



2018

October-December

African Journal of Environmental Research. Vol 1, No. 2, 2018. pp 104-117

## THE EFFECT OF CLAY MINING ON THE QUALITY OF RIVER EZE IN OZUBULU, ANAMBRA STATE, NIGERIA

Angela O. Akanwa

Department of Environmental Management, Chukwuemeka Odumegwu Ojukwu University,  
Uli, Nigeria  
angela.akanwa1@gmail.com

### Abstract

*In Nigeria, clay is a widely distributed and abundant mineral resource for major industrial processes with varied applications and uses. The unregulated means of harvesting clay resources has placed risks on water sustainability. Globally, water pollution is fast becoming a serious environmental problem caused by unsustainable human means of exploiting natural resources. The study investigated two clay mining sites and their effects on River Eze in Ozubulu, Anambra State during the rainy season. It employed survey and experimental methods. Laboratory analysis was used to determine the physiochemical parameters (pH, turbidity, TDS, EC, BOD, DO) of River Eze. The water samples were also tested for heavy metals (Pb and Zn) using spectrometer (AAS) analysis. A total of three (3) water samples were collected from River Eze and (1) water sample from River Odoakpu to serve as a control sample. The survey method included field observation, photography and structured questionnaires. A total of 150 questionnaires were randomly administered to the residents. Findings from the study indicated that (1) the water samples from River Eze had higher Biological Oxygen Demand (BOD) levels than the permissible limits of the Federal Ministry of Environment (FMENV), (2) the pH values were within the permissible limit set by the World Health Organisation (WHO), (3) the EC, TSS, TDS were within the permissible limits of WHO/FMENV standards, (4) the control sample has low BOD of 20mg/l and other parameters were within the permissible limit of FMENV, (5) the heavy metal (lead) values were higher than the permissible limits of WHO standards, however, zinc samples analysed were within the permissible limit set by WHO/FMENV. It was evident that the nearness of the clay harvesting sites to Eze River is major cause of pollution. The results indicated that River Eze may have a toxic effect on aquatic ecosystem and the health of the rural dwellers that use the river water directly for domestic purposes without treatment. The study recommended effective Environmental Impact Assessment (EIA) practice, application of best sustainable practices for clay harvesting, enforcement of laws and policies covering environmental protection and regular water quality assessment.*

**Keywords:** clay mining, environment, heavy metals, sustainability, water quality

### INTRODUCTION

Mining is the process of extracting minerals and geological materials from the earth surface. Mining supports 14.4 percent of the world's total economy, while using less than 1 percent of the global surface area (mit.edu, 2015). It contributes to the progress of industries and it is an important source of employment and wealth creation in many developing countries, including Nigeria (Tauli-Corpuz, 1997; UNEP, 1997; Azapagic, 2004; Akanwa, 2016). Its wide

applications are in geology, industries, agriculture, environmental remediation and construction (Aramide, Alaneme, Olubambi, & Borode, 2014). Mining is a productive venture, even though it severely discomfits the world, threatening environmental resources.

There has been a widespread recognition of more than 80 deposits of clay resources in different parts of Nigeria including the Ozubulu deposit in Anambra State, though with differing properties owing to their geologic differences (Kefas, Patrick, & Ciroma, 2007). The abundant deposits of clay in Nigeria have been investigated and confirmed by various studies such as Igbokwe and Ogbuagu, 2003; Suleiman and Ahmed, 2003; Lawal and Abdullahi, 2010; Obaje, 2013, among others. There is active mining of clay resources in Ozubulu due to the lithological characteristics of the underlying formation of the area. The mining area lies within 6,000m depth of sedimentary rocks that comprise ancient Cretaceous Deltas mostly of Nkporo Shale, the Mamu Formation, the Ajali Sandstones and Nsukka Formation, constituting the main deposits (Igwe, 2016). The abundance of this natural resource in the State has triggered unsustainable excavation of clay resources with identifiable negative impacts on the environment.

This process was duly confirmed by Garrett Hardin's concept of the tragedy of the commons (1968) which explained that any shared and unregulated resource such as clay resource found in rural areas will be unsustainably exploited. Given that the process of exploitation will lead to the depletion of the shared resource by individuals, acting independently and rationally according to each one's self-interest, despite their understanding that depleting the common resource is contrary to the group's long-term best interests. Furthermore, increasing population and urbanization coupled with unattended enforcement of environmental laws has created the impetus for unsustainable extraction of natural resources resulting in land degradation, vegetation loss and water pollution, among others (Akanwa, Onwuka, Okoye, & Onwuemesi, 2011). Several studies have confirmed that mining activities significantly degrade the water resources (Akanwa, 2016; Akanwa, Okeke, Nnodu & Iortyom, 2017a; Akanwa, Onwuemesi, Chukwurah & Officha, 2017b; Suraj & Neelakan, 2014; Ashraf, Muaah, Yusoff, Wajid, & Mahmood, 2011; Tejpal, Jaglan & Chaudhary, 2014; Jaiye, 2013; Ayantobo, Awomeso, Oluwasanya, Bada, & Taiwo, 2014; Asante-Kyei & Addae, 2016; Karmaka & Das, 2012).

However, this study is based on the concept of Sustainable Development which refers to the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987). The core component of this definition is the conservation and development of resources, especially surface water. This is because out of all the natural resources available in the world, water forms an integral part in the survival of humans both by direct consumption and maintaining environmental balance (Karmaka & Das, 2012). About 2.1 billion people across the world lack access to safe, readily available water. It is projected to increase with the rise of global temperatures as a consequence of climate change (WHO, 2006). In addition, industrial activities produce a lot of waste, which is indiscriminately disposed into water, hence, polluting water supplies (Akanwa, Onwuka, Okoye, & Onwuemesi, 2011).

Basically, the concept of sustainable development and natural resource management are mutually supportive and their integration forms the basis for the conservation of

environmental, social and economic components (Moughtin, Cuesta, Sarris & Signoretta, 1991). This makes up the main thrust of this study since clay mining activities in Ozubulu could have direct effect on the quality of adjoining River Eze.

### **Statement of Problem**

Developing countries like Nigeria adopt the open pit method in most of their mining operations (Akanwa, 2016; Asante-Kyei & Addae, 2016). This method often goes unregulated and lacks pollution control. It entails the removal of the entire vegetation cover, which has a destructive effect on the natural environment especially in rural settings where mining companies do not adhere to mining laws and officials hardly enforce the laws, requiring restoration to its original condition after excavation.

As the miners dig the soil for clay minerals continuously, the land surface, the grasses, shrubs and trees are completely lost. These clay sediments are transported and dumped into surface water, while the presence of heavy metals increase toxicity levels with health implications when the polluted water is ingested (Singh, 2009; Rea & Silberlyed, 2009). Furthermore, as rain falls, dust, particulates and other chemicals are also washed downstream into the river causing sedimentation. The waste remains modify the stream morphology by disrupting channels, diverting the river flows and changing the slope or bank stability of a stream channel. These activities over time can significantly change the characteristics of stream sediments, reducing water quality.

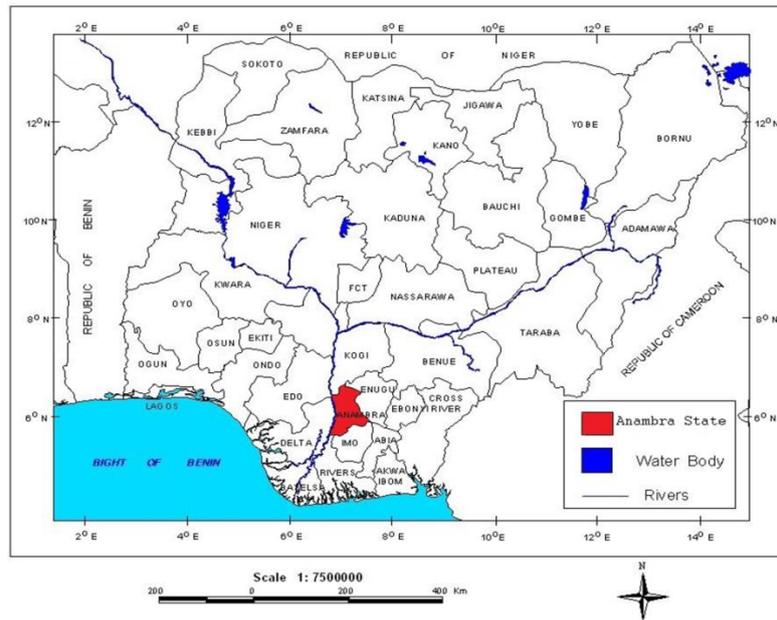
When the water quality is affected it increases the turbidity levels of the water which reduces the light available to aquatic plants for photosynthesis. Obviously, there is decreased food production for sea predators and the life of aquatic habitat is threatened. Other primary effects of clay mining apart from surface water pollution includes degradation of vegetation, natural landscape, ecological disturbance, pollution of air, damage of biodiversity, loss of animals and possible spread of water-borne diseases like cholera, dysentery, typhoid, and other diseases due to several pollutants in the river (Sharma & Sharma, 2016; Aigbedion & Iyayi, 2007). The main purpose of the study, therefore, is to investigate two clay mining sites/operations and their effect on River Eze in Ozubulu, Anambra State, Nigeria with the following objectives;

- a. To examine the mining methods used in excavating clay at the two sites in the study area.
- b. To analyse the physio-chemical parameters and heavy metals concentrations (lead and Zinc) of River Eze.
- c. To compare the physio-chemical properties and the heavy metal concentrations (lead and Zinc) with FMENV and WHO standards.

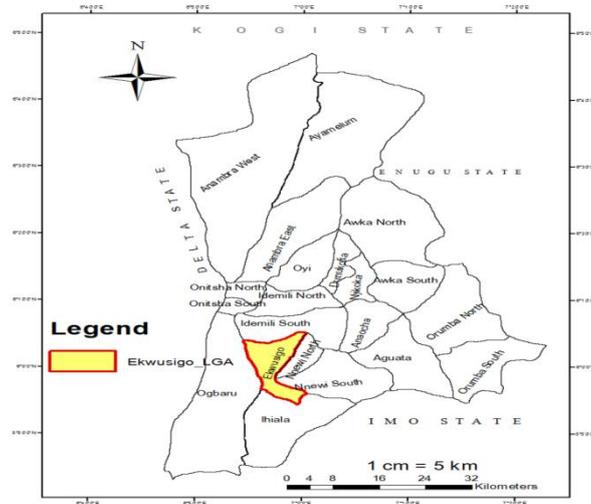
### **Study Area**

Ozubulu is the headquarters of Ekwusigo Local Government Area (LGA) of Anambra State (See Figures 1 and 2). It is the most densely populated of the four (4) Towns that make up Ekwusigo LGA. (Ozubulu, Orafite, Ihemboosi and Ichi). Ozubulu is made up of (4) villages namely: Amakwa, Egbema, Eziora and Nza. It shares boundaries with Nnewi and Oraifite in the North, in the south with Ihemboosi and Okija, in the West with Atani and in the East with

Ukpor. The geographical co-ordinates of Ozubulu are Latitudes 5°57'N and 5°95'N and Longitudes 6°50'E and 6°83'E.



**Figure 1: Map of Nigeria showing Anambra State**  
Source: Department of Environment Management, COOU (2018)



**Figure 2: Map of Anambra State showing Ekwusigo Local Government Area**  
Source: Department of Environment Management, COOU (2018)

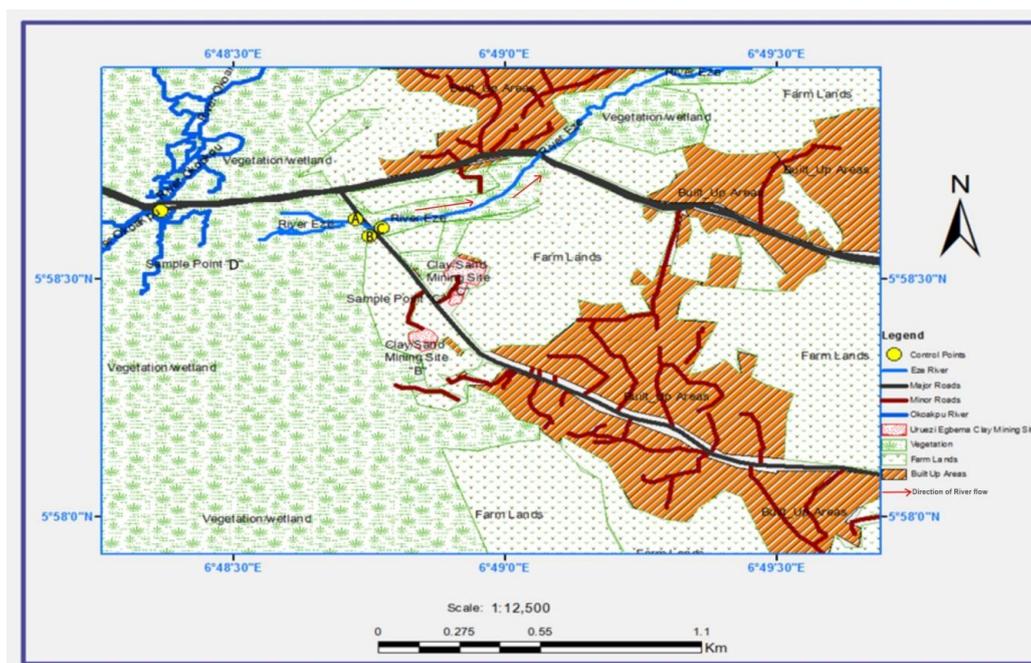
Ozubulu has a tropical climate, characterized by mean maximum temperature of 33°C and minimum temperature of 23°C. The relative humidity is generally high throughout the year, with figures ranging between 70-85% and its annual precipitation is in excess of 2000mm (Okwa, Ombada, & Dambatta, 2009; Igwe, 2016). The soils are lateritic in nature, derived from underlying sandstones and shells. They are well-drained and weakly consolidated in

most parts of the area. Topographically, the area is characterized by rolling undulating terrain. Most of the lowlands are rivers or streams that trigger major morphological expressions of massive sheet, rills, channel and gully erosion due to clay and sand mining activities. Geologically, its rocks are sandstones, calcareous shale and shelly limestone in thin bands (Igwe, 2016).

## **METHODOLOGY**

The study investigated two clay mining sites and their effect on River Eze in Ozubulu, Anambra State, Nigeria (See Figure 3). The study employed survey and experimental methods. The experimental method involved laboratory analysis of physio-chemical parameters (pH, turbidity, TDS, EC, BOD, DO) and heavy metals (Pb and Zn) of the River in order to determine their concentration levels. The pH was measured using laboratory pH meter Hanna model HI991300 (APHA; 1998). Turbidity by Nephelometric turbidity unit (NTU), TDS using APHA2510 ATDS 139 tester, conductivity using APHA 1998, BOD was determined by the Respirometric method, dissolved oxygen (DO) content of the samples was determined before and after the incubation, while heavy metals Lead (Pb<sup>2+</sup>) and Zinc (Zn<sup>2+</sup>) was analysed using Atomic Absorption Spectrophotometer (AAS).

A total of four (4) (A, B, C, D) water samples were collected. Three (3) (ABC) water samples were collected from 3 different points along River Eze (See Figure 3). Each water sample was collected at an interval distance of 5m from each other. Sample A was collected at 5m, sample B, at 10m and sample C at 15m. The fourth water sample (D) was collected from River Odoakpu to serve as a control. This is located upslope about 80km away from River Eze in Uruezi-Egbema (See Figure 3). The first water sample (A) was collected from River Eze at the discharge point of clay debris near the sand/clay mining site.



**Figure 3: Thematic Map showing Clay/Sand Mining Sites at Uruenzi-Egbema and the water sampling locations.**

Source: Department of Environment Management, COOU (2018)

The water samples (ABC) from River Eze were collected with the aid of clean 55cl plastic bottles which were rinsed thoroughly (to avoid cross contamination) with water gotten from River before the proper collection of the water sample. Grab samples were collected by dipping the plastic bottles into the River to get a representative fraction of the River Eze. The samples were stored in an iced cooler to avoid exposure to external factors such as air, light. The survey method included field observation; photography and a total of 150 structured questionnaires randomly administered to the residents.

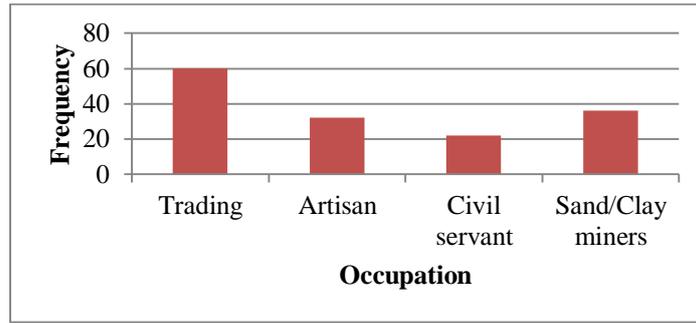
## RESULTS AND DISCUSSION

Table 1 shows the occupational status of the respondents. 40% of the respondents are traders, 21.3% are artisans, 14.7% are civil servants, and 24% are workers from the mine site. From the table, traders are the majority, followed by workers from the mine site. The data is presented in a bar chart (figure 4). This showed that clay mining is the second largest occupation from which residents earn their income. This is a result of several clay deposits and clandestine mining sites in the study area.

**Table 1: Occupational status of the respondents**

Occupation	Frequency	Percent (%)
Trading	60	40.0
Artisan	32	21.3
Civil servant	22	14.7
Sand/Clay miners	36	24.0
Total	150	100

Source: Fieldwork, 2018



**Figure 4: Bar chart of respondents by their occupation**

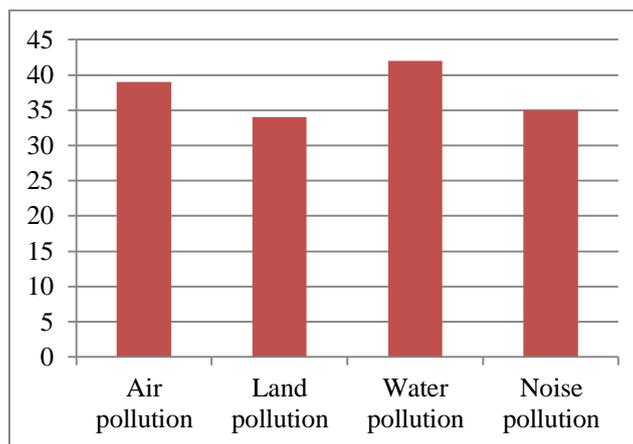
Source: Fieldwork, 2018

Table 2 shows the responses of the respondents as regards pollution in the study area. 26 % of the respondents experienced air pollution, 22.7% experienced land pollution, 28% experienced water pollution and 23.3% of the respondents experienced noise pollution. From this data it is obvious that water pollution and air pollution are the environmental problem experienced in the study area. The data is presented on bar chart (figure 5)

**Table 2: Environmental impact of mining pollution on the environment**

Type of pollution	Frequency	Percent (%)
Air (dust) pollution	39	26
Land pollution	34	22.7
Water pollution	42	28
Noise pollution	35	23.3
Total	150	100

Source: Fieldwork, 2018



**Figure 5: A bar chart of respondents by the environmental problem in the area**

Source: Fieldwork, 2018



**Plate 1: Open pit mining method**  
Fieldwork, 2018



**Plate 2: Artificial pond in the mining site**  
Fieldwork, 2018

### **Effect of method of clay mining the study area**

The study identified that the open pit method was used during clay harvesting in the study area. It employed the use of excavators, pail loaders, shovels and diggers. This information was gotten during the interview session and pictures were taken (See plate 1). The huge deposits of clay in the study area have given rise to heavy mining operations in the area (See Figures 3 & 4).



**Plate 3: The first mining site**  
Fieldwork, 2018



**Plate 4: The Second mining site**  
Fieldwork, 2018

### **Effect of clay mining on surface water**

Mining activities in the study area caused the stagnation of water in open pits which led to the creation of artificial ponds in the site during the rainy season (see plate 2). This situation was

confirmed by Akanwa, Onwuemesi, Chukwurah and Officha (2017b); Asante-kyei and Addae (2016) in their studies. It was also confirmed by the assertion of Sharma and Sharma (2016); Suraj and Neelakan (2014). The artificial ponds, which have led to the death of stray animals, were created as a result of pits in the study area. This is also in agreement with the study of Asante-Kyei and Addae (2016) carried in Ghana.

Observation of the study area revealed that due to the application of open pit method in clay mining there were huge effects of mining operations on the soil, vegetation, trees and surface water. It was also revealed that a large chunk of arable land had been degraded due to mining. Grasses, shrubs, economic trees have been destroyed as a result of clay mining in the area and animals have been displaced from their habitat (See plates 1 and 2). Clay mining has adversely affected the soil, biodiversity and ecosystems in the area. It is also confirmed by studies carried out by Mbaya (2013) and Akanwa (2016) that clay harvesting causes huge losses in vegetation. Additionally, clay harvesting has greatly improved the income level of the miners who are mostly youths selling a truck load of clay resource for ₦6,500 at an average rate of 30 trucks daily.

The nearness of the clay mining sites to the River Eze is a major source of pollution. It was discovered that the mine debris consisting of clay particles and plant particles were deposited into the nearby River. The runoff from the mining site flows into the River and this has altered the natural concentration of the water body. This process was evident as this study was carried out during the rainy season. Silt from the mining site is transported and deposited into the River, thereby causing siltation and colour change (see Plate 5). The major effect of clay on water body is the change of water colour due to the dissolved clay particles in the water. Since clay is made up of different colours such as red, blue, black and grey, water bodies that are affected also assume such colours as shown in (Plate 5). Increased colour may interfere with the passage of light, thereby impeding photosynthesis. Ashraf Muaah, Yusoff, Wajid and Mahmood (2011) affirmed that the deposition of particles downstream pollutes the water body.



**Plate 5: Showing the siltation of River Eze by mine debris from the clay mining site**  
Fieldwork, 2018

**Table 3: Result of Physiochemical analysis of the water samples**

Sample	pH	Turbidity NTU	Conductivity $\mu\text{s}/\text{cm}$	TDS mg/l	TSS mg/l	DO mg/l	BOD mg/l	Pb <sup>2+</sup> Ppm	Zn <sup>2+</sup> Ppm
Sample D-control	6	3.0	43.60	0.54	0.52	41	20	0.143	0.071
Sample A	6.63	7	64.30	0.06	0.04	56	340	0.05	0.113
Sample B	6.74	12	68.70	0.1	0.09	50	200	0.078	0.11
Sample C	6.66	16	69.60	0.04	0.02	62	340	0.054	0.057

Source: Fieldwork, 2018

**Table 4: Descriptive statistics of physiochemical parameters of water samples compared to FMENV Standard.**

S/N	Parameters	Min. Value	Max. Value	FMENV Permissible limit	WHO
1	Ph	6.00	6.74	6-9	6.5-8.5
2	Turbidity	3.00	16.0	-	-
3	Conductivity	43.60	69.90	-	250
4	TDS	0.04	0.54	2000	100
5	TSS	0.02	0.52	30	-
6	DO	41	62	-	-
7	BOD	20	340	30	-
8	Lead (Pb <sup>2+</sup> )	0.05	0.143	<1	0.01
9	Zinc (Zn <sup>2+</sup> )	0.057	0.113	<1	3

Source: Fieldwork, 2018

Huge variations were observed from the physiochemical parameters of the samples analysed. The pH range for this study was 6.00 - 6.74 as presented on Table 4. The control (sample D) had the lowest pH (6.00) and sample C had the highest pH (see Table 3). This result showed that the pH were all within the WHO permissible limit of 6.5-6.9. The result indicated that the river is slightly acidic (6.63, 6.4 and 6.66) probably due to organic acids produced by the clay debris deposited into the river. The pH of water affects the solubility of many toxic and nutritive chemicals. As acidity increases, most metals become more water soluble and more toxic (Asaolu, 2012). The availability of these substances in aquatic organisms therefore can be detrimental.

The conductivity range for this study was 43.60 – 69.60 $\mu\text{s}/\text{cm}$ , the control had the lowest conductivity level of 43.60 $\mu\text{s}/\text{cm}$  and sample C had the highest conductivity. This result is within the tolerable limit of conductivity set by WHO, which is 250 $\mu\text{s}/\text{cm}$ . The TDS value for this study is very insignificant (0.04-0.54 mg/l) compared to the standard set by WHO/FMENV. Additionally, the TSS range for this study is insignificant compared to the FMENV standard. The BOD range of this study was 20-340 mg/l which is higher than the standard set by the FMENV of 30mg/l. The control sample has low BOD of 20mg/l and it is within the permissible limit of FMENV. The other samples A, B and C had high BOD values which are above the permissible limit set by FMENV. The high BOD level is an indication that there is accelerated bacterial growth in the river and that the oxygen levels in the river is consumed. This implies that the oxygen may diminish to levels that are lethal for most fish and many aquatic insects to survive (Muhamad & Muzaffar, 2017). This is obviously ascribed to

organic contaminations entering the river from the clay mining sites which are the only sources of pollution in the area.

The level of heavy metals (lead) analysed was 0.05 ppm. This was above the WHO standard of 0.01ppm. However, the level of Zinc in the analysed samples was within the permissible limit set by WHO. The high levels of lead indicated in the River Eze may have toxic effect on the aquatic ecosystem and the health of the rural dwellers that use the river water directly, without treatment, for domestic purposes (Singh, 2009; Rea & Silberyed, 2009).

The results from the study showed that mining operations alter the natural concentration of River Eze. This is caused by siltation from the mining site. The study concluded that if mining of clay persists in the area without enforcement of laws, it will cause more havoc to the environment especially the water body and loss of vegetation cover and biodiversity. It will also increase other environmental problems in the area. In essence, water quality is highly variable over time due to both natural and human factors. This study was carried out during the wet season and water temperature, photosynthetic activity, nutrient loads, suspended sediment and flows all vary with seasonal changes especially during wet season due to excessive water inflow (run-off mechanisms affect pollutant wash-off). Furthermore, oral interviews from the residents of the community and the miners indicated that they are not environmentally aware of the consequences of their actions on the river. They insisted that traditionally “rivers are flawless” and the deposited clay debris in River Eze find ways of flowing out into other rivers over time without pollution. Though clay mineral is continually demanded for several purposes in the area such as bricks, roofs, walls and floor tiles, pottery, arts, as well as binding agents in industries, unfortunately, there are still high levels of environmental ignorance in the study area as regards their actions.

## CONCLUSION

The study investigated the effect of two clay mining sites on River Eze in Ozubulu. The huge deposits of clay resources have escalated mining activities in the study area. Mining as a vibrant occupation in the area, has without doubt increased the economic conditions of the region by providing employment and means of livelihood for the people, although with adverse effect on the River Eze which is a major source of water supply for domestic, agricultural, industrial and other uses for the rural residents. It is evident from the results of this study that Lead and BOD of the water samples were found to be above the recommended permissible limits stipulated by WHO and FMENV. Other parameters were within the allowable limits, implying that clay mining have altered the water quality of River Eze. However, it is concluded that if the unsustainable clay mining activities is not addressed through the enforcement of laws, monitoring and conservation, it will cause more havoc to surface water supply thereby, frustrating the efforts of sustainable development goals. In order, to reduce the high levels of BOD and Lead present in River Eze thereby ensuring sustainable clay mining the following should be practiced;

- Proper use of clay resources in the study area. This will ensure sustainability through the application of clay resource for highly valued products other than common products like bricks, pottery, tiles and pots. Its abundance and nature of exploration indicates that it's not sustainably harnessed.

- Application of appropriate knowledge, technology and engineering experience to enable proper planning while extracting the resource. This will prevent extensive land degradation and river pollution.
- Protection of water bodies through proper disposal of debris during extraction is expedient since pollution is introduced by clay debris at discharge points along the river and extends downstream as pollutants are transported through river network.
- Monitoring of government policies and better implementation of mining rules by the local authorities covering the mining community.
- Creation of awareness through rural campaigns and programmes in order to avoid sabotage of other efforts employed towards sustainable development
- Regular water quality assessment and pollution control combining natural degradation and dilution by natural run-off to reduce downstream effects of Lead and BOD excessive levels.

## REFERENCES

- Aigbedion, I & Iyayi, S. E. (2007) Environmental Effects of Mineral Exploitation in Nigeria. *International Journal of Physical Sciences*, 2 (2): 33-38.
- Akanwa, A. O. (2016) Effect of quarrying activities on local vegetation cover in Ebonyi State, Nigeria. A Ph.D. Thesis from the Centre for Environmental Management and Control (CEMAC) University of Nigeria Nsukka (UNN), Nigeria.
- Akanwa, A. O., Okeke, F. I., Nnodu, V. C. & Iortyom, E. T. (2017a). Quarrying and its effect on vegetation cover for a sustainable development using high resolution satellite image and GIS. *Journal of Environmental Earth Sciences, Springer*, 76, ( 4),1-12.
- Akanwa, A. O., Onwuemesi, F. E., Chukwurah, G. O. & Officha M. C. (2017b) Effect of open cast quarrying technique on vegetation cover and the environment in South Eastern, Nigeria. *American Scientific Research Journal for Engineering, Technology and Sciences (ASRJETS)*, 21, (1), 227-240.
- Akanwa, A.O & Ikegbunam, F.I (2017) Mineral Exploitation, A Risk Factor in Achieving Environmental Sustainability and the Millennium Development Goal in Nigeria. A paper presented on the Evaluation of Millennium Development Goals in Nigeria 2<sup>nd</sup> International Conference on the Environment (FESCON, 2017). Chuwuemeke Odumegwu Ojukwu University (COOU), Uli, Anambra State.
- Akanwa, A.O., Onwuka, S.U., Okoye, A.C & Onwuemesi, F.E (2011). Assessment of Ground water Quality around Open Waste Dump Sites in Ifejika and Obosi in Anambra State: *Anachem Journal*, 5 (1): 903-910
- Aramide, F. O., Alaneme, K. K., Olubambi, P. A., & Borode, J. A. (2014) Characterization of some Clay Deposits in South West Nigeria. *Leonardo Electronic Journal of Practices and Technology*, 25: 46-57.

- Asante-Kyei, K & Addae, A. (2016) The Economic and Environmental Impacts of Clay Harvesting at Abonko in the Mfantisman West District of Central Region, Ghana. *American Scientific Research Journal of Engineering, Technology and Sciences*, 18 (1): 120-132.
- Ashraf, M.A., Muaah, M. J, Yusoff, I., Wajid, A., & Mahmood, K. (2011) Sand Mining Effects, Causes and Concerns: A Case Study from Bestari Jaya, Selangor, Pennisular Malaysia. *Scientific Research and Essays*, 6 (6):1216-1231.
- Ayantobo, O. O., Awomeso, J. A., Oluwasanya, G. O., Bada, B. S., & Taiwo, A. M. (2014). Gold Mining in Igun-Ijesha South West Nigeria: Impacts and Implications for Water Quality. *American Journal of Environmental Sciences*, 10 (3): 289-300.
- Azapagic, A. (2004) Developing a Framework for Sustainable Development Indicators for the Mining & Minerals Industry. *Journal of Cleaner Production*, 12: 639–662.
- Badmus, B. S., & Olatinsu, O. B. (2009) Geophysical Evaluation and Chemical Analysis of Kaolin Clay Deposit of Lakiri Village South Western Nigerian. *International Journal of Physical Sciences*, 4(10):592-593.
- Moughtin, C., Cuesta, R., Sarris C. & Signoretta, P.(1991) *Urban Design: Methods and Techniques*. Great Britain: Architectural Press.
- Garrett. H (1968) The Tragedy of the Commons. *Science*. 162 (3859):1243-1248.
- Igbokwe, P. K., & Ogbuagu, J. O. (2003) Effects of Process Parameters on the Extraction of Aluminium from Indigenous Kaolinite Clay Deposit. *Nigerian Journal of Engineering Research and Development*, 2 (2): 23-26.
- Igwe, P. U. (2016) Deforestation: Impacts on the Socioeconomic Activities of the people of Ekwusigo Local Government Area, Anambra State, Nigeria. *African Journal of Education, Science and Technology*, 3(2):76-82.
- Jaiye, D. J. (2013) The Environmental Implication of Illegal Mining Activities in Nigeria: A Case Study of Pandogari and Barkin Ladi/Buruku Surface Mines in Niger/Plateau States. *Journal of Humanities and Social Sciences*, 13 (5): 13-19.
- Johnson. S.W (1997) Effects of Submarine Mine Tailings Disposal on Juvenile Yellow fin Sole (*Pleuronectes asper*): A Laboratory Study. *Marine Pollution Bulletin*, 36 (4)
- Karmaka, H. N, & Das, P. K. (2012). Impact of Mining on Ground and Surface Waters. *International Mine Water Association*. pp. 187-198.
- Kefas, H. M., Patrick, D. O. & Ciroma, T. M. (2007). Characterization of Mayo-Belwa Clay. *Leonardo Electron Journal of Practices and Technologies*, 11: 123-130.
- Lawal, A. O., & Abdullahi, Y. (2010). Evaluation of Industrial Potentials of Alluvial Clays from the Confluence of Rivers Niger and Mimi. *Science World Journal*, 5 (3): 213-221
- Mason. R.P. (1997) “Mining Waste Impacts on Stream Ecology”. In C. D. Da Rosa (Ed.). *Golden Dreams, Poisoned Streams, How Reckless Mining Pollutes America’s Waters and How We Can Stop It*. Washington, DC: Mineral Policy Center.
- mit.edu (2015). Mining. Retrieved 2018, from Mission 2015: Biodiversity: <https://web.mit.edu/12.000/www/m2015/2015/mining.html>
- Obaje, S. O., Ombada, J. I., & Dambatta, U. A. (2013). Clays and their Industrial Applications: Synoptic Review. *International Journal of Science and Technology*, 3 (5):264-270.

- Okwa, O. O., Akinmolaya, F. I., Carter, U., & Hurd, H. (2009). Transmission Dynamics of Malaria in Four Selected Ecological Zones of Nigeria in the Rainy Season. *Annals of African Medicine*, 8 (1):1-9.
- Sharma, G. & Sharma, A. (2016). Clay and Clay Minerals in Bikaner: Sources, Environment Pollution and Management. *AIP Conference*
- Suraj, R. & Neelekan, R. (2014). Clay Mining Areas and its Impact over the Hydrologic Ecosystem in a Mining District, South India. *International Journal of Advancement in Remote Sensing, GIS and Geography*, 2 (2): 18-26.
- Tauli-Corpuz, V. (1997, January). The globalisation of mining and its impact and challenges for women. Retrieved 2018, from Third World Network: <https://www.twn.my/title/mining-cn.htm>
- Tejpal, Jaglan, M. S., & Chaudhary, B. S. (2014). Geo-environmental Consequences of River Sand and Stone Mining: A Case Study of Narnaul Block, Haryana. *Transactions Institute of Indian Geographers*, 36 (2): 217-234.
- UNEP (1997). *Industry and Environment, Mining and Sustainable Development*. Available online at: <http://www.uneptie.org/vol20no4.html>
- WHO (2006) Guidelines for Drinking – water Quality. 1st Addendum VI.1.Recommendations. 3rd Edition, 2006. [http://www.who.int/water\\_sanitation\\_health/dwq/gdwq0506.pdf](http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf) Accessed on 18/01/2009
- World Commission for Environment and Development (WCED) (1987). *'Our Common Future'*. Oxford University Press