

Reclamation of the Enugu Coal Mine Site at Abandonment

Amosu Cyril Olumuyiwa



Abstract: Mining of coal (fossil fuel) resources in Enugu resulted in groundwater pollution/depletion and left the mine site with the potentials of air pollution, loss of landscape/aesthetic degradation and soil contamination. Other Environmental impacts were extensive soil damage, alteration in microbial communities and affecting vegetation leading to destruction of vast amounts of land and displacement of dwellers. Reclamation is the process to restore the ecological integrity of these disturbed mine land areas. It includes the management of all types of physical, chemical and biological disturbances of soils such as soil pH, fertility, microbial community and various soil nutrient cycles that makes the degraded land soil productive. Mining does not mean permanent loss of land for other use. On the other hand it holds potential for altered and improved use apart from restoring for agriculture, forestry and irrigation. This paper attempts to view the best practices for reclaiming the abandoned Enugu coal mine site which ceased production since 2002.

Keywords: Reclamation, Mining, Coal, Enugu, Soil, Production, Abandoned



Figure 1: Locational Map

I. INTRODUCTION

Location and Geology of Enugu Coal Mine

The Enugu coal mine is situated in Nigeria with the geographical position system (gps) coordinates of latitude and longitude of 6° 27' 35.8704" N and 7° 32' 56.2164" E. It has its Universal Transverse Mercator (UTM) for easting and northing as 339,535.91 and 714,279.07. Coal geology is a mixture of sedimentary rock and ancient vegetation which have been changed due to heat and microbial activities over considerable period of time (see figure 1 – 5).

The first discovery of coal was in 1909, in Enugu, at the ridge of Udi. This was discovered by a British mine engineer called Albert Kitson. Coal extraction (figure 6) started with the Ogbete mine in 1916. The Enugu coal mine production attained about 183,012 tonnes in 1920 and about 574,758 tonnes in 1960. However, production got crippled and abandoned in the mine due to the civil war which went on the 6th of July, 1967 to 15th of January, 1970. All efforts for revamping and recovery met a brick-wall. The major aim for the application of the Enugu coal is for the running of the Nigeria railway works.



Figure 2: Enugu from the west



Figure 3: Satellite image of Nigeria Enugu Escarpment

Manuscript received on 8 October 2021 | Revised Manuscript received on 28 October 2021 | Manuscript Accepted on 15 November 2021 | Manuscript published on 30 November 2021.

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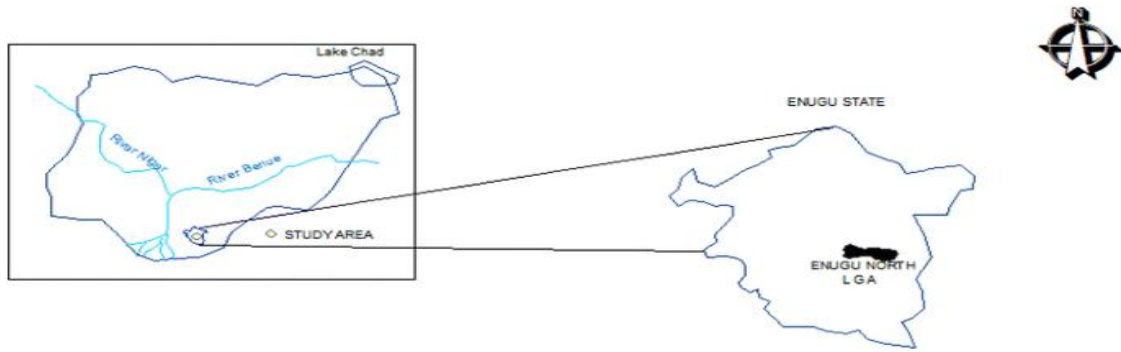


Figure 4: Study Area: Map of Enugu Coal Mine in Nigeria



Figure 5: Enugu Coal Mine Enugu in Nigeria (sciencedirect.com)



Figure 6: Enugu Ekulu Coal Mine (ejatlas.org; engineersforum.com.ng; mosaicmanagementltd.com and grassroot.ng)

Mine Site Remediation Issues

1. Soil:

Apart from landscape damage, the operations of mining create sands that are laden with heavy metals that have mixed with the parental soils which eventually contaminates land areas and water bodies (see Figure 7).



Figure 7: Acid Mine Drainage in Enugu coal mine causing Water and Soil Contamination (dayoadedayo.com)



2. Water:

- a) The main sources of pollution associated with mining is acid mine drainage (AMD) (see Figure 7) caused by pyrite (especially exposed iron sulphide) which reacts with the water and oxygen, forming sulphuric acids and dissolving iron which later precipitates (yellow, orange or yellow sediments) down to aquifers sources (surface and ground water) which invariably causes harm to man, wildlife and the environment (Ezemokwe and Madubuike, 2015) WHO (2011) also made report of a total dissolved solids (TDS) values that range between 21.80 mg/l and 520 mg/l that were below their permissible limits of 0.00-1500 mg/l even though these may still be hazardous to the aquatic ecosystem in the location (WHO, 2011).
- b) Slurry tailings that are dumped into water or close to it contaminates it through leaching which leads to death of aquatic life and hazards to the ecosystem.

3. Air Quality:

Fugitive dust increases the particulate matter (PM) in the composition of the air around the location of mine which when inhaled causes serious respiration hazard.

Reclamation Solutions

1. Revegetation and Reforestation:

Plants (Grasses, trees, etc.) which can inhabit animals are cleared and relocated under the supervision and instruction of professionals and properly saved for future reclamation, ever before mining operation commences.

The nature of soil to relocate should possess microbes like bacteria so as to provide the necessary nutrients for the growth of plant. Such microbes include *Agrobacterium rhizogenes*, *Pseudomonas fluorescens*, *Ectomycorrhizal fungi* and *rhizosphere bacteria*. The fixing of fungi and bacteria at the same time gives correct and significant effect, and prevents behaviour of opposition (Krummelbein and others, 2012). For best results, the following process is adopted:

The selection of plants/crop should be based locational adequacy and behaviour for advancing the productivity of neighbourhood soil, according to the following conditions which are viewed as advantageous to make available new ecosystem for fauna and flora, to hold water, retain carbon dioxide and profit the weather (Logters, 2004):

- i. Minimal applications of fertiliser to the soils dumped initially
- ii. Remains of plants and its root proceeds.
- iii. High application of dumped substrates that has potential production
- iv. Minimal necessity for storage of water;
- v. Inherent penetration and crop's root absorption potentials

The choice of cultured species is normally advised when revegetating. Afforestation is embraced to return the area of mining into an environment enveloped with trees. The Forestry Reclamation Approach (FRA) has imbibed a new step to afforestation for surfaced mines that are already abandoned which are viewed in five ways (Sullivan and Amacher, 2010):

- establishing an adequate plant root system suitable better growth;
- redressing the topsoil in a loose manner;

- applying land covers that are suitable for tree improvement;
- planting valuable crops and trees that are viable, on time
- applying the best tree techniques of planting.

2. Soil Amendments:

Topsoils will be reused after being removed and stockpiled initially; but where the topsoil does not exist, new soil is needed which must be compatible with the environment. Deeper soils from the minesites can be combined with top soils (NSE, 2009). Vigorous revegetation is advised to appropriate new growth of the roots of crops into the soils for a long period mostly when the weather is wet, (Krummelbein and others, 2012). Soil analysis should be carried out at different stages of mining in order to assess it before mining begins and at the time of revegetation armed with adequate knowledge of the concepts applied and the unknown connected with samples (Hursthouse 2012). For these soils to become reusable, they will go through the restoration process, of which mine spoils does not possess nitrogen, carbon and phosphorus (Tripathi and Singh, 2008). Also low or acidic pH should be remediated by applying lime or ash for good return of plant growth (Bian and others, 2010; Krummelbein and others, 2012). In all of these, the best suggested depths is not more than 100 cm. The quantity of the fertiliser and its type required to improve the topsoil relies on the state of the covering soil on the minesite and its anticipated use (i.e. forestry or to agricultural). Sewage sludge and other organic residues can be used to improve the structure of the soil and its water-retaining propensity.

3. Water Drainage:

This is beneficial as a function of local geo-topography. Here, stones are applied to water drainage canals in order to avert loss of water and erosion of soil (Jason, 2015).

4. Refill and Ground Surface Reshaping:

Once mining is complete in a specific area at the mine, active reclamation begins, even as other parts of the mine are in operation. The first step is to refill the ground with gangue and reshape the surface, according to the specifications set in the original mining permits, and determined based on the original terrain (Jason H., 2015).

Reclamation and Rehabilitation: Statutory Provisions, As Per MCDR, 1988

1) As Per Section 23 – Abandonment of Mines:

- a) The owner of mines, contracted mining engineer, or mine manager of every mine shall communicate to the Regional Controller, Mine Controller, Controller General, with specific notice to get to them within ninety days when abandonment comes to play.
- b) This specific notice shall be followed-up with sectional plans on any suitable scale.
- c) The manager, mine owner, mining engineer and agents in mines are not to abandon a mine fully or in part.
- d) Unless a final mine closure is reached, he leaseholder is not advised to abandon any portion of the mine

e) The authorized officer on board kicks against any form of abandonment; and if it he chooses to , it has to be on his own terms and conditions.

2) **As Per Section 34 - Reclamation And Rehabilitation Of Lands:**

Phased restoration, rehabilitation and reclamation of abandoned mines shall be carried out by holders of licences or by those who vie for mining lease or license during mining operations before final abandonment of mine (Sauvick M. and Krishna K., 2016).

II. LITERATURE REVIEW

The most critical processes in the ecosystem development include colonization by appropriate selected species, accumulation of nutrients both in plants and soils, changes in soil structure and reduction in toxicity, these critical processes lead to distinct and characteristic flora (Bradshaw, 1983; Hington and Lindman, 1987). Successful biological reclamation restores the natural capital of biota and productivity of land, which have been previously destroyed by mining operations (Sheoran and Poonia, 2010). If preserved surface soil layer is going to be used in agricultural reclamation, Ličina et al. (2017) suggest a prior metal assessment as a component of a future rehabilitation policy for topsoil in food and fodder production (Ličina et al, 2017). According to Miletic (2004), one of the main limiting factor for the growth and development of the forest trees on the reclaimed mine soils in mining basin is the lack of nitrogen (Miletic 2004). Previous studies have shown that bioremediation uses biological agents such as fungi, bacteria, and green plants (phytoremediation) to remove, mineralize or neutralize hazardous substances in soil (Adetitun et al, 2018; Akande et al, 2018 and Abbaslou and Bakhtiari 2017). Previous studies have revealed that wastewater use for irrigation and waste disposal on the soil results in heavy metal accumulation in soils and bioaccumulation in plants beyond maximum permissible limits for both humans and livestock consumption (Alam et al, 2018; Karbassi et al,2014 and Ghaderi, 2012). The

Reclamation for forestry is decided by the topography or terrain, and the soil property (Simmons, 2008). The approach of gangue filling reclamation technology is appropriate for all kinds of mining areas (Miao and Zhang, 2007). Switchgrass has been used in reclamation studies on roadsides (Skousen and Venable, 2008), surface mines (Skeel and Gibson, 1996; Marra and Skousen, 2012; Dere et al., 2011), sand and gravel mines (Gaffney and Dickerson, 1987), lignite overburden (Skousen and Call, 1987), and lead and zinc mines (Levy et al., 1999; Skousen, and Venable. 2008; Skeel, and Gibson, 1996; Dere, Stehouwer, and McDonald. 2011; Gaffney and Dickerson. 1987; Skousen and Call,1987; Levy, Redente and Uphoff. 1999). Ore deposits are often associated with arsenic, lead, mercury and other toxic metals which often find their way into the air, water and food chains once they are released from underground rock formations during mining (Amosu, Enitan and Eniola, 2021).

III. MATERIAL AND METHODOLOGY

Data Collection

Table 1: The Nigerian Coal Corporation – A Production Performance Evaluation from 1960–1987.

Production Levels	
Years	Tonnes Produced
1916	25,511
1920	180,122
1930	347,115
1940	318,594
1950	583,425
1960	565,681
1970	24,404
1980	118,317
1987	117,159
EQUATION	$y = -323.6x^2 + 1E+06x - 1E+09$
R²	R² = 0.578

Quantitative Economic Research Bureau (Godwin, 2008).

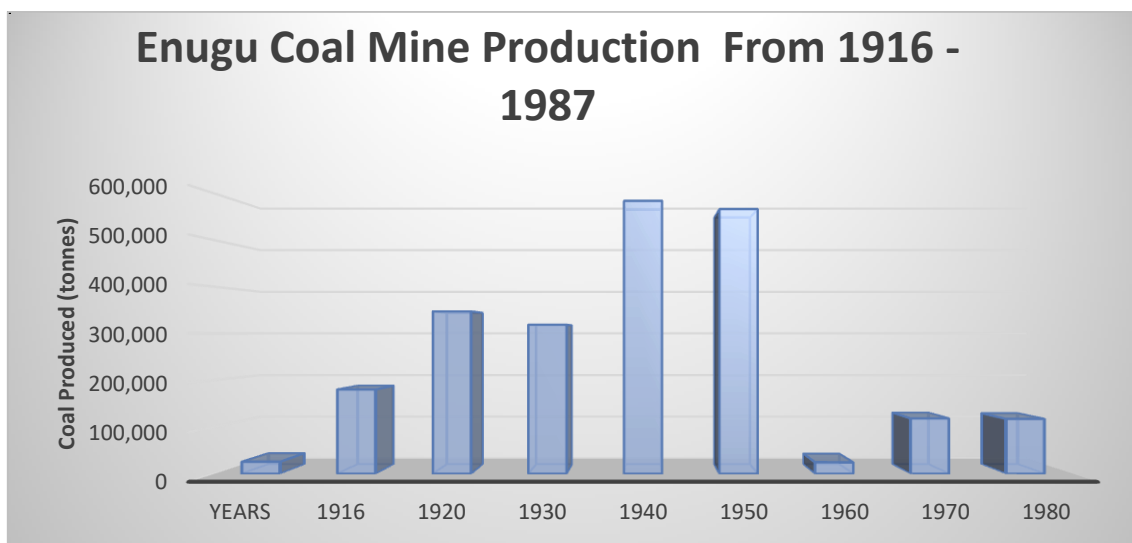


Figure 8: Annual Production capacity of coal in Enugu Coal Mine.



Table 2: Analysis and report of Ezemokwe and Madubuiké, 2015 showing the quality of water in two mine zones situated in Enugu (i.e. Onyema and Okpala) in which he discovered the mean values of some heavy metals as 5.5mg/l.

Heavy Metals	Metallic Concentrations (mg/l)
Cadmium	0.33
Arsenic	0.06
Lead	0.53
Chromium	0.06
Mean Value	5.4

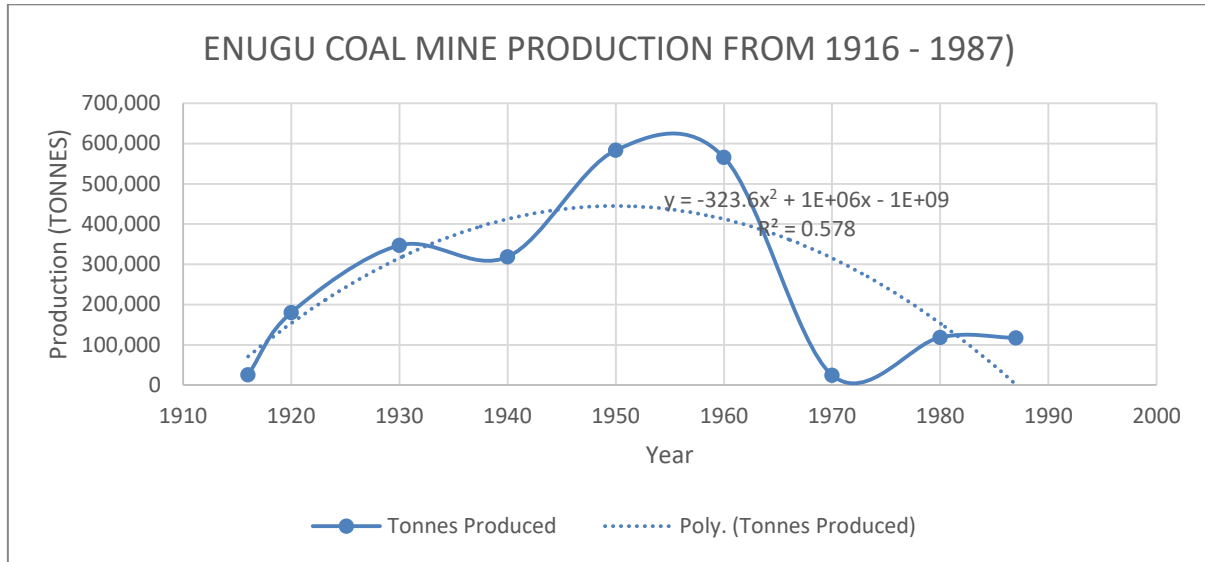


Figure 9: Straight line plot for the annual production capacity of coal in Enugu Coal Mine.

This exceeds the permissible limits of the World Health Organization (WHO) of 0.0-5.0mg/l for all identified metals (WHO, 2011).

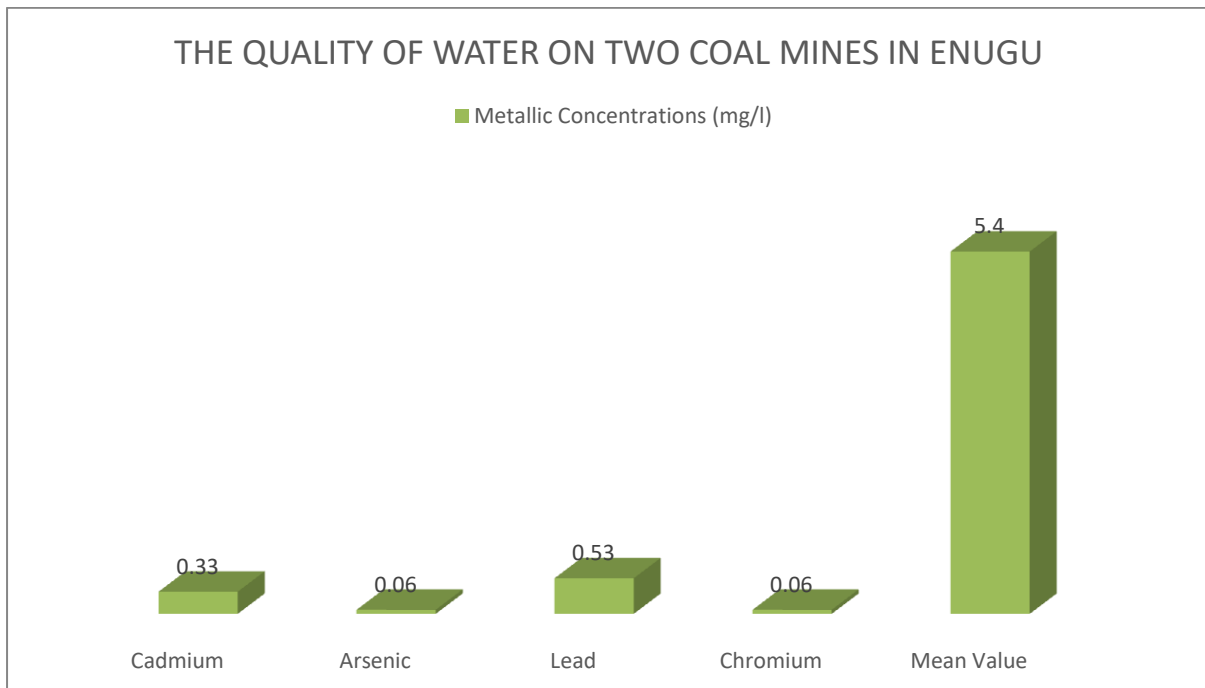


Figure 10: Metallic Contamination of the quality of water after production is carried out in the Enugu Coal Mine.



Data Review and Analysis

Considering Figure 8, as compiled by Godwin, 2008, the production capacity for coal kicked-started sweetly at a high production rate of 25,511 tonnes per year in 1916. This rose continuously until a peak of 583,425 tonnes was produced in 1950. Production however declined the next year by about 3%, in 1960. It picked up again with high hopes to 118,317 tonnes which it maintained with a little rise later, but which also dropped at the close of 1987 by another 0.9%.

Figure 9 confirms the certainty in data of production that was discussed previously; using the polynomial order, the correlation was calculated as R^2 equals to 0.578 showing there is almost average chance of either an advance or decline in coal production rate on the Enugu Coal Mine.

Using Figure 10, compiled by Ezemokwe and Madubuike, 2015; it is evident that the metallic concentrations in the Enugu Coal Mine is getting alarming since it exceeded the permitted mean threshold for the hazardous metallic compounds found on it.

IV. RESULTS AND DISCUSSION

The production on the Enugu Coal Mine declined at the tail-end of production year in 1987. Even though it had the potential for future production, it got abandoned possibly due to the high value of hazardous concentrations of metals that came with its coal production.

V. CONCLUSION AND RECOMMENDATION

The program of reclamation is essential after mining activities is terminated in a minesite, for sufficient restoration and return to original state. There are many alternatives for this process of restoration of land integrity. Government should assist for funding through revenues, levies and other supports. Legal acts should be promulgated and permission to work or get licence/lease should be adequately put in place to check mining operations before and after it commences.

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