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Short communication

The environmental implications of the exploration and exploitation of solid minerals in Nigeria with a special focus on Tin in Jos and Coal in Enugu

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ABSTRACT

Mining activities can have serious negative effects on the environment, these effects occur from the exploration stage to the closure stage of a mine's operation. Nigeria has different minerals and exploration/exploitation of these minerals can affect the environment. The objective of this paper is to consider how the exploration and exploitation of Tin in Plateau and Coal in Enugu has affected the environment. The Jos field (Plateau State) is used as a case study for areas with existing mines and the coal mines at Enugu represent areas with closed mines. The methodology used for this research includes a field survey; direct mapping of mining activities; assessment of the impacts of exploration and exploitation; documentary analysis; and observations. The results include analysis of the mining impacts of Tin and Coal on the environment. It is hoped that the conclusion of this study will enable Nigeria to put in place and enforce certain minimum environmental standards for solid mineral exploration and exploitation. In addition, best management practices for reclaiming surface mines could also be put in place.

1. Introduction

A mineral can be defined as a naturally occurring element or chemical compound, crystalline in nature, formed as a result of geological processes (Nickel, 1995). They occur as aggregates, commonly referred to as rocks (Oshin, 2003). Minerals can be classified into the following groups based on their composition and uses: metallic minerals (e.g. Iron and Gold.); industrial minerals (limestone and baryte); construction minerals (gravel sand and rock aggregates); gemstones (Emerald and topaz); and mineral fuels (Coal and hydrocarbons).

For any mineral to be exploited, exploration must have taken place. The exploration phase includes a geological survey, an airborne geophysical survey, geochemical analysis, and reserve estimate. After a mineral deposit has been proven to be commercially viable, exploitation activity may commence (Newman, Rubio, Caro, Weintraub, & Eurek, 2010; Al-Usmani, 2011). The exploitation stage of a solid mineral consists of the mining of the relevant mineral. Mining could be open-pit when the mineral deposit occurs at shallow depths (e.g. coal and tin) and underground mining (coal). All the stages of mining result in different environmental damages (Newman et al., 2010; Al-Usmani, 2011), which were highlighted in a flow chart by Ashton, Love, Mahachi, and Dirks (2001); Pring, Otto, and Naito (1999) and Miranda et al. (2003).

Nigeria is a country endowed with vast and varied solid mineral resources which are widely distributed in virtually all of the states within the federation, including the Federal Capital Territory. Aigbedion and Iyayi (2007), Mallo (2012), and Adekoya, Kehinde-Philips, and Odukoya (2003) listed some of the minerals in Nigeria and their current level of exploitation. There have been a series of negative reports from illegal mining of gold and mercury in the Northern part of Nigeria. If mining activities are not monitored and best practices are not put into place, the consequences can be devastating. Therefore, there is a need to protect the environment and the monitoring of mining activities is required.

The objective of this study is to consider how the exploration and exploitation of Tin in Plateau and Coal in Enugu have affected the environment. The Jos field (Plateau State) is used as a case study for areas with existing mines and the coal mines at Enugu represent areas with closed mines. This study hopes to enable Nigeria to put in place and enforce certain minimum environmental standards for solid mineral exploration and exploitation. In addition, best management practices for reclaiming surface mines could be put in place.

Earlier studies on the environmental implications of solid mineral exploration and exploitation in Nigeria encompassed studies on selected aspects of the environment, i.e. water and ecology, and these studies seldom encompassed the entire environment. Musa and Jiya

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(2011) assessed the impact of Mining Activities on Vegetation in Jos Plateau using the Normalized Differential Vegetation Index (NDVI) and concluded that mining greatly affected the natural ecology of the study area and organisms and plants were stripped of their natural habitat due to tin mining activities. Gyang and Ashano (2010) assessed the effects of mining on water quality in some selected parts of Jos Plateau and concluded that tin mining has no significant effect on the quality of water in the region. Ndace and Danladi (2012) assessed the biophysical impacts of tin mining activities in Jos, and he concluded that mining has greatly affected the natural ecology and therefore mining sites should be monitored, their environmental damages should be determined, mitigation studies should be performed, and there should be regular inspections to keep these activities under control. Qureshi, Maurice, and Öhlander (2016) assessed the potential of coal mine waste rock in generating acid mine drainage (AMD) and concluded that the waste rocks (WRs) have significant AMD-generation potential and may significantly impair the quality of natural waters, by leaching excessive quantities of major and trace elements, when compared to the world health organization (WHO) drinking water standards.

2. Methodology

The methodology used for this research included a field survey by visual inspection and land surveying; direct mapping of mining activities; assessment of exploration and exploitation impacts (which was carried out by visiting the site, analyzing and assessing each impact on the atmosphere, landscape, lithosphere and hydrosphere); documentary analysis by reviewing literature; and observations (physical). Each method presents various opportunities for gathering as much information as possible on the potential environmental implications of mineral exploration and exploitation activities.

Two specific study areas with different types of minerals were visited in order to discover the environmental implications of exploration and exploitation activities. In the study, *the northern and the southeastern parts of Nigeria* were visited to see the type of exploration and exploitation activities carried out and their impacts on the environment. The Jos Plateau with a metallic mineral (Tin) was chosen as the northern sector of Nigerian mining activity and Enugu (Coal) as the southeastern part of Nigeria. These places were chosen because of active mining activities which are ongoing in these regions.

As stated earlier, Nigeria is endowed with abundant and varying mineral resources, which occur in various geological terrains of Nigeria. Fig. 1 shows the geological map of Nigeria. There is an almost equal distribution of the Pre-Cambrian Basement Complex of Nigeria and Cretaceous Sedimentary rocks. The basement complex rocks and the associated older and younger granites contain substantial solid mineral resources, some of which are gold, iron, tin and several gemstones. The sedimentary rocks are host to hydrocarbons (coal).

2.1. Tin (cassiterite)

The Jos Plateau is located within the middle belt of Nigeria covering an area of 8600 km^2 with an approximate distance of 104 km from north to south, and 80 km from east to west. It has steep escarpment edges with a descent of about 600 m to the surrounding plains. The southern part of the Jos Plateau extends towards the River Benue flood plain and is located in the Benue lowlands. The coordinates are: latitude 10°11′N and 8°55′N and longitude 8°21′E and 9°30′E (Musa & Jiya, 2011; Ndace & Danladi, 2012). The geological sequence of the Jos Plateau and its environs is almost entirely made up of plutonic and volcanic rocks belonging to four main age groups, with sediments restricted to valley alluvium (Table 1). Geologically, Younger Granites, a series of non-orogenic intrusives and associated volcanics dominate the area. The Jos Plateau forms the focal area of the Younger Granite province and it is the principal center of the associated tin and columbite mineralization. Early volcanic members, largely rhyolites and acid tuffs, are preserved through cauldron subsidence or in deeply eroded vents. These were succeeded by granitic ring-dykes and plutons, composed of hornblend, biotite and riebeckite-granite. Minor basic and intermediate rocks are also represented. The Younger Granites have recently been shown to be of Jurassic age.

Tin in Jos-Plateau is one of the oldest mineral resources known worldwide and is of importance because of its hardening effect on copper. Its mineral exploration and exploitation activity boomed within Nigeria and, since then, tin ore has been mined in several parts of Nigeria including the Plateau Province, Bauchi, and Ilesha, with over 80% of the production coming from the Jos Plateau. The exploration for tin started in the early part of the last century. In tin mining in Plateau, the open cast mining method was used because the plains of Plateau were flat and tin was concentrated in old stream beds and was washed down from the younger granite outcropping units (Gyang & Ashano, 2010).

Tin was mined from the Jos Plateau, with the cassiterite mineral coming from the plateau highlands. There was a rapid increase in production from 1.36 tons in 1904 to 5573 tons over a period of ten years, and the highest production level was 15,842 tons in 1943. An unmined reserve of about 3500 tons is still believed to exist in the sub-basalt tin of Ngell (Mallo, 2012).

2.2. Coal

Coal is now known to occur in several parts of Nigeria, but the first and most studied is Enugu Coal. The coal resources discovered in Nigeria occur within geological units known as "Coal-measures". The coal measures (Fig. 2) are concentrated within the Anambra Basin, but also occur in other rocks within Nigeria such as Lafia-Obi in Plateau state, Lamja, Gombe in Bauchi state and Afikpo in Imo state. The Oyeama mine and Okpara mine are in Anambra State while the Owupka and Okaba coal mines are in Benue State (Ezekwe & Odukwe, 1980; Godwin, 1980). Coal outcrops were discovered by British geologists in 1909 and actual mining started in 1916 in Enugu. Results of detailed geological mapping and drilling revealed that the Enugu area has five coal seams. According to Coker (2003), the coal seams are of good quality and dip to the west or West-North-West (WNW) at a low angle of 1°–3°. Six fault systems striking WNW are located within the coal beds.

The major types of coal are lignite, sub-bituminous, anthracite and bituminous (Idris, Onaji, Aberemi, & Aroke, 2016). A little below bituminous, in terms of quality, is sub-bituminous which is the major type found in Nigeria (Ezekwe & Odukwe, 1980; Godwin, 1980). The Nigerian Coal Corporation (NCC) operates four mechanized long wall faces at Enugu (Godwin, 1980). Coal can be mined by both the open cast mining method and the underground mining method. Nigeria's most exploited coal mines are located at Enugu where NCC operated two underground coal mines and commercial production started in 1916, the peak in coal production was in the late 1950s reaching approximately 920,000 tons per annum. After this there was a sharp decrease in production because of the Nigerian civil war, which started in 1966 as the mines were abandoned and flooded, and in 1968 coal output was nil. Production resumed in 1972 after the war. In 1976, coal mining was mechanized but the mechanization failed and, to date, the corporation encountered many problems and the mines were later abandoned at a point of no recovery (CPE-TEMEC, 2009; Godwin, 1980; Ogunsola, 1990).

3. Results

3.1. Direct mapping of mining activities and the field survey

Exploration for minerals include geological mapping and remote sensing, both of which rarely impact the environment. Detailed geological mapping and ground geophysical follow-up require the cutting of

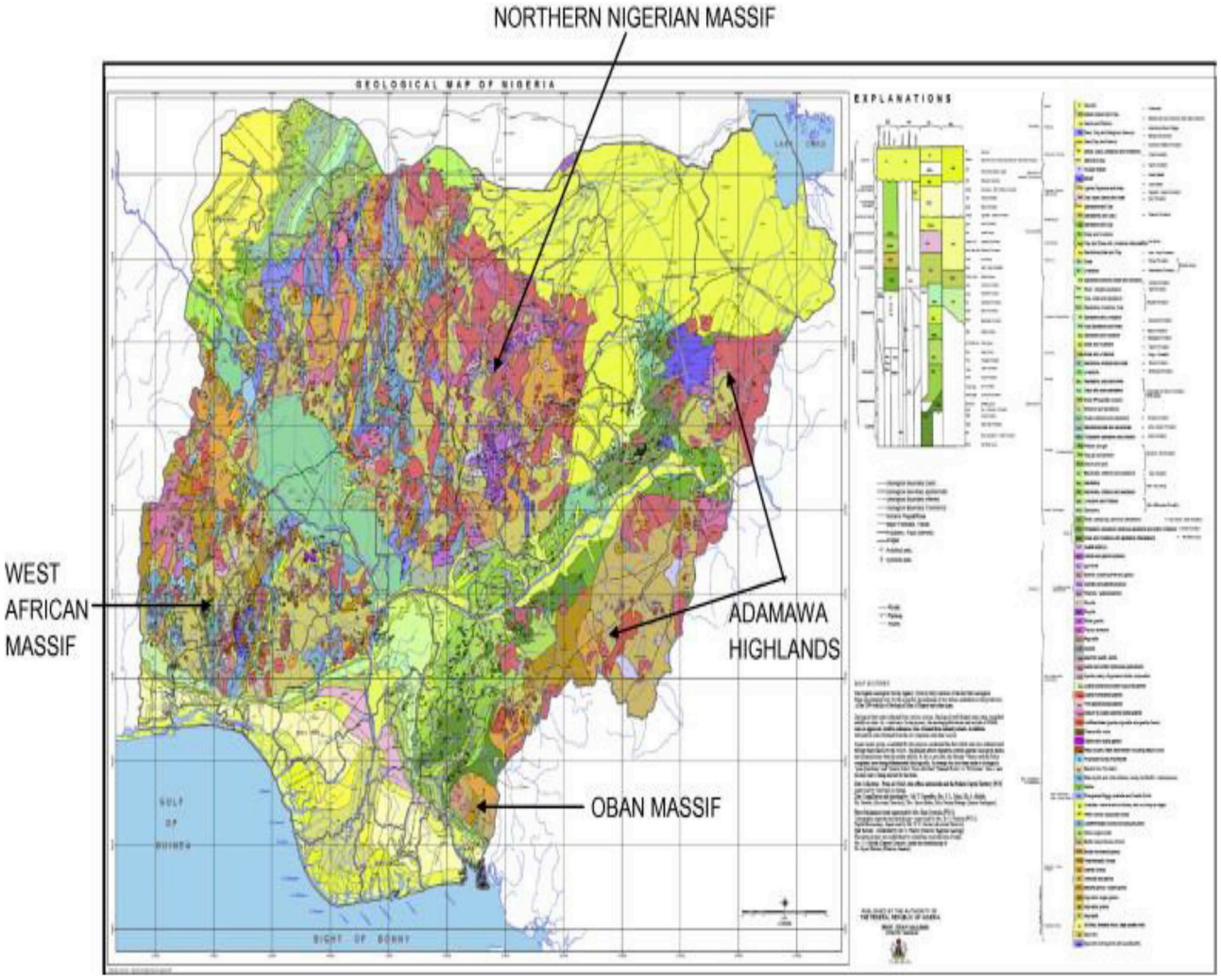

Fig. 1. Geological map of Nigeria.

traverses, pitting, trenching and drilling. These activities have minimal impact on the environment, except for the destruction of vegetation, noise and vibration, groundwater aquifer contamination through drilling, and fluid disposal (Al-Usmani, 2011; Ezeaku, 2012; Musa & Jiya, 2011).

Exploitation of solid minerals consists of site preparation, mining, mineral processing, transportation of raw materials to processing site(s) and mine closure or abandonment. The environmental impact of exploitation includes air, land and water pollution, damage to vegetation, ecological disturbance, degradation of the natural landscape, radiation hazards, geological hazards and socio-economic problems (Aigbedion & Iyayi, 2007; Miranda et al., 2003).

3.2. Assessment of exploration and exploitation impacts; documentary analysis and observations

Tin and coal have gone through the exploration stage, and exploitation has been ongoing for many years, therefore, the effect of their exploration and exploitation is quite apparent. It is hoped that the observed impacts on the environment from the exploitation of tin and coal will be useful antecedents in putting together a comprehensive environmental management standard for the mining industry.

3.2.1. Tin (cassiterite)

In the Jos Plateau mining sites, a period of erosion followed the formation of the Younger Granites, resulting in the formation of the major morphological units of the Jos Plateau and the surrounding Kaduna-Bauchi plains. Alluvium deposited by the Plateau Rivers was covered in early Tertiary times by the extensive lava flows of the Older Basalts. The basalts have largely decomposed to clays capped by laterite and dissected by subsequent erosion. Later deposits of alluvium are the source of most of Nigeria's cassiterite production, a further volcanic episode provided the well-preserved cones and the lava flows of the Newer Basalts. It is known that almost all tin production on the Plateau

Table 1
A generalized succession of rock in the Jos Plateau and environs.

Quaternary	Newer Basalt	Lava flows and volcanic cores
Tertiary-Quartenary	Alluvium	
Lower Tertiary	Older Basalt	Lava flows now largely decomposed overlying alluvium
Jurassic	Younger Granite	Granites, Porphyries and rhyolites
Pre-Cambrian to Lower Paleozoic	Crystalline Basement	Migmatites, gneiss and older granites

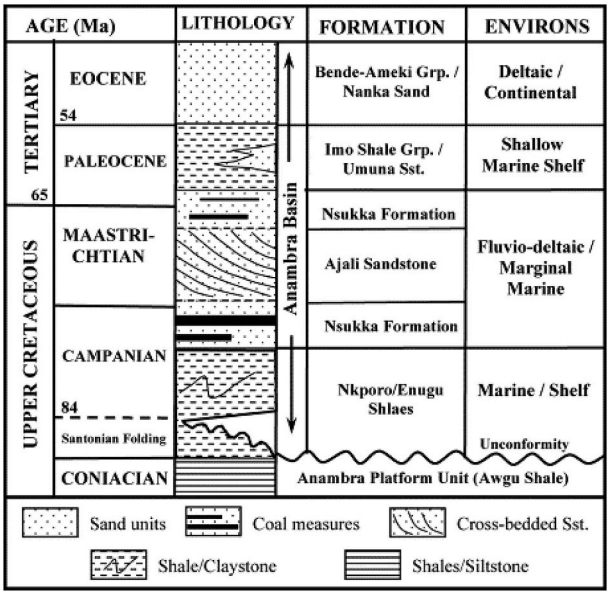

Fig. 2. Origin and stratigraphy of the Anambra basin (Tijani & Nton, 2009).

is derived from alluvial concentration shed from the Younger Granites. However, some are also mined from pegmatites. (Macleod, Turner, & Wright, 1971). Various techniques have been used to map the buried river channels and pegmatites; these being magnetic, gravity, electrical resistivity and seismic refraction geophysical methods. These methods had minimal impact on the environment since they involved precut traverses.

The landscape in Jos is stable and has some vegetation. However, during exploitation/mining, the most used technique, trenching and pitting, adversely affected the landscape and hydrosphere. Exploitation is mainly performed through open pit mining, which has resulted in the formation of wasteland, damage to the natural drainage, pollution and destruction of the natural habitat (surface and groundwater). Smelting also emits pollutants into the air. It was also observed that some other minerals such as monazite, pyrochlore and xenotime, which are obtained as byproducts of tin, are radioactive. Because these other minerals were mostly treated as waste and dumped in tailing ponds or just abandoned in many closed mines, the incidence of radiation contamination cannot be ruled out.

Mining pools are a result of abandoned open pit mines and thereby enhance erosion. Such pools contain a large amount of tailings and are therefore unable to support any form of living things. Since such pools are not fenced and are close to populated areas, accidents are likely to occur. The most devastating effect of this is surface and groundwater pollution. The current interest in gemstones has further increased the devastation of the environment, since pits are dug in search for pegmatites containing gemstones, after which such pits and trenches are also abandoned thus creating bad land or hummocky topography punctuated by irregular holes and trenches (Adekoya et al., 2003).

3.2.2. Coal

The environmental hazards created by mining in the Enugu field include:

- Subsidence (e.g. Iva valley).
- Mine waste dumps which change the existing topography.
- Pollution of rivers, streams and groundwater by acid water from the mines.
- Flooding of the mine by acid water which can corrode machinery and affect the health of miners.
- Inadequate ventilation which also affects the well-being of the miners.
- Air pollution resulting from coal dust.

Table 2 shows the summary of the major assessments of tin and coal exploitation activities.

4. Discussions

4.1. Potential environmental implications of minerals exploration and exploitation activities

4.1.1. Environmental implications of tin mining

The environmental damages caused by tin mining in Jos-Plateau include: the destruction of pastoral land while searching for cassiterite; mine dumps; mine tailings containing radioactive waste; and also mine ponds. These mine ponds have resulted in several deaths. Additionally, during tin mining, radioactive minerals were released into the environment. Soil degradation was caused by erosion, resulting in loss of soil nutrients, organic matter and damage to the properties of soil and crops. Before the first Mining Law was approved in 1946, no documented regulation for mineral extraction, processing and reclamation were available. The 1946 Act which included environmental protection in the regulation of mining activities still failed to protect the environment from the negative impacts of mining. The cost of a lack of environmental protection in the Act is evident in the Plateau tin mining fields (Chindo, 2012).

4.1.2. Environmental implication of coal mining

Mining of coal generates waste rock (WRs) that are major potential sources of Acid mine drainage (AMD) (discharges carrying high loads of sulphide oxidation products and associated metals). AMD usually contains toxic heavy metals, and it is a critical environmental pollution problem in mines. The impacts of AMD include the degradation of water quality, aquatic life, and the health of humans, plants and animals. In the Enugu coal mines, the underground mining method was employed. This mining method exposes the coal contained in the overburden to water and air, and uncovers iron sulfide (pyrite), and

Table 2
Assessments of tin and coal exploitation activities.

Jos Plateau Existing Mine Site	Closed Coal Mines in Enugu
Decomposition of basalts to clays capped by laterite and dissected by subsequent erosion	Subsidence of some valleys, e.g. Iva valley
Erosion of the Younger Granites in the Jos Plateau	Pollution of rivers, streams and ground water by acid water in the mines
Landscape and hydrosphere adversely affected by trenching and pitting activities	Mine waste dump caused changes in the existing topography
Smelting resulting in air pollution	Air pollution from coal dust
Pollution and destruction of natural habitat	Flooding of mines by acid mine water that corroded machinery and affected the health status of miners
Formation of waste land	Inadequate ventilation of mines which affected the well-being of mine workers
Minerals such as monazine, pyrochlore and xenotine which are byproducts of tin can be radioactive	Deforestation and alteration of landscape
Damage to the natural drainage	
Surface and groundwater pollution	

when waste rock containing sulfides is exposed to air, an oxidization reaction occurs which releases sulfuric acids. The main sources of the product of sulfide oxidation are iron sulfide minerals (mainly pyrite and pyrrhotite) which are present in metallic ores, coal beds or strata overlying and underlying the coal exposed to oxygen and water. This results in an increase in acidity and an increase in concentrations of dissolved metals in the water, also causing the pH of surface and underground water to be very low. AMD from abandoned coal mines can contaminate both groundwater and surface water if not properly managed and can also affect the health of communities that rely on this water for drinking or for agriculture. AMD may be of minor importance when a mine is in active production, because water pumping keeps the water tables low, but it becomes severe in closed and abandoned mines due to the rebound of water tables.

Another major problem which is encountered is flooding. The problem of flooding cannot be stopped by abandoning a mine because mine water from mines will still continue to discharge into the River. To revive this abandoned mine, both problems of flood control and acid mine drainage would need to be addressed.

4.2. The need for best management practices

It can be seen from Fig. 3 that mining activities have impacts on the atmosphere, landscape, lithosphere and hydrosphere. The pollution caused by the exploitation of mineral resources is explained using Fig. 3.

4.2.1. Atmosphere

- **Dust and gas emissions**: this is mostly experienced during blasting activities and the construction of roads which was explained in mine ***development activities***. Dust and gas pollute the air and this can lead to sicknesses such as catarrh and silicosis. The ***coal mining*** industry is a major source of greenhouse gas methane emitted into the atmosphere, also there was noise pollution and the emission of dust and fumes from both the stockpiles and the transportation system of ***coal***. Radioactive minerals such as monazite, pyrochlore and xenotime, which were obtained as by-products of ***tin mining in the Jos Plateau***, cause health problems. Most of these minerals were left as waste in many mining sites in the Jos Plateau which led to the death of people. These deaths were connected to the high level of radiation from monazite-rich sand that was used for the construction of the houses the people lived in.
- **Change in air circulation**: this is mostly experienced in underground mines that are not properly ventilated, also during mining, the explosives and other chemicals used can affect the circulation of air. If not properly taken care of, this can lead to the death of mine workers. In a ***coal mine*** using an underground mining method, there can be a change in air circulation due to the explosive gas contained within the coal seam that is being mined.
- **Microclimate change**: the amounts of energy required for the extraction and transportation of minerals can cause acid rain and also increase global warming because the heavy-duty machines used in operations tends to emit greenhouse gases which can confine the outgoing heat from the surface of the earth. Acid rain can destroy buildings and trees, and harm animals.

4.2.2. Landscape

- **A general threat to ecology**: mine construction and mine development activities include deforestation which is a major ecological threat. In most cases, the ecology is completely destroyed and there is widespread soil disturbance. Mine construction also results in soil erosion which promotes a variety of environmental changes

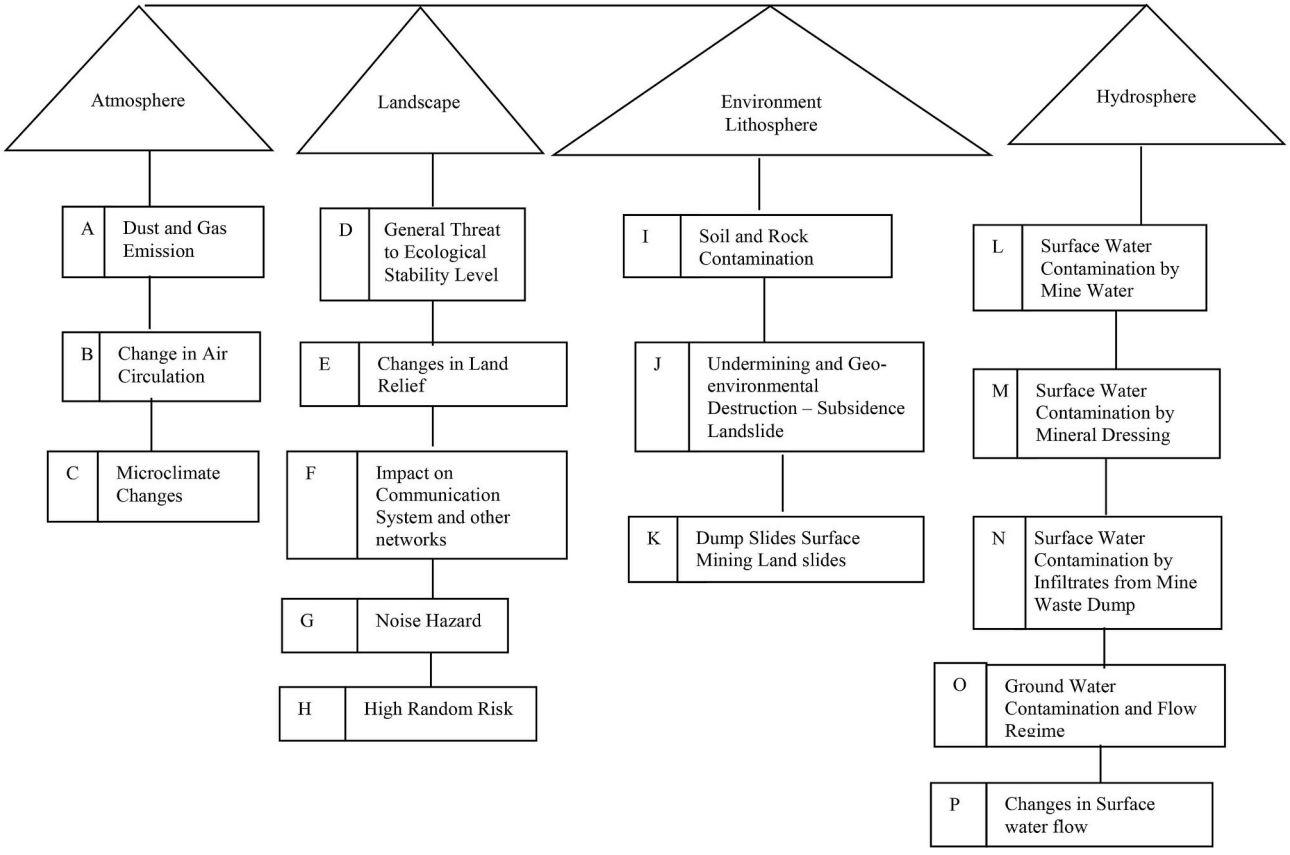

Figure 3. Main environmental pollution hazards caused by the exploitation of mineral resources.

associated with disturbed areas, which can lead to altered plant community species and a loss of habitat for indigenous fauna and flora.
- **Changes in land relief**: mine development results in soil disturbance and this results in soil erosion. Sediments, soil and contaminants are transported into rivers and streams resulting in the loss of or changes to the land relief.
- **Impact on the communication system and other networks**: activity such as blasting can induce lightning, which can alter the communication system and other available networks.
- **Noise hazard**: plants and machinery, blasting and drilling activities bring about major noise pollution in mine sites.
- **High random risk**: these include mine workers not using their personal protective equipment (PPE) such as helmets, nose mask, eye protection glasses, gloves, safety boots, and visibility clothes during their work on mining sites which can be very dangerous. A mine worker working with explosives during blasting without a nose mask and gloves creates a high level of risk.

All the points listed under landscape are experienced in all mine sites irrespective of the mineral being mined.

4.2.3. Lithosphere

- **Soil and rock contamination**: this generally occurs as a result of the heavy metals contained in the soil and rock.
- **Undermining and geo-environmental destruction – subsidence/landslide**: during mining operations, there are alterations in the equilibrium of the geological environment which causes some impacts and risks such as landslides, subsidence, and quakes. In the Iva valley, there was an occurrence of subsidence, ***as a result of coal mining*** which led to water diversion into the mines. There are also risks of workers falling into abandoned shafts and pits that are not adequately protected or marked, for example in coal mines where the underground mining method is used.
- **Dump slides surface mining landslides**: during blasting activities, minor earthquakes occur which results in unpleasant movements in the earth (landslides) causing cracks in buildings.

4.2.4. Hydrosphere

- **Surface water contamination by mine water**: acid mine drainage (AMD) occurs when minerals and ***coal deposits*** containing sulfide minerals, e.g. pyrite (FeS_2) are exposed to air, thus releasing sulfuric acid causing the pH of the water to become very low (as low as 2). AMD in an ***abandoned coal mine in Enugu*** had negative effects on the quality of both groundwater and surface water. Mine water is a huge problem which is a danger to aquatic life and adversely affects the health of communities that rely on this water source for drinking-water and agriculture.
- **Surface water contamination by mineral dressing**: chemical agents (e.g. cyanide or sulfuric acid) used in processing ores can spill, leak, or leach from the mine site into water bodies thereby contaminating or polluting the water. These chemicals are highly toxic to both humans and wildlife.
- **Surface water contamination by infiltrates from a mine waste dump**: mine construction results in soil disturbance where soils and sediments (mine wastes) are transported into streams and rivers, resulting in the loss or alteration of habitats for aquatic organisms, as well as changes in water quality.
- **Ground water contamination and flow regime**: the breakdown of pyrite and other sulphides by water or air releases acid, sulphate and metals into the environment.
- **Changes in surface water flow**: siltation of rivers can occur, which changes the water flow. Siltation occurs when there is a build-up of fine solid particles on the bed of a river. Large quantities of mine dumps are produced during mining activities, and because these dumps are unstable, they can easily be blown away by wind when dry and eroded by heavy rain when wet. Thus, rain and wind transport fine particles into nearby water or rivers, forming a build-up of suspended solids and finally siltation.

It is evident from the above that the exploration and exploitation of solid minerals will continue to impact the environment, the best solution is to minimize the effects, and in addition, carry out reclamation of the mine sites. It has become imperative to adopt Best Management Practices (BMPs). According to Norman, Wampler, Throop, Schnitzer, and Roloff (1997), BMPs apply to reclamation, planning and specific methodologies which promote an integrated approach to mining.

The government put in place a number of laws, e.g. the Mineral and Mining Decree of 1999, which address, among others, the environmental conservation issues, but there is a need to issue stringent sanctions against those who fail to comply with the environmental protection regulations. Decree 86 of 1992 introduced mandatory environmental impact assessments for all new development projects, and recommends environmental audits for all existing projects. The 1995 Federal Environmental Protection Agency (FEPA)/Federal Ministry of Environment (FMEnv) Environmental Impact Assessment (EIA) sectoral guidelines for solid minerals, beneficiation and the metallurgical process, must be enforced. In addition, the Government, miners and other stakeholders in the solid mineral industry should adopt the revised Berlin Guidelines of 1999.

5. Conclusions and recommendations

5.1. Conclusions

Extraction of mineral resources is the backbone of the national economy in many countries. However, urgent attention should be paid to the implications of these exploitation activities such as abandoned sites, loss of biodiversity, and the use of chemicals with potential health risks to mine workers and communities, etc. More emphasis should be placed on waste minimization and the adoption of best practices and these must be enforced through legislation. From the studies carried out, it was concluded that the exploitation activities of tin and coal have huge environmental implications.

It was evident that the landscape of the Plateau contains a lot of dangerous mining ponds that have degraded the area and serve as contaminants for both humans and animals. The natural ecology was greatly impacted by deforestation and the mine sites became prone to erosion due to a lack of vegetation in the areas. There were several abandoned mine ponds and mine spoils in the mine sites. The pollution in the mine area was as a result of the byproducts of tin that were treated as wastes and dumped in tailing ponds or abandoned in closed mines. In many of the mine sites in Jos Plateau, best practices have not been adopted, but in some cases a small amount of remediation had been done to some of the abandoned mine ponds; some were used for irrigation and block making. Also, the closed mine in Enugu was highly polluted with toxic heavy metals which are dangerous to humans, plants and water. There were incidences of groundwater pollution, loss of landscape or land degradation, and flooding. There were serious problem related to AMD, which requires the urgent attention of the Ministry of Mines and Steel Development (MMSD), none of the fundamental principles for the mining sector had been adopted and no remediation has begun.

Compliance with the mineral laws in these mining sites are minimal and enforcement and supervision are non-existent. It can be said that the goal of the MMSD is yet to be achieved on the basis that there are huge inefficiencies and poor supervision. The awakening interest in solid minerals exploitation in the country, if not properly controlled, will release further havoc on the environment.

5.2. Recommendations/the way forward

While the renewed interest in solid minerals exploitation will yield more revenue for the country, if not properly controlled it will lead to further devastation to the environment. The case histories of Tin in Jos and Coal in Enugu show clearly that exploitation of these minerals pose numerous environmental hazards. Emphasis should be placed on enforcing the relevant laws guiding mineral exploration and exploitation. In addition, stringent sanctions must also be put in place against violators. For Jos and Enugu, an environmental audit should be carried out and restoration should start. There is a need for the Government, professionals and all stakeholders to adopt and enforce the fundamental principles for the Mining Sector Berlin Guidelines, as revised in 1999. There is a need for constant dialogue and education of all concerned with the exploration and exploitation of solid minerals. Awareness needs to be raised concerning the fact that the methods used for exploration and exploitation must address environmental problems, help to mitigate existing concerns, evaluate the extent of existing problems, predict where pollutants will go in the environment (surface and subsurface) and design facilities that will drastically reduce environmental problems.

Conflicts of interest

Authors state that there is not any conflict of interest.

Ethical statement

Authors state that the research was conducted according to ethical standards.

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