Global Journal of Science Frontier Research: H
Environment & Earth Science
Volume 17 Issue 3 Version 1.0 Year 2017
Type : Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Environmental Impacts of Mineral Exploration in Nigeria and their Phytoremediation Strategies for Sustainable Ecosystem

By Odoh Chuks Kenneth, Akpi Uchenna Kalu & Anyah Francis
University of Nigeria

Abstract- Mineral exploration and processing have caused varying degree of environmental damage in Nigeria. These include alteration of ecological state, air, water, soil pollution, destruction of soil flora and fauna, loss of vegetation, landscape degradation and radiation emission. Since mineral exploration is still at the developmental state and in the hands of artisanal miners in most developing nations, the environmental impact of their ill-fated activities is inevitable. For a robust, sustainable eco-mining to be achieved, government agencies, environmentalist and industrial prospectors must take sound precautionary measures in remedying polluted sites and limiting re-introduction of hazardous material into the environment.

Keywords: *phytoremediation; sustainable ecosystem; mineral exploration; pollution; eco-mining.*

GJSFR-H Classification: *FOR Code: 060299*

ENVIRONMENTALIMPACTSOFMINERALEXPLORATIONINNIGERIAANDTHEIRPHYTOREMEDIATIONSTRATEGIESFORSUSTAINABLEECOSYSTEM

Strictly as per the compliance and regulations of:

Environmental Impacts of Mineral Exploration in Nigeria and their Phytoremediation Strategies for Sustainable Ecosystem

Odoh Chuks Kenneth [α], Akpi Uchenna Kalu [σ] & Anyah Francis [ρ]

Abstract- Mineral exploration and processing have caused varying degree of environmental damage in Nigeria. These include alteration of ecological state, air, water, soil pollution, destruction of soil flora and fauna, loss of vegetation, landscape degradation and radiation emission. Since mineral exploration is still at the developmental state and in the hands of artisanal miners in most developing nations, the environmental impact of their ill-fated activities is inevitable. For a robust, sustainable eco-mining to be achieved, government agencies, environmentalist and industrial prospectors must take sound precautionary measures in remedying polluted sites and limiting re-introduction of hazardous material into the environment. Unlike the conventional physical and chemical remediation techniques that are uneconomical with potentials of generating large volume of chemical wastes, phytoremediation is said to be otherwise. However, as efforts are being made to minimize wastes disposal in mining industries through recycling, landfill and/or in-pit storage, scientific green-base technology such as phytoextraction, phytostabilization, phytovolatilization, rhizodegradation, phytodegradation and rhizofiltration could be adopted through legislative enactment as a requisite strategy for the return of abandoned mine sites to it aesthetic natural setting by industrialist.

Keywords: phytoremediation; sustainable ecosystem; mineral exploration; pollution; eco-mining.

I. Introduction

Since the birth of industrial revolution, man has continued to introduce hazardous materials into her environment at an alarming rate. These materials mostly consisting of inorganic substances (heavy metals) pose serious health and environmental threat.In mid 1990s it was reported that on an annual basis, about 700 million kg of metals in mine tailings were disposed on land globally (Warhurst 2000).The impact of these materials occasion by this act is so enormous. In an abandon or unreclaim mining sites, these tailings containing heavy metals spread across tens of hectares of land via eolian dispersion and water erosion for hundreds of years (U.S. Environmental Protection Agency (USEPA) 2004; Warhurst 2000; Blanchard *et al*., 2008).As a rising global phenomenon, Nigeria has for decades witnessed it share of the deal owing to her exploration activities. Though, being a major source of revenue for most developing nations (Tauli-Corpuz, 1997), mining naturally destroy the environment by producing high amount of wastes that have long time deleterious impact. This has been a major set-back unlike the developed society where in-pit storage, backfilling, co-disposal and dry-stacking facilities are used by industries that are required by law to remediate or contain tailings piles (Coates, 2005; Gonzalez and Gonzalez-Chavez 2006). As a multi facet stage operational activity that incorporates locals, small and large scale industrialist, it renders adverse environmental, health and socio-economic effect to immediate communities.

Exploration of solid minerals in Nigeria began during the pre-colonial era. In 1903/1904 the British colonial government organised mining operation covering both the northern and southern protectorate. This grew and metamorphosed leading to classification of Nigeria as a leading producer of coal, columbite and tin in 1940s. At this time, the minerals were said to be the main source of revenue for the government (Ajakaiye, 1985; Chuku, 1988). This however resulted to influx of mining companies, increased commercial activities while connecting the country to the rest of the world.

In modern society, mining operation by industries and artisanal has been the major cause of environmental pollution (air, water, and soil), geochemical cycles alteration and ecological imbalance. Tailing being a significant source of air pollution in the form of particulate matters, carbon monoxide, persistent free radicals and volatile organic and heavy metal particles can lead to disease and death in people with heart or lung disorder. This also accelerates lung cancer and chronic respiratory disease in children at long term exposure (USEPA, 2006). According to world health organisation (WHO) report, death due to air pollution in 2012 was approximately 7million (WHO, 2012). In water, they can cause alteration of aquatic biota diversity as they get threatened through disruption of their natural functions (Henry, 2000), while ultimately raising much concernon the safety of food, fruit and cash crops grown in a nearby farmland that has got long history of mining

Author α σ: Department of Microbiology University of Nigeria, Nsukka. Enugu Nigeria. e-mail: kenchuks974@gmail.com
Author ρ: Department of Biological Science Abubakar Tafawa Balewa University, Bauchi Nigeria.

Global Journal of Science Frontier Research (H) Volume XVII Issue III Version I Year 2017

activities (soil pollution). As human and animal poisoning occur through the ingestion of these contaminated foods (Bartrem *et al*., 2014; Oramah *et al*., 2015), it present health challenges such as dizziness, kidney pain, respiratory problems, miscarriages and deaths as associative costs in communities with records of mining activities (Twerefou *et al.,* 2015).

Some of the well documented heavy metals with history of long persistence, severity and toxicity are the sulfur or nitrogen ligand bonded heavy metal complexes (Tl^{+}, Tl^{3+}, Pb^{4+}, Bi^{3+}, Pd^{2+}, Pt^{2+}, Cu^{+}, Ag^{+}, Au^{+}, Cd^{2+} and Hg^{2+}) (Kushwaha *et al*., 2015) because of their strong affinity with cysteine (sulfur group) and lysine (nitrogen groups) (Shaw *et al*., 2004). The buildup of these toxic metals in the environment beyond the recommended limit owing to mineral exploration, couple with their non-biodegradability cum bioaccumulation capacity in living system raises serious public health concern (Chaturvedi *et al.,* 2015).

In Nigeria, the growing anxiety of rising environmental pollution and degradation has been stressed. Following the exploitation of land for its abundant resources, various forms of pollution contributes to the reduced environmental quality (Udiba *et al*., 2012). This however question the safety of nearby water bodies and air quality inhaled by residence within the mining sites because of the acid mine drainage (AMD) and mercury amalgamation method used by locals. Unlike the developed society, there has not been accurate data quantifying the numbers of abandoned mine in Nigeria. Though the current dominance of petroleum industry as the nation economic stream has tampered on the progress of this sector for decades, informal miners and companies (sometime unlicensed) have become very active and strive even with the absence of a clearly defined policy, standards and sound regulations and reforms.

With growing realization that mining activities could be carried out in a more ecofriendly approach where economic gains are maximized, social conditions improved and with less damages to the environment, concerted effort via government intervention in the areas of (i) adequate funding of National Environmental Standards and Regulations Enforcement Agency (NESREA) (ii) prompt monitoring and compliance of nation-wide sanitation activities (iii) organization, education and retraining of artisanal miners (iv) and full implementation of the year 2020 national technical working group report on minerals and metals development has been emphasized (Isa *et al.,* 2013).With the aforementioned anomalies in the nations mining industry couple with widespread ecological impacts on adjacent societies in the form of pits, land degradation, siltation, erosion, water contamination, loss of vegetation, climatic alteration and radiation, this work was therefore designed to address these challenges in Nigeria in the midst of its quest for safe and sustainable environment while also improving sound health of her growing populace.

II. Mineral Exploration in Nigerian

It has become clear that mineral exploration present an indelible mark to the ailing environment, most significantis the alteration of the ecological settings. With large deposit of mineral resources spread across Nigeria from Jos(tin and columbite) in the north to Edo (lead) in the south and Enugu (coal) in the east to Ogun (limestone) in the west, stories of the negative effect of mining on the environment are bound. Records have shown that the solid mineral sector is the second major source of pollution after crude oil (Adekoya, 2003). As large heap and dump of solid wastes, tailing and effluent get released, they distort the natural sanity which interfaces with quality of life and regular functioning of the ecosystem(Nnabo and Taiwo, 2001). One of the factors that is always in association with mining operations is influx of people which most often exert pressure on the already stress edenvironment. Because local artisan are always ill equip with expertise, machineries, lack laws or regulations governing their operations and environmental standard, it is expedient to witness a more pronounce decay in the form of landscape damage, increased soil erosion, deforestation, loss of vegetation, loss of cultivable land and ecological imbalance. More so, building collapse due to noise and vibration during blasting of rocks with explosives has been a usual occurrence. Widespread environmental deterioration in the form of air particulate emissions, chemicals flow from abandoned mines, radioactive waste, water contamination and land degradation is no longer news.

Table 1: Mineral deposit in Nigeria, their location and levels of exploration

Minerals	Locality	Level of exploration
Barytes	All region of the federation	L
Beryl	Enugu	S
Clay	Ijero-ekiti, Josplateau,Saki, Falanasa	L
Coal	Enugu	L
Construction sand	Jos plateau, Akwanga	L
Construction stones and laterites	Jos plateau	S
Feldspar	All region of the federation	S
Glass sand	Ijero-ekiti	M.S

Gold	Ishiagu,Enyigba,Ameka,Ameri	Dormant
Gypsum	All region of the federation	S
Iron	Itakpe	L
Lead	Ishiagu, Enyigba, Ameka, Ameri	M
Limestone	Okpilla, Burum, Igara, Igheti, Gwazom, Warake	L
Marble	Ugheli, Wumo, Fika, Ozobulu, Naragua, Kano, Ikorodu, Ire	M.L
Monazite	Jos plateau	Dormant
Niobium	Jos plateau, Oro, Saki, Idiko	Won as by-product of tin mining
Oil and gas	Niger delta	L
Ruby	Niger delta	S
Sapphire	Niger delta	S
Silver	Igara, Kalambaina, Danbala	Won as by-product of lead Mining
Tin	Jos plateau	M, S.
Tomaline	Niger delta	S
Topaz	Niger delta	S
Xenotime	Dagbala, Birnigwari, Itagumodi	S
Zinc	Okpilla	Won as by-product of lead Mining

L = Large scale exploitation; M = Medium scale exploitation; S = Small scale exploitation

Aigbedion & Iyayi, (2007)

III. Impact of Mineral Exploration in Nigeria

a) *Air pollution*

During blasting, explosion and crushing, large amount of fine particles get released and dispersed by wind. These dust particles are minute and are less than 10 microns. When found in the ambient air as airborne particulate matter (PM), they pose health threats to people. As derivatives of marble and granite processing, Ndinwa, (2014) in Auchi Edo state reported its role on the poor quality of nearby vegetable garden grown around factories or mining sites. At maximum level of exposure via inhalation, respiratory disorders, silicosis, and lung diseases manifest due to occupational hazards (Nnabo and Taiwo, 2001). The gold mining activities is no doubt the major cause of silicosis and silico-tuberculosis that has been reported in mining areas in Zamfara, Oyo, Ishiagu and Enyigba, where dust from gold mining sites has high silica content (Akabzaa and Darimani, 2001). Sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and black smoke at sufficient contact can exacerbate the condition of people with asthma and arthritis. The release of dust into the environment in all stages of coal mining in Maiganga has been found to be so enormous, as it accelerated during dry season when huge dust are usually generated due to strong wind (Wu and Liu, 2011). Discharge of volatile elements and compounds during combustion present substantial amount of pollution into the environment and trigger health condition such as pneumoconiosis (Chen *et al*., 2014; Mukherjee, 2011). In Sagamu and Ewekoro, Ogun state, records of people living with eyes pain, asthma and respiratory attack of all kinds have since emanated from adjacent community owing to the activities of industries(cement factory) and mining operations (Aigbedion, 2005).

b) *Water pollution*

The memory of the death of more than 200 children (<5 years old) due to lead poisoning in Zamfara State, Nigeria in 2010 has since remain fresh and not easily for gotten. To many, it was a single well known incidence out of many pocket of associative death that has occurred across the country. Findings has shown that a child dies every eight seconds from water related issues and a total of five million death yearly from water linked disease and poor sanitation (Shivaraju, 2012). In a recent study conducted by Abu and If a time him, (2016) in It akpeKogi state, implicated the over three decades of iron ore exploration as a cause of gastro-in test in alirritation, catharsis, dehydration, dry skin and coloration of teeth to the populace. The heaping of mine wastes containingmagnetite, zircon, ilmenite, monazite, silica sand, thorite, and amethyst present public health threat during rainfall, as their seepage or possible flow to a nearby water source is certain. As this event occurs, the water turbidity or acidity level get elevated (Dhameja, 2006), making it unfit for aquatic life and domestic use. Emerging indications has shown that some of the abandoned mine ponds has become death traps due to accidental fall (Merem *et al.,* 2017; Faden, 2015) in remote areas where hope of portable water isloss, thus compelling the villagers to channelrun off rainwater into old mine pit for irrigation farming and other domestic use. This odd activities couple with ingestion of heavy metals via the food chain and leaching of mine wastes into ground water will no doubt have deleterious impact on human health after sufficient level of exposure and bioaccumulation. In Maigangacoal mine, the surface water and ground water seems extremely unfit for both domestic and industrial use (Wu and Liu, 2011). The peculiarity of mining region is the groundwater encroachment that occurs during exploration, which result in elevated sulphate metal content, and increase acidity of acid mine drainage (Öhlander *et al.,* 2012). When low grade ore, tailings and piled rock or dump of sulphide bonded metals such as pyrite (FeS_2), marcasite (FeS_2), pyrrhotite (FeS), chalcopyrite ($CuFeS_2$), arsenopyrite (FeAsS), and galena (PbS) get exposed to air and water they oxidize forming sulphuric acid and ferrous hydroxide

$$2FeS_2 + 6H_2O + 7O_2 \rightarrow 4H_2SO_4 + 2Fe(OH)_2$$

As the acid flows, it unbound other sulphide containing heavy metal complexes (Cu, As, Pb, Cd Ni. Zn), thus releasing them into the environment and water source. Being an oxygen and water accelerated phenomenon, it has led to significant loss of aquatic life (Abu and If a time him, (2016), and estimated liability of over $ 20 billion annually in Europe and America (Taylor, 1998). Conclusively, coal high moisture content is an indicator of sulphide-rich coal deposits, high porosity and possible water seepage and increased hazardous effect on human due to acid mine drainage.

c) Vegetation loss and deforestation

One of the first casualties of mineral exploration in any region is loss of Vegetation and deforestation. The vegetation damage usually occurs at the time of mine development. Emerging evidence has shown that rural communities in northern part of Edo state have suffered immensely from these ecological problems. In oil spill prone environment (Ogoni land) records of damage of vegetation and plantation such as oil palm tree due to activities of crude oil exploration has long existed. Aigbedion (2005) in his research credited the decrease in kola nut plantation output in Shagamu to its adjacent cement factory location. This challenge, having been linked in the gradual encroachment of Sahara desert in the tropics and concomitant depletion of Lake Chadbasin, are responsible for the increased atmospheric carbon dioxide content and global warming. With sufficient arable lands get rapidly depleted due to clearing of vegetation, setting of camp sites, excavator and heavy machinery installation cum road construction for easy traffic, a lot of protective plants, cash crops and plantations are lostvia accelerated soil erosion and flooding, thus leading to economic loss.

d) Landscape degradation and soil erosion

The aesthetic nature of any environment is in relation to its landscape formation. In Nigeria, the presence of thousands of abandoned mine pits as observable in Jos mining zone has tampered with the serenity of the region. The destruction of natural landscape, creation of pit and indiscriminate dumping of heaps as observed in Imeke, Igara and Ikpeshi where granite quarries and marble quarries are explored are examples. In Nkalagu, Gboko andAshaka, the stories remain the same as some of the open hole serve as an artificial lake for local communities. Apart from dreaded landscape that accompanied this activity in Jos and Bukuru metropolis in the 1970s, some part of its environment e.g., Gyel and Sarbobarki has continue to feel the impact of mining effects. As difficult as restoration of landscape due to mining is, one viable option still remain, waste filling of the pits once mining is over. However this is unattainable because most miners are not landowners and so care less about the community (Ogola *et al*., 2001). With the world human population being on continuous rise couple with advancement in technology and innovations, there has been concomitants decline in environmental quality and life sustenance ability (Kogbe and Obialo, 1976). Mining activities such as excavation has exposed all the landscape to severe erosion as itsprevalent underlain by crystalline rocks where quarrying activities occur on daily basis.

e) Geological and radiation hazards

The distortion of natural environmental equilibrium via exploration of minerals has initiated a number of geological hazards such as flooding, landslide and subsidence. Certainly, this altered geological structure is not without consequences as it could lead to loss of life and properties. In Nigeria, Niger delta and Iva valley in Enugu, cases of subsidence have been reported due to oil drilling and coal mining (Aigbedion, 2005).Undoubtedly, most communities near mining sites have witnessed slight earth movement via blasting of rock (Ajakaiye, 1985).As mining involves the removal of large amount of soil which contains radioactive materials, the possibility of their intake by human through food chain is understandable. Following the build-up of these chemical agents in the biosphere (air, water and soil) against biotic life, their radiation effects is said to be concentration dependents (Ademola, 2008). In Jos Plateau State, the associative by-product of tin mining such as monazite, pyrochlore and xenotime are radioactive. Some remnant of these materials which were abandoned at the closure of mining operation still exact its effect till date. Møller and Mousseau (2013); Aliyu and Ramli (2015) opined that the emitted radiation induces change in immunology, physiology, point mutation and increase in disease frequency. However, there have been records of mysterious death by people who are believed to have used monazite soil for house construction (Aigbedion, 2005).

IV. Remediation Strategies

Utilization of plants as a sound biotechnological approach for the reclamation of devastated environment has been highlighted. These conditions largely depend on the survival strength of plants in stressed environment. The efficiency of phytoremediation techniques depend to a large extent on the soil properties, type of contaminant and it bioavailability (Cunningham and Ow, 1996). In advanced society like USA, over 200 radiobiological sites have been restored using this approach (Rajiv *et al.,* 2009).Owing to inherent benefits of plant base remediation using fast growing and high biomass crop like Poplar, Willow and Jetropha(Abhilash *et al*., 2012),they have proven to be a promising technology with phytoextraction, phytostabilization, rhizodegradation, phytodegradation, rhizofiltration and phytovolatilizationas viable techniques of choice.

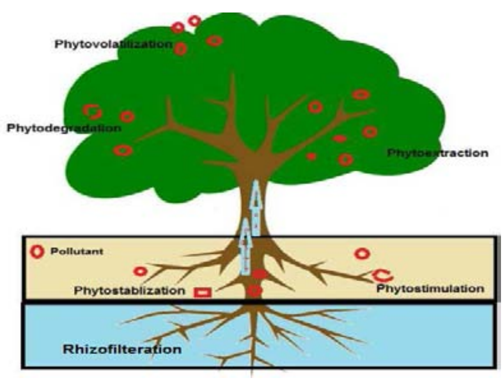

Figure 1: Phytoremediation processes (Parul and Sonali, 2014)

a) Phytoextraction

This is the uptake of contaminants by plant root to the harvestable region. Its principle of operation involves absorption, accumulation and translocation of pollutant to the plant biomass. Zhang *el al*. (2010) was of the opinion that this form of phytoremediation is primarily meant for the treatment and restoration of abandoned mine sits as it restores the sanity, fertility and structure of soil if properly harnessed. The unearthing of hyper-accumulator plants has widened human expectation and hope of the prospect of safe, clean environment in the nearest future. Phytoextraction mechanism of action is relianton mobility/bioavailability of metals, rate of metal uptake, amount of soil metal content, translocation and plant tolerance to metals. Tremendous success has been recorded via this approach in remediating site polluted with copper, zinc and nickel (Parul and Sonali, 2014). Addition of chelating agents such as ethylene diamine tetraacetic acid (EDTA) in fields has shown to be positive for more heavy metal recovery (Pedron *et al*., 2009), as it unbound the non-bioavailable forms of the pollutant. However, lowering the soil pH using acidifier or/and ammonium containing fertilizer increases translocation of the non-bio available forms of pollutants (Salt *et al.,* 1995). Barbafieri *et al*. (2012) in their view opined that cytokines, indole-3-acetic acid (IAA), ethylene and gibberellic acid (GA) enhances efficient clean-up of mining sits.

Table 2: List of environmental pollutants, their remediation approach and its associated plants

Pollutants	Remediation approach	Possible plant
Petroleum compound e.g. Crude oil	Rhizodegradation	*Cynodon dactylon* *Andropogon gerardii* *Elymus canadensis*
Heavy metals e.g. (Pb, Cr, Cu)	Phytostabilization	*Brassica juncea,* *Helianthus annus*
Zn, As, Hg, Ni, Se and uranium	Phytovolatilization	*Populus* sp *Arabidopsis thaliani* *Typha latifolia L*
Zn and Cd Acid mine drainage and industrial discharge	Phytoextratcion, Rhizofiltration	*Thlaspi caerulescence* *Helianthus annus*
Polycyclic aromatic hydrocarbons (PAHs)	Rhizodegradation	*Metigo sativa,* *Andropogon gerardii* *Festuca arundinacea*
Pentachloro phenol (PCPs) and Poly chlorinated biphenyl (PCBs)	Rhizodegradation	*Angropyron cristatum* *Phragmites australis* *Solanum nigrum*
Pesticides, herbicides, benzene, toluene, ethyl benzene and xylene	Phytodegradation Phytovolatilization	*Populus* sp
Cyanide	Phytotransformation	*Salix* spand *sorghum* sp

b) Phytostabilization

This is the stoppage of vertical and horizontal migration of toxic chemicals such as heavy metals in soil, sludge and sediment. It's an in-place inactivation and long-term containment of pollutants. Significantly, under these remediation techniques, pollutants mobility is greatly reduced by preventing their access to ground water and the food chain (Erakhrumen, 2007). Unlike the conventional remediation process (chemical and physical), Phytostabilization is found favourable because of their low cost and easy handling (Berti and Cunningham, 2000). It's the most appropriate green base technology suitable for re-vegetation of deforested mining sits. High metal tolerance plant with dense root architecture and canopies are found preferable. Its mechanisms of action consists immobilization, precipitation and valence reduction of metal within the rhizosphere (Yoon *et al.,* 2006; Wuana and Okieimen, 2011). Considering its role in ecological defacement, Phyto stabilization could hoard possible disaster caused by wind erosion (entire plant) and water erosion (plant root).Phytostabilization is an efficient mechanism of choice when rapid immobilization is needed to keep ground and surface waters safe (Zhang *et al*., 2009). In curtailing the geological and radiation hazard in abandoned mining region, phytostabilizing plant agents are vital as they prevent human exposure especially in radionuclide contaminated areas such as zinc, arsenic, cadmium tailings and uranium mining sites (Rajiv *et al.,* 2009).

c) Rhizodegradation and Phytodegradation

Rhizodegradation involves the dissolution of organic compound aided by rhizobacteria within the rhizosphere(Mukhopadhyay and Maiti, 2010).Through plant-microbe interaction, efficient uptake, metabolism and degradation of contaminants are achieved.As plants secrete nutrientse.g carbohydrates, amino acids and flavonoids, they in turnenhance microbial activities thus leading to attenuation of soil contaminants. Rhizodegradation process is facilitated by the presence of protein synthesized by plants or by soil organisms such as bacteria, yeast, and fungi. Prasad and Freitas, (2003) in their submission acknowledged this technique as being essential for the breakdown of organic pollutants. Prominent among them include chlorinated solvents, agrochemicals, petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), benzene, ethylbenzene, xylenes (Pivetz, 2001).

Phytodegradation involves the breakdown of organic base pollutants by plants with the help of enzyme. This operation is independent of activities of rhizospheric bacteria (Vishnoi and Srivastava, 2008). Dehalogenase and oxygenaseare some of the essential plant enzymes capable of detoxifying soil organic pollutants (Yadav *et al.,* 2010). Their action is limited to organic substances as inorganic pollutants such as heavy metals cannot be degraded. The elimination of most environmental xenobiotic using this technique has recorded much success. As anauspicious remediation strategy, genetic engineering of plant of interest e.g. (transgenic poplars) has been reported (Doty *et al.,* 2007).

d) Rhizofiltration

This mechanism is used by plant roots to absorb and precipitate metal contaminants usually at low concentration in aqueous medium (Ensley, 2000). It is effective in cleaning virtually all aquatic environment, using extensive and massive rooted aquatic plants. In the case of terrestrial plants, they can be done using hydroponically grown crop, with capacity of substantial root biomass and large surface area. Application of rhizofiltration in the clean-up of acid mine drainage, industrial discharge, and agriculture runoff has been recorded. The emergence of this form of phytoremediation approach has recorded success in the remediation of cadmium, lead, chromium, zinc, copper and nickel contaminated water body (Chaudhry *et al.* 1998; USEPA, 2000). In spite of it *ex situ* and *in situ* application, it advantage also extend to the use of hyperacumulator and other plant species, among which are tobacco, corn, sunflower, rye, indian mustard and spinach (Chhotu *et al*., 2009). Consequently, researching *Limnocharisflava*(L.) and Buchenaurhizofiltration potential when grown on cadmium hydroponic experimental site has shown positive prospect according to (Abhilash *et al.,*2009).

e) Phytovolatilization

USEPA (2000) report defined phytovolatilization as the uptake of soil contaminant by plant for further transformation into gaseous form and its subsequent transpiration into the atmosphere. This technique extracts mostly volatile pollutants for onward air release using their foliage (Karami and Shamsuddin, 2010). Substances which are mostly absorbed via plant root find their way into the aerial tissues such as leave where they are finally released through the leaf pores (stomata). Some of the pollutants that have successfully utilized this technology include volatile organic compounds (VOCs), selenium (Se) and mercury (Hg) (Cunningham and Ow, 1996). The uniqueness of this form of remediation is that once the contaminant is released, the control over their migration to other media is ceased. Lately, it has been discovered that volatilized mercury get re-deposited into the ecosystem through precipitation. This calls for more research to avoid increasing more burdens to the already devastated ecosystem. One of the most intensely studied elements for possible gaseous release is selenium (McGrath, 1998). In the time past, scientist have tried to genetically engineer plants species capable of accommodating elemental form of this metal, due to the threat it poses to human especially when found in high deposit (Brooks, 1998). A good number of plants have also been found to have the capacity of growing efficiently in high Selenium soil while releasing dimethyl selenide and dimethyl diselenide (Banuelos, 2000). Elsewhere, indication has emerged that both accumulator and non-accumulator plants conveniently volatilize selenium and other volatile metals. Pilon-Smits *et al.* (1999) report implicated Cattail'*Typhalatifolia*L' (aquatic plants) as a potential candidate for phytovolatilization.

V. Conclusion

Mineral exploration has impacted negatively on our environment. As a promising economic stream in Nigeria and most developing world, concerted effort must be taken to ensure safe operational activity by artisans in mining industries. This is necessary so as to avoid effort in futility were the health and environmental burden credited to odd mining process could override its economic benefit. With prevailing consequences of mineral exploitation such as abandoned sites, vegetative loss and deforestation, radiation and land degradation being inevitable as observed in this review, attention on the possible ways of limiting its progressive damage on health and environment is paramount. However, utilizing green-based biotechnology (phytoremediation), an eco friendly remediation strategy will not only reclaim the abandoned mine but restore the sanity, aesthetic and natural settings of the environment when properly harnessed.

References Références Referencias

1. Abhilash, P., Pandey, V.C., Srivastava, P., Rakesh, P.S., Chandran, S., Singh, N., Thomas, A.P (2009).Phytofiltration of cadmium from water by *Limnocharisflava* L.grown in free-floating culture system. Journal of Hazardous Material 170 (2-3): 791-797.
2. Abu, H.O., Ifatimehin .O.O (2016).Environmental Impacts of Iron Ore Mining On Quality of Surface Water And Its Health Implication On The Inhabitants of Itakpe. International Journal of Current Multidisciplinary Studies 3 (6): 318-321
3. Adekoya, J.A (2003).Environmental effect of solid minerals mining," Journal of Physical Sciences Kenyapp.625-640.
4. Ademola, J.A. (2008). Exposure to high background radiation level in the tin mining area of Jos Plateau, Nigeria. Journal of Radiological Protection 28: 93-99.
5. Aigbedion, I., Iyayi, S.E (2007). Environmental effect of mineral exploitation in Nigeria. International Journal of Physical Sciences 2 (2): 33-38.
6. Aigbedion, I.N (2005). Environmental Pollution in the Niger-Delta, Nigeria. Inter-Disciplinary Journal of Enugu Nigeria 3 (4): 205-210.
7. Ajakaiye, D.E (1985). Environmental problems associated with mineral exploitation in Nigeria. 21st Annual Conference of the Nigeria Mining and Geosciences Society, Jos Nigeria.
8. Akabzaa, T.M., Daimani, A (2001). Impact of mining sector investment in Ghana: A study of the Tarkwa Mining Region. A draft report prepared for SAPRI
9. Aliyu, A.S., Ramli A.T (2015). The world's high background natural radiation areas (HBNRAs) revisited: A broad overview of the dosimetric, epidemiological and radiobiological issues. Radiation Measurements 73: 51-59.
10. Banuelos, G.S (2000). Factors influencing field phytoremediation of selenium laden soils. In: Phytoremediation of contaminated soil and water, (Eds: N. Terry, G. Banuelos). Boca Raton: Lewis. pp. 41-61.
11. Barbafieri, M., Peralta-Videa, J.R., Pedron, F., Gardea-Torresdey, J.L (2012). Plant Growth Regulators and Improvements in Phytoremediation Process Efficiency: Studies on Metal Contaminated Soils. In: Phytotechnologies: Remediation of Environmental Contaminants. Published by CRC Press-550 Pages Editor(s): Naser A. Anjum; Maria E. Pereira; Iqbal Ahmad; Armando C. Duarte; Shahid Umar; Nafees A. Khan ISBN 9781439875186
12. Bartrem, C., Tirima, S., von Lindern, I., von Braun, M., Worrell, M.C., Mohammad Anka, S., Moller, G (2014). Unknown risk: co-exposure to lead and other heavy metals among children living in small-scale mining communities in Zamfara State, Nigeria. International Journal of Environmental Health Research 24, 304-319. http://dx.doi.org/10.1080/09603123.2013.835028
13. Berti, W.R., Cunningham, S.D (2000). Phytostabilization of metals: Phytoremediation of toxic metals using plants to clean up the environment (Eds: I. Raskins and B.D. Ensley). Wiley, New York. pp. 71-88
14. Blanchard, C.L., Tanenbaum, S., Lawson, D.R (2008). Differences between weekday and weekend air pollutant levels in Atlanta; Baltimore;
15. Brooks, R.R., Chambers, M.F., Nicks, L.J., Robinson, B.H (1998). Phytomining. Trends in Plant Science 3, 359-362
16. Chaturvedi, A.D., Pal, D., Penta, S., Kumar, A (2015). Ecotoxic heavy metals transformation by bacteria and fungi in aquatic ecosystem. World Journal of Microbiology and Biotechnology 31, 1595-1603.
17. Chaudhry, T.M., Hayes, W.J., Khan, A.G., Khoo, C.S (1998). Phytoremediation-focusing on accumulator

plants that remediate metal contaminated soils. Australian Journal of Ecotoxicology 4:37-51
18. Chen, J., Liu, G., Kang, Y., Wu, B., Sun, R., Zhou, C., Wu, D (2014). Coal Utilization in China: Environmental Impacts and Human Health. Environmental Geochemistry Health 36, 735-753.
19. Chhotu, D., Jadia, D., Fulekar, M.H (2009). Phytoremediation of heavy metals: Recent techniques. African Journal of Biotechnology 8(6): 921-928.
20. Chuku, D.U (1988). *Distribution of gold mineralization in the Nigerian basement complex in relation to organic cycles and structural setting*. Precambrian Geology of Nigeria, Geol, Surv: Nigeria Publ.
21. Coates W (2005). Tree species selection for a mine tailings bioremediation project in Peru. Biomass Bioenergy 28:418-423
22. Cunningham, S.D., Ow, D.W (1996).Promises and prospect of phytoremediation. Plant Physiology 110, 715-719
23. Dhameja, S.K. (2006). Environmental Science.3rd Edition. Delhi, S.K. Kataria & Sons, 41-44:62-69.
24. Doty, S.L., Shang, Q.T., Wilson, A.M., Moore, A.L., Newman, L.A., Strand, S.E (2007). Enhanced metabolism of halogenated hydrocarbons in transgenic plants containing mammalian P450 2E1.Proc.Natl. Acad. Sci. USA 97, 6287–6291.
25. Ensley, B.D (2000). *Rationale for the use of phytoremediation.* Phytoremediation of toxic metals: using plants to clean-up the environment. John Wiley Publishers: New York
26. Erakhrumen, A.A (2007). Phytoremediation: An environmentally sound technology for pollution prevention, control and remediation in developing countries. Educational Research and Review 2 (7): 151–156
27. Faden, J. (2015). Jos a Century of Tin Exploration and Environmental Neglect. International Center for Investigative Reporting.
28. Gonzalez, R.C., Gonzalez-Chavez, M.C.A (2006). Metal accumulationin wild plants surrounding mining wastes: soil and sedimentremediation (SSR). Environmental Pollution 144, 84-92.
29. Henry, J.R. (2000). An overview of phytoremediation of lead and mercury–NNEMS Report. Washington, D.C. pp. 3–9.
30. Isa, A., Abdulrafiu, A., Eshchanov, B., Raheem, M., Spasojevic, T.S (2013).The Nigeria mining sector: An overview of economic implications, environmental degradation and impact on climate change. 24th Colloquium of African Geology (CAG24), Millennium Hall Ethiopia, Addis Ababa, Geological Society of Africa. http://www.CAG24.org.et
31. Karami, A., Shamsuddin, Z.H (2010). Phytoremediation of heavy metals with several efficiency enhancer methods. African Journal of Biotechnology 9 (25): 3689-3698 doi: 10.5897/AJB09.854
32. Kogbe, C.A., Obialo, A.U (1976).Statistics of mineral production in Nigeria (1916 - 1974) and contribution of the mineral industry to the Nigeria economy. Geology of Nigeria, Lagos Nigeria: Elizabethan Publishing Co.
33. Kushwaha, A., Rani, R., Kumar, S., Gautam, A (2015). Heavy metal detoxification and tolerance mechanisms in plants: Implications for phytoremediation. Environment Review 23, 1-13 doi.org/10.1139/er-2015-0010
34. McGrath SP (1998). Phytoextraction for soil remediation. In: Plants that hyperaccumulate heavy metals: their role in phytoremediation, microbiology, archaeology, mineral exploration and phytomining, pp. 261-288 (Brooks, R.R., Ed.), New York, CAB International
35. Merem1, E.C., Twumasi, Y., Wesley, J., Isokpehi, P., Shenge, M., Fageir, S., Crisler, M., Romorno, C., Hines, A., Hirse, G., Ochai, S., Leggett, S., Nwagboso, E. (2017) Assessing the Ecological Effects of Mining in West Africa: The Case of Nigeria. International Journal of Mining Engineering and Mineral Processing 6 (1): 1-19DOI: 10.5923/j.mining.20170601.01
36. Møller, A.P., Mousseau, T.A (2013). The effects of natural variation in background radioactivity on humans, animals and other organisms. Biological Reviews 88: 226-254.
37. Mukherjee, S (2011). Concept of Geomedicine and Medicinal Mineralogy, in S. Mukherjee, *Applied Mineralogy: Applications in Industry and Environment* (New Dehli: Capital Publishing Company 2011) 526-569.
38. Mukhopadhyay, S., Maiti, S.K (2010). Phytoremediation of metal mine waste. Applied Ecology and Environmental Research 8(3): 207-222.
39. Ndinwa, C.C. (2014). Environmental and Health Impact of Solid Mineral Exploration in South Northern Nigeria. A Case Study of Igara Edo State. Review of Environment and Earth Sciences 1:2:24-36.
40. Nnabo, P.N., Taiwo, A.O (2001). A historical survey of solid mineral exploitation and associated problems with examples from parts of Nigeria. Journal of Environmental Sciences 4, 42-54
41. Ogola, J.S., Mitullah W.V., Omulo, M.A (2001). Impact of Gold Mining on the Environment and Human Health: A Case Study in the Migori Gold Belt, Kenya. Environmental Geochemistry and Health 24: 141-158. doi: 10.1023/A:1014207832471
42. Oramah, I.T., Richards, J.P., Summers, R., Garvin, T., McGee, T (2015). Artisanal and small-scale mining in Nigeria: Experiences from Niger, Nasarawa and Plateau states. The Extractive

Industries and Society 2, 694-703. http://dx.doi.org /10.1016/j.exis.2015.08.009

43. Parul, S.,Sonali, P (2014) Status of Phytoremediation in World Scenario. International Journal of Environmental Bioremediation & Biodegradation 2 (4): 178-191. doi: 10.12691/ijebb-2-4-5.
44. Pedron, F.,Petruzzelli, G., Barbafieri, M., Tassi, E. (2009). Strategies to use phytoextraction in very acidic soil. Chemosphere 75: 808-814
45. Pilon-Smits, E.A.H., de Souza, M.P., Hong, G., Amini, A., Bravo, R.C (1999).Selenium volatilization and accumulation by twenty aquatic plant species. Journal of Environmental Quality 28, 1011-1017.
46. Pivetz, B.E (2001). Ground Water Issue: Phytoremediation of contaminated soil and ground water at hazardous waste sites pp.1-36.
47. Prasad, M.N.V., Freitas, H (2003). Metal hyperaccumulation in plants-Biodiversity prospecting for phytoremediation technology. Electronic Journal of Biotechnology 6(3): 285-321.
48. Rajiv K.S., Dalsukh, V., Shanu, S., Shweta, S., Sunil, H. (2009).*Bioremediation of Contaminated Sites: A Low-Cost Nature's Biotechnology for Environmental Clean-up by Versatile Microbes, Plants & Earthworms*.In: Solid Waste Management and Environmental Remediation. Nova Science Publishers, Inc. ISBN: 978-1-60741-761-3.
49. Salt, D.E., Blaylock, M., Nanda-Kumar, P.B.A., Dushenkov, V., Ensly, B.D., Chet, I., Raskin, I (1995). Phytoremediation: A novel strategy for the removal of toxic elements from the environment using plants. Biotechnology13: 468-475.
50. Shivaraju, H.P (2012). *Int. J. Res. Chem. Environ. Vol. 2 Issue 1, 44-53.*
51. Tauli-Corpuz, V (1997). The globalization of mining and its impact and challenges for women. !http://www.twnside.org.sg/bookstore.htmO; 1997.
52. Taylor, G (1998). Acid drainage: sources, impacts and responses, *Groundwork Overview* 3.
53. Twerefou, D.K.., Tutu, K.., Owusu-Afriyie, J., Adjei-Mantey, K. (2015).Attitudes of local people to mining policies and interventions. International Growth Centre, Ref: E-33107-GHA-1. Retrieved from https://www.theigc.org/wp-content/uploads/2015/08/Twerefou-et-al-2015-Working-paper-1.pdf
54. Udiba, U.U., Akpan, E.R., Ogabiela, E.E., Magomya, A.M., Yebpella, G.G., Apugo-Nwosu, T.U., Hammuel, C., Ade-Ajayi, A.F., Aina, O.B (2012).*Journal of Basic and Applied Scientific Research,* 2012, 2 (2), pp 1658-1666.
55. USEP (2004). Abandoned Mine Lands Team: Reference Notebook. Available: http://www.epa.gov/aml/tech/refntbk.htm
56. USEPA (2000).Introduction to Phytoremediation.EPA 600/R-99/107.U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH. http://www.epa.gov/swertio1/download/remed/introphyto.pdf
57. USEPA (2006).Air quality criteria for lead.(Final Report, 2006), Washington, DC, EPA/600/R-05/144Af-BF.
58. Vishnoi, S.R., Srivastava, P.N (2008). Phytoremediation-green for environmental clean. In: The 12th World Lake Conference, pp. 1016–1021.
59. Warhurst, A (2000). Mining, mineral processing and extractive metallurgy: an overview of the technologies and their impact on the physical environment. In: Environmental Policy in Mining: Corporate Strategy and Planning for Closure (Warhurst A, Noronha L, eds). Boca Raton, FL:CRCPressLLC.
60. WHO (2012) Burden of disease from Ambient Air Pollution for 2012 http://www.who.int/phe/ health_ topics/outdoorair/databases/AAP_BoD_results_ March2014.pdf?ua=1.
61. Wu, Q., Liu, S (2011). The Classification of Mine Environmental Geology Problems in China. Environment Earth Science64, 1505-1511.
62. Wuana, R.A., Okieimen, F.E (2011). Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. International Scholarly Research Network Ecology 2011: 1-20. doi:10.5402/2011/402647.
63. Yadav, R., Arora, P., Kumar, S., Chaudhury, A (2010).Perspectives for genetic engineering of poplars for enhanced phytoremediation abilities. Ecotoxicology 19, 1574-1588.
64. Yoon, J., Cao, X., Zhou, Q., Ma, L.Q (2006). Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of Total Environment 368, 456-464.
65. Zhang, H., Zheng, L.C., Yi, X.Y (2009). Remediation of soil co-contaminated with pyrene and cadmium by growing maize *(Zea mays L.).* International Journal of Environmental Science and Technology 6, 249-258.
66. Zhang, X., Xia, H., Li, Z., Zhang, P., Gao, B (2010). Potential of four forage grasses in remediation of Cd and Zn contaminated soils.Bioresour. Technology 101, 2063-2066.
67. Öhlander, B., Chatwin, T., Alakangas, L (2012). Management of Sulfide-Bearing Waste, a Challenge for the Mining Industry. Minerals 2, 1-10.

This page is intentionally left blank