of the intensity of secondary 2˚ characteristic radiation. Mining has being taking place for decades and not much was known on its quality since most of the artisanal miners do not border to know the grade of the mineral as well as the authorities controlling the operation. All they are concerned, was to make money and carter for daily needs. Therefore, the purity of the gypsum for industrial application is paramount for the study.

Regional Geology of Chad Basin

The Chad Basin is an extensive structural depression, occupying an area of about 2,335,000 km2 in six countries, including Chad Republic, Niger Republic and extending into Cameroon, Central Africa Republic, Sudan and northeast Nigeria (Adebanji et al., 2014). In Nigeria only 10% of the South-west corner of the Chad Basin is situated in north eastern part of the country (Barber, 1965).

The works of Oteze and Fayose, 1988; Obajeet al., 2011; Adepelumiet al., 2011) also revealed that the basin constitutes only 6.5% of the entire basins and covers about 152, 000km2 in Borno, Bauchi, Plateau and Kano states. The Nigerian sector of the basins (also known as Borno basin) is believed to be genetically linked with the Benue Trough, thus representing the northern border of a NE—SW trending aulacogen basin (Olade 1975).

Nwajide, 2013 revealed that almost all sedimentary basins in Nigeria except Iullemmeden basin are directly or indirectly related to the dominant Cretaceous tectonic sedimentation of the Benue Trough. Chad basin is generally separated from Upper Benue Trough by the Zambuk ridge which runs roughly eastward from Gombe town through Zambuk to Biu plateau (Offodile, 1976).

The study of the Cretaceous systems and inland basins in Nigeria dated back to the early 1950s when exploration for oil began in the country (Nwojijiet al, 2013). Tectonically, the chad basin presents a complex tectonic history that is not fully understood. The evolution and origin of Chad Basin is associated with the separation of the African and South African continents in the early Cretaceous (Burke, 1976. Genik, 1995).

The basin is genetically and physically related to the fault and rift systems termed the West and Central African Rift Systems (WCARS), whose origin is attributed to the Cretaceous breakup of Gondwana and the opening of the South Atlantic Ocean and the Indian Ocean (Fairhead1986)**.**

An active phase of sea floor spreading in the Atlantic during mid-Cretaceous resulted in the subsidence of the

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS June 2024 | Special Issue on Education

West African intecratoic basin leading to the widespread Cenomanian - Turonian marine transgression into the Chad Basin (Carter et al., 1963). Avbovboet al, 1986 classified the basin as rift related having observed in preponderance of tensionally induced basement tectonics and complex pattern of faulting. The Benue—Chad axial trough is believed to be the third and failed arm of a triple junction rift system that preceded the opening of the South Atlantic during the Early Cretaceous and the subsequent separation of the African and South American continent (Genik 1992; Avbovboet al. 1986; Olade 1975; Burke et al., 1972; Carter et al., 1963).Sedimentation started with the deposition of continental, poorly sorted, sparsely fossil ferrous, medium to coarse grained sandstone with some shale intercalations (Bima).

The formation rest directly on the Precambrian Basement Complex (Carter et al., 1963; Avbovboet al., 1986). Deposition took place under varying conditions with each deposit representing one complete cycle of transgression and regression. It has been divided into six formations based on the nature of sedimentary deposits within the depression. The divisions are named Bima, Gongila, Fika, Gombe, Kerri-Kerri and Chad formations. The agerange from Albian to recent (Okosun 1995).

RESULTS AND DISCUSION

Result of the geochemical analysis of the gypsum samples is presented in Table 1 from three (3) dominant mining sites at different depths varying from 3m to 5.7m. Concentration of the various oxides composition of Alangafe, Mamuji and Turmi shows that $Si0_2$ ranges from 1.2% to 2.96%, Al_20_3 from 0.00% to 1.09%, Fe_20_3 from 0.00% to 0.44%, Ca0 from 33.15% to 33.33%, Mg0 from 0.95% to 1.29%, $S0_3$ from 38.65% to 43.25%, K_2O from 0.03% to 0.09%, and Na_20 from 0.04% to 0.07%.

Table 1: Chemical Composition of Gypsum

Major Oxides Sample ID	**AG1**	**AG2**	**AG3**	**AG4**	**AG5**	**MG1**	**MG2**	**MG3**	**MG4**	**MG5**	**TG1**	**TG2**	**TG3**	**TG4**	**TG5**
SiO3	1.49	1.22	1.61	1.91	2.17	5.1	1.99	3.19	2.96	2.44	1.76	1.72	1.91	1.2	1.3
Al2O3	0	0.09	0.05	0.15	0.25	1.09	0.17	0.57	0.52	0.33	0.08	0.07	0.14	0.09	0.05
FeO3	0.05	0.08	0	0.44	0.14	0.32	0.04	0.25	0.19	0.15	0	0.03	0.04	0.06	0.07
CaO	32.4	32.4	32.49	33.14	33.33	34.04	32.22	32.77	33.34	32.8	32.18	32.33	32.47	32.47	32.15
MgO	0.98	0.94	1	1.01	0.98	1.1	1	1.04	1.29	1.04	0.99	1.09	1.06	0.95	0.95
SO3	42.63	43.09	42.91	41.85	41.03	38.65	41.89	40.46	40.29	41.41	42.77	42.6	41.88	43.25	42.79
K2O	0.04	0.02	0.04	0.06	0.07	0.17	0.04	0.1	0.09	0.07	0.04	0.04	0.05	0.02	0.02
Na2O	0.07	0.07	0.04	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Sum of Conc	77.66	77.91	70.14	78.63	78.04	80.54	77.42	78.45	78.75	78.31	77.89	77.95	77.62	78.11	77.4
Purity	88.25	89.19	88.2	86.64	84.93	80.01	86.71	83.75	83.4	85.72	88.52	88.19	86.69	89.53	88.58
Combine Water	19.185	19.391	19.175	18.834	18.464	17.394	18.85	18.206	18.131	18.634	19.244	19.172	18.845	19.463	19.256

Source: Field work (2021)

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS June 2024 | Special Issue on Education

Table 2: Average weight (%) of combined Water, Free Water and Purity

Sampling Site	Sample ID	Combined Water	Free Water	Purity
Alangafe	AG	19	1.55	87.44
Mamunji	MG	18.24	0.98	83.92
Turmi	TG	18.19	1.27	88.3

Source: Field work (2021)

The average weight (%) of combined Water, Free Water and Purity (Table 2) analyzed in the laboratory for the three mining sites indicates that gypsum from Turmi (TG) has the highest purity with 88.30%, followed by Alangafe (AG) with 87.44% and Mamunji (MG) with lowest purity 83.92%. The Gypsum were of high quality and can be used for different companies and industries such as Plaster of Paris (POP), paints etc. The order of purity is Turmi>Alangafe>Mamunji.

Table 3: Chemical Composition of Gypsum from Study Area (Alangafe) with ASTM standards

OXIDES	Average weight (%)	ASTM standard (%)
CaS04	74.98	79.1
Mg0	0.98	<3.00
K20+Na20	0.11	<0.0603
Combined water	19	20.9
CaS04.2H20	87.44	84 — 100

Source: Alangafe from field work and ASTM standards (Yuguga et al., 2023)

Table 4. A Comparison between the chemical data obtained from study area of the samples from Alangafe with imported gypsum from Morocco and Spain, reveals that the gypsum from Alangafe is of low purity but meets AmericanSociety for Testing and Materials (ASTM) required limits of 84 — 100% purity for industrial application.

Table 4: Comparison of Chemical Composition of Gypsum from Nigeria (Alangafe, Yobe) with that from Morocco and Spain

Elemental Oxides	Nigerian weight % Alangafe Gypsum	Morocco weight % Moroccan Gypsum	Spain weight % Spanish Gypsum
SiO3	1.68	0.6	0.5
Al2O3	0.01	0.12	0.53
Fe2O3	0.14	0.05	0.16
CaO	32.74	33.89	31.44
MgO	0.98	-	-
SO3	42.24	47.32	44.85

K2O	0.05	-	-
Na2O	0.06	-	-
Combined water	19	15.67	18.38
Cas04.2H20	87.44	96.88	94.67

Source: AlangafeYobe field work (2021) , Spain and Morocco Gypsum (Yuguda et al., 2023)

SOCIO-ECONOMIC IMPACTS AND CONCLUSION

Mining open remote places and provide modern amenities to improve the standard of living. It is a major economic activity in many developing countries including Nigeria (UNEP, 1997). Mining only take place where the mineral of interest is quantified and economically viable (Ako, et al., 2014). Mineral abundance contribute greatly to nation development and the more a nation has it, the richer it becomes (Davis and Tilton, 2003). Mining operation provide employment and income to both skilled and unskilled, foreign exchange and economic development (Ross, 2014, Obaje, 2005). Gypsum has been used traditionally for construction purposes especially for exterior decoration and structural application in Spain, Southern Mediterranean and the near Middle-East where the architectural use of gypsum had a longstanding traditional history (Pedro and Kertin, 2021). Gypsum serve as a good soil amendment for agricultural activities (Makkuet al., 2020).

Locally, gypsum has been used in farmlands to improve fertility, neutralize soil acidity and reduce soil erosion. Its directly applied in powdered form on the surface of the soil p (Anthet al., 2023; Daniel and Anil, 2023; Filho et al., 2020). The mineral serve as basic raw materials for many industries to produce different products for human well-being (Yugudaet al., 2023). Artisanal mining have being taking place in the study area for decades as means of livelihood using simple tools which is considered as informal mining due to nature of its operation.As at the time of this study, a head pan of gypsum was sold at the cost of ₦1, 500 and a ton sold at ₦60, 000. For every new mining pit to be dug in the site, a sum of ₦50, 000 was paid as revenue to State government and Fika LGA task force in-charge of the operation and other logistic. Furthermore, for each trailer to load the mineral, a required amount of N5, 000 was charged from the vehicle owners which transport the gypsum to Sokoto cement factory to produce cement. Fika LGA generates huge income from the local miners and create business opportunities for many traders and nearby villages. When proper attention is given by the State government, the sector can generate huge revenue and enhance the mining in the locality as well as attract foreign investors since large quantity of gypsum is found in Fika and the mineral is of high grade (purity) for industrial application. The largest known gypsum resources in Nigeria are mainly in north-eastern part of the country, and the best gypsum deposit are located in Nafada, Gombe and Fika in Yobe State (Anigbogu and Ogezi 1998, El-Nafaty and Baba, 1995). Monitored locations for socioeconomic analysis of gypsum outputs were Gawara, Turmi, Ganjuwale, Garin Ari, Bulaburin and Mamunji.

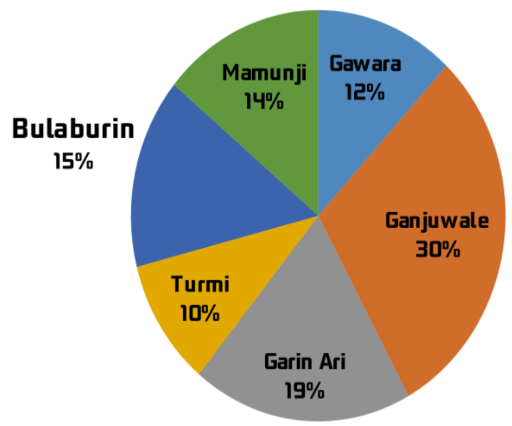
Table 5: Gypsum Output from six (6) dominants mining sites in Fika LGA

Output Weeks	**Gawara**	**Ganjuwale**	**Garin Ari**	**Turmi**	**Bulaburin**	**Mamuji**
			In Ton(s)			
1	184	399	303	226	237	171
2	174	465	295	130.5	278.5	234
3	122.5	260	152.5	98	214.5	108.5
4	176	333	253	138	310	164
5	183.5	486.5	313	188.5	176.5	282.5

6	170	464.5	155	128	257.5	220
7	222	437.5	247.5	110	75	198
8	119	448	345	109	150.5	155.5
Total	1351	3293.5	2064	1128	1699.5	1533.5

Source: Field work (2021)

Table 5 revealed that the total gypsum output of the active mining sites monitored for the period of eight (8) weeks was approximately 1, 1070 tons which roughly amount to the sum of six hundred and sixty four million two hundred thousand naira **(₦664, 200,000.00k)**. This means a large amount of money was generated by the artisanal miners aside other charges paid to Fika LGA for permit within the two (2) months of data collection. Therefore when proper attention is given to this sector, more employment will be generated as well as a source of revenue to Fika LGA and Yobe State. Hence, the standard living of the villagers would also be improved and foreign investors attracted.



Source: Field work (2021)

Fig 2: Show the percentage of gypsum output of the dominant mining sites in Fika Local Government Area.

From figure 2, it can be deduced that ,Ganjuwale has produced 30% gypsum output amounting to about (₦197,640, 000) making it the most dominant mining site followed by Garin Ari with 19% amount to (₦123,840,000) Bulaburin 15% amount to (₦102,000,000) Mamunji 14% amount to (₦91,980, 000) Gawara 12% amount to (₦81,060, 000) and Turmi 10%, amount to (₦67,680,000). The data was obtained from the months of February to April, 2024 which was the peak period for mining activities before the onset of the rainy season where most of the miners return home for agricultural practices. Negative socioeconomic impacts of mining observed cannot be ignored owing to the positive impacts. There is need to highlight some negative effects of the mining so as to balance the equation. Vast agricultural lands have been damaged, economic trees destroyed, old mining pits were abandoned and the soil left bare thereby exposing it to erosion. Hazardous substance might be attached to soil particle and organic matter and easily transported to nearby river and pollute the water which might pose threat to human health. Exposure to gypsum mining through inhalation, skin and eye contact lead to irritation of mucous membrane and respiratory system which also leads to cough, sneezing and discharge of mucus, skin and eyes irritation (NOISH, 2005). When mining is not formalized, organized, planned and controlled, it lead to severe environmental degradation, social disruption and conflict (Opafunso, 2010). Mineral exploitation and development have resulted to environmental damages including ecological instability, destruction of natural flora and fauna, air, water and land pollution, instability of soil and rock masses, landscape

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS June 2024 | Special Issue on Education

destruction and radiation hazards (Eptein, 2001, Aigbedion and Iyayi, 2007). Abandonment of old mine sites without reclamation poses major environmental challenge as vast farmlands deforested and barely exposed to erosion (Bala and Ashiru, 2021). Traditionally and religiously, culture, ethics and morals are distorted in mining sites due to presence of different people from different background. Miranda et al., 1998 opined that mining operation lead to cultural decadence such as alcoholism, prostitution and Sexual transmitted diseases commonly referred to as (STDs).

Mining is one of the major economic activities in the study area. Besides creating employment opportunities and income to the inhabitants, it also benefits the LGAs through revenue generation. Since the discovery of easily accessible high grade gypsum deposit in Yobe State coupled with high demand by manufacturing industries, gypsum exploitation has become widespread by artisanal miners in Fika and Fune LGAs. The results of the geochemical analysis shows that the mineral is of high grade which can be used for industrial applications since it falls within the American Society for Testing and Materials (ASTM) limit ranging from 84 — 100%.

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ISSN No. 2454-6186 | DOI: 10.47772/IJRISS |Volume VIII Issue IIIS June 2024 | Special Issue on Education

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