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Effect of Artisanal Gold Mining at *Maiwayo* Environ Northern Nigeria: Implication for Environmental Risk

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Abstract

Gold mining operations are particularly dangerous, as heavy metal bearing rocks containing gold are mined, crushed and liberated into any available water body, thus, posing a lot of health and environmental hazards. The study areas, Maiwayo and Gada-Eregi are two areas close to each other less than a kilometer away from the gold mining site, which is about 120 meters from the main road, near Bidda in Niger State. The area is well drained by numerous seasonal streams and is dissected by flowing River Chanchaga. The methodology adopted for this study were 3 primary approaches of Preliminary and field investigation, followed by Laboratory analysis of samples of water and soils collected, to ascertain the extent of pollution from the mining site. It was discovered that both the soil samples contain high amount of heavy metals, thus exposing it to hazardous elements. However, risks associated with environment and domestic socio-economic developments were also noted. Recommendations were offered on ways to tackle these woes.

Keywords: *Gold Mining, Environmental Degradation, Maiwayo and Gada-Eregi, Nigeria.*

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Background to the Study

Absence of organized research techniques for gold, despite the great potentials in the mines, coupled with high rate of unemployment and poverty, paved way for the invasion of the Nigerian gold fields by intense artisanal gold miners. The main target of artisanal miners was to mine primary and alluvial gold deposits with little or no consideration for the environment, thus, expelling a lot of heavy metals associated with quartz as gangues and other sundry poisonous by-products into the environment and any available water source (Open wells and rivers) stressed that artisanal mining has caused a lot of negative impacts on the several communities of the world. It was estimated that about thirteen million people across thirty countries are directly involved in artisanal mining out of which a significant number of them are women and children (NiMet, 2010). A 2006 review of environmental impact statements found that water quality predictions made after considering the effects of mitigations largely underestimated actual impacts to groundwater, seeps, and surface water (see Table 1)

Surrounding communities are also affected by mining. There are many diseases that can come from the pollutants that are released into the air and water during the mining process. For example, during smelting operations enormous quantities of air pollutants, such as the suspended particulate matter. Arsenic particles and cadmium are emitted. Metals are usually emitted into the air as particulates. There are also many occupational health hazards. Most of the miners suffer from various respiratory and skindiseases. Miners working in different types of mines suffer from asbestosis, silicosis, black lung disease etc.

Materials and Methods

Preliminary and Field work Investigation

The methodology adopted for the study involved three primary approaches; the preliminary studies, fieldwork and Laboratory analysis. A preliminary survey was embarked on to have a vivid background of the research terrain and to delineate areas to be sampled. The topographic map of the study area (see Table 1; Bida sheet 184 NW) on a scale of 1:50,000 was acquired and enlarged to a scale of 1:8,500. The geologic mapping was conducted on a scale of 1:8500. Wells, streams and river Chanchaga water samples were systematically collected and neatly sealed in a 100 ml plastic container before sending to the laboratory for analysis (Abdullahi, 2012). Depths to water level for all well water samples taken were measured using tape rule and the positions of sampling points and the elevation above sea level were also noted using a global positioning system Soil and water samples were analyzed using these methods (Tables 2 and 3) (Abdullahi, 2012; Kankara, 2008)

Laboratory Analysis

The water samples were analyzed following procedures as recommended by ASMA, APHA and EPA. The parameters investigated included; Total Hardness, Alkalinity, Potassium (K^+), Sodium (Na^+), Nitrate (NO_3), Bicarbonate (HCO_3^-), Chloride (Cl^-), Sulphate (SO_4^{2-}), Iron (Fe), Copper (cu), Zinc (Zn),Lead (Pb), Manganese (Mn), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD). For effective monitoring of the physico-chemical and biological characteristics of the soil and water samples collected, the samples were immediately taken to the Laboratory for relevant analysis. Sample preparation and preservation followed American Public Health Association (APHA) guidelines, which include cooling the samples to 40°C and in some cases preservation with acid. All the physic-chemical and microbial analyses were carried out according to the procedures outlined by Analysis of the Association of Analytical Chemical (AOAC, 1998)

Results and Discussion

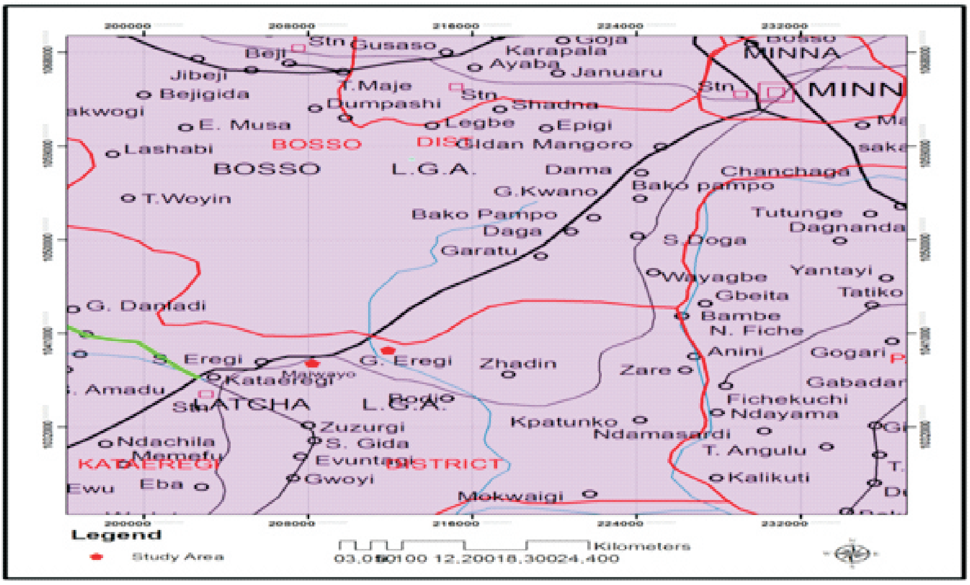
Table 1 presents a summary of the main characteristics of the Maiwayo and Gada-Eregi Basin while Table 2 shows Soil Sample Analysis Result for the Study Area. Table 3 shows the Statistical summary of all Parameters Analyzed for the Water Samples.

Table 1: Detailed Characteristics of Maiwayo and Gada-Eregi Areas.

Variables	**Detailed Characteristics**
Geology	Gritty clayey/Sedimentary area
Soil Type	Alfisol
Topography	Peniplanation/Pediplained/Undulating
Mean Annual Rainfall	1, 100mm/a
Catchment Area	120km
Mean Stream Slope	1.1^{o}
Average Stream Density	$1.69km^{2}$
Average Drainage Density	$1.10km^{1}$
Length of Overland flow	498m
Mean Elevation	623m
Mean Slope of the Basin	2.5^{o}
Peak Run-off	82m/s
Surface Run-off Recession	0.03

Source: Kankara, 2008

The mean values for the water quality parameters are presented in Tables 2 and 3. In some cases, high values of standard errors were obtained especially for TSS, PO_4^{3-}, BOD and COD. These were attributed to the fact that the wells were unprotected, most times without lids and concrete linings. In addition, the wells were all public utilities. They varied with seasonal change and distance from pollution source. The type of waste (municipal solid wastes or excreta) affected parameter concentration. Seasonal variation from dry to rainy periods increased the concentrations of Cu, Pb, faecal coli form, total coli form, BOD, COD, electrical conductivity, total dissolved solids in most cases.



Source: Field work, 2008 & 2012

Table 2: Soil Sample Analysis Result for the Study Area

Elements	SAMPLE A (ppm)	SAMPLE (ppm)
Silver (Ag)	5.124	3.642
Lead (Pb)	33.912	12.05
Nickel (Ni)	6.074	17.442
Gold (Au)	45.754	12.734
Manganese (Mn)	39.0	18.0
Cupper (Cu)	4.0	5.60
Zinc (Zn)	13.7	17.7
Iron (Fe)	1244	2396
Bicarbonate(HCO_3)	2.014	1.160

Source: Field Investigation, 2012

Table 3: Statistical summary of all Parameters Analyzed for the Water Samples

Parameters/Elements	Mean	Min.	Max.
Temperature (0°C)	28.95	28.0	30.0
pH	7.01	6.1	7.43
Conductivity	256.6	71	775
Total Hardness	162	68	480
Alkalinity	156.60	50	376
Chloride	29.27	11.34	119.13
Nitrate	1.75	0.11	3.88
Phosphate	0.08	0.015	0.16
Sodium	20.02	0.81	42.1
Potassium	11.65	0.00	36.36
Bicarbonate	151.32	56	396
Copper	0.05	0.00	1.15
Zinc	0.10	0.00	0.56
Lead	2.76	0.00	41.0
Manganese	0.69	0.00	7.41
Iron	5.70	0.36	62.0
Total Dissolved Solids	208.89	45.44	604.6

Soil and water

Two soil samples were taken from selected pits from the mining site and sent to the laboratory for analysis. The aim of doing this was to ascertain if the soil samples contain hazardous elements or not. The result of the soil analysis revealed that the two soil samples contains high amount of heavy metals. Heavy metals also occur naturally, but rarely at toxic levels except when the equilibrium existing between it and the host rock is distorted (Figure 3). A total of twenty water samples were analyzed and their statistical summary of all parameters is presented in bar charts (Adekoya, 2003; Garba, 1988). At Gada-Eregi, four water samples were collected from the wells within the village and the remaining six samples were collected from points spread within the river Chanchaga at Gada-Eregi which is the village where most of the miners converge to mill and wash their crushed rocks to recover gold.

Lead and Heavy Metals Concentration

Dissolution and transport of metals and heavy metals by run-off and ground water is another example of environmental problems with mining in the area. The area suffers from heavy metal contamination. Water in the mine containing dissolved heavy metals such as lead and cadmium leaked into local groundwater thereby contaminating it. Long-term storage of tailings and dust can lead to additional problems, as they can be easily blown off site by wind.

The implantation of a mine is a major habitat modification, and smaller perturbations occur on a larger scale than exploitation site, mine-waste residuals contamination of the environment for example (Kankara, 2008). Adverse effects can be observed long after the end of any mine activity. Destruction or drastic modification of the original site and anthropogenic substances release can have major impact on biodiversity in the area. Destruction of the habitat is the main component of biodiversity losses, but direct poisoning caused by mine-extracted material and indirect poisoning through food and water, can also affect animals, vegetal and microorganisms. Habitat modification such as pH and temperature modification disturb communities in the area. Endemic species are especially sensitive, since they need very specific environmental conditions. Destruction or slight modification of the habitat puts them at the risk of extinction. Habitats were damaged because there was no enough terrestrial as well by non-chemicals products, such as large rocks from the mines that are discarded in the surrounding landscape with no concern for impacts on natural habitat (Uzi, 2009).

Concentrations of heavy metals are known to decrease with distance from the mine, and effects on biodiversity follow the same pattern. Impacts can vary greatly depending on mobility and bioavailability of the contaminant: less-mobile molecules will stay inert in the environment while highly mobile molecules will easily move into another compartment or be taken up by organisms. For example, speciation of metals in sediments could modify their bioavailability, and thus their toxicity for aquatic organisms (Kankara, 2008).

Bioaccumulation too plays an important role in polluted habitats near the mines sites: mining impacts on biodiversity should be, assuming that concentration levels are not high enough to directly kill exposed organisms, greater on the species on top of the food chain because of this phenomenon. Adverse mining effects on biodiversity depend to a great extent on the nature of the contaminant, the level of concentration at which it can be found in the environment, and the nature of the ecosystem itself. Some species are quite resistant to anthropogenic disturbances, while some others completely disappeared from the contaminated zone. Time alone does not seem to allow the habitat to recover completely from the contamination. Remediation takes time, and in most of the cases will not enable the recovery of the diversity present before the mining activity.

The Nigerian Standard for Drinking Water Standard recommended an acceptable limit of 0.03mg/l of lead in all drinking water. Range of Lead concentration in all the water samples is between 0.5 mg/l-41.0 mg/l which is far above the permissible limit. Sample mwy1 and mwy2 with 0.5mg/l and 10.0mg/l are water samples collected from the mining pits at Maiwayo village while mwy3, mwy5 and mwy7 whose values are 0.6mg/l ,41.0mg/l and 0.5mg/l are all well water samples from Maiwayo. Unfortunately, 80% of the water samples that had lead in them is those from Maiwayo water wells. The major reason for this high presence of lead in could be due to the fact that almost 90% of the labourers working in the mines are in contact with lead contained in rocks bearing gold (Figure 1).

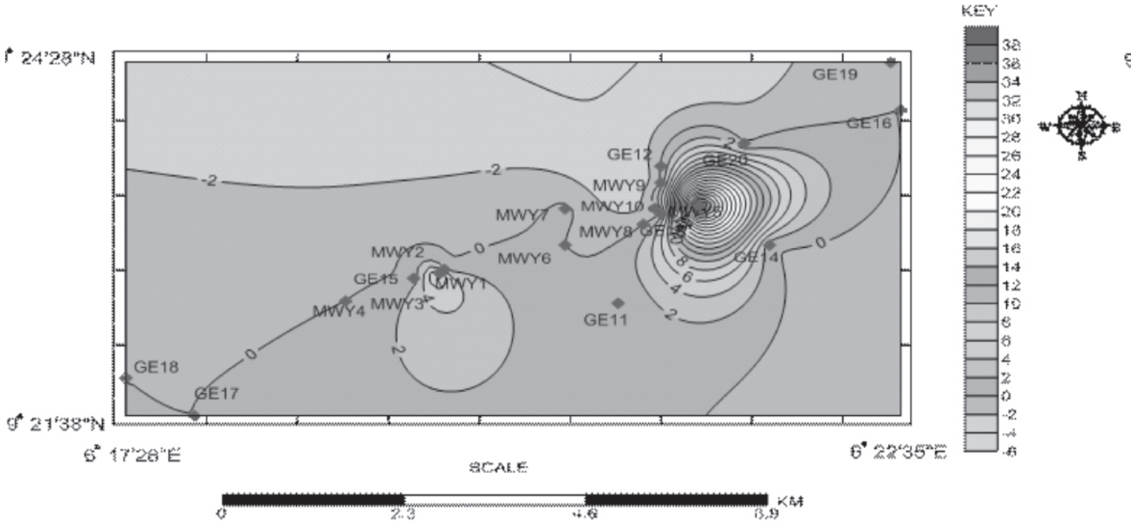


Figure 1: Concentration Map of Lead in the Study Area

Surface and Ground water Pollution

The process of getting gold out of the crushed rocks (gangue) brings it into contact with people and ground and surface waters where heavy and poisonous metals contained in the rocks as gangues are deposited. These activities are capable of polluting both surface and underground water system in the research area through the release of heavy metals contained in the host rocks thereby posing a great health threat to humans, aquatic life and livestock within that immediate environment and even the downstream consumers of the polluted water (NSDWQ, 2007; Ako et al, 2014)

Environmental and Socio-Economic Impacts

However, the risk associated with gold mining operations are numerous starting from the dangerous pits and underground tunnels (Lotos) created as a result of this operation which are normally dangerous to humans as well as animals. These risks could set in during exploration/ mining process when a lot of poisonous metals hosted by the auriferous quartzite are let loose by the laborers. Prostitution and illicit use of drugs constitute a social menace in mining areas. Most artisanal miner usually feels that to be active in the pits, there is the need for them to use hard drugs to stimulate their body system and women to give them joy. In most artisanal gold mines visited, the disease (AIDS) has wiped off a lot of lives (Hentsche et al, 2002).

Plate I: Women crushing auriferous quartzite at Maiwayo with Children arround them
(Note the possibility of direct inhalation of heavy metals by the Children).

No matter how large or small gold mining operation is, it has the potential of improving the living standard of the people living in that Community. The only problem is the series of health and environmental risks associated with the operation generally. This risk begins from the exploration stage and continues throughout the lifespan of the mine. The impact may even stretch several years beyond the life span of the mining operation (Adelakan et al, 2011). Gold mining operations has the potential to significantly affect the socio-economic opportunities of the poor in those communities by boosting their income level.

Furthermore, the environmental impact of mining in the study area includes erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater, surface water by chemicals from mining processes. In some cases, additional forest logging is done in the vicinity of mines to increase the available room for the storage of the created debris and soil. Besides creating environmental damage, the contamination resulting from leakage of chemicals also affects the health of the local population (Maest, 2006). Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned to close to its original state. Some mining methods may have significant environmental and public health effects. Abdullahi (2012) provide an overview of the life-cycle wide environmental impacts of heavy metals associated with gold mining in the said area.

Erosion of exposed hillsides, mine dumps, tailings dams and resultant siltation of drainages, creeks and rivers can significantly impact the surrounding areas too. It also caused destruction and disturbance of ecosystems and habitats, and because farming is done it also disturbed or destroyed the productive grazing and croplands. Still, it also produces noise, dust and visual pollutions. Gold mining in the area had bad effects on the surrounding surface and ground water. Studies revealed that protective measures are not taken. The result showed that there are unnaturally high concentrations of some chemicals, such as arsenic, sulfuric acid, and mercury over significant areas of surface or subsurface. Runoff of mere soil or rock debris -although non-toxic- also devastates the surrounding vegetation. The dumping of the runoff in surface waters or in forests of Maiwayo and Gada-Eregi are the worst options (ICMIHNE, 2008).

Submarine tailings disposal is regarded as a better option (if the soil is pumped to a great depth). Mere land storage and refilling of the mine after it has been depleted is even better, if no forests need to be cleared for the storage of the debris. There is potential for massive contamination of the area surrounding mines due to the various chemicals used in the mining process as well as the potentially damaging compounds and metals removed from the ground with the ore. Large amounts of water produced from mine drainage, mine cooling, aqueous extraction and other mining processes increases the potential for these chemicals to contaminate ground and surface water (Maest, 2006). Maiwayo is a well-regulated mine area, therefore hydrologists and hydro geologists take careful measurements of water and soil to exclude any type of water contamination that could be caused by the mine's operations. The reducing or eliminating of environmental degradation is enforced in the Nigerian mining Act which was amended in 2007 by the federal and state mining laws, by restricting operators to meet standards for protecting surface and ground water from contamination. This is best done through the use of non-toxic extraction processes as bioleaching in some instances, by the artisan miners (Diehl, 2004).

Effect on Other Aquatic organisms

The mining industry can impact aquatic biodiversity through different ways. Direct poisoning is the first one, and risks are higher when contaminants are mobile in the sediment or bio available in the water. Mine drainage can modify water pH, and it is hard to differentiate direct impact on organisms from impacts caused by pH changes. Effects can nonetheless be observed and proved to be caused by pH modifications. Contaminants can also affect aquatic organisms through physical effects: streams with high concentrations of suspended sediment limit light, thus diminishing algae biomass. Metal oxide deposition can limit biomass by coating algae or their substrate, thereby preventing colonization (Uzi, 2009).

Factors that impact communities in acid mine drainage sites vary temporarily and seasonally: temperature, rainfall, pH, salinization and metal quantity all display variations on the long term, and can heavily affect the communities of Maiwayo. Changes in pH or temperature can affect metal solubility, and thereby the bio available quantity that directly impact organisms. Moreover, contamination persists over time: ninety years after a pyrite mine closure, water pH was still very low and micro organisms populations consisted mainly of acidophil bacteria. Algae communities are less diverse in acidic water containing high zinc concentration, and mine drainage stress decrease their primary production. Diatoms community is greatly modified by any chemical change. The pH phytoplankton assemblage and high metal concentration diminishes the abundance of planktonic species. Some diatom species may however grow in high-metal-concentration sediments. In sediments close to the surface, cysts suffer from corrosion and heavy coating. In much polluted conditions, total algae biomass is quite low, and the planktonic diatom community missing. In case of functional complementarily however, it is possible that phytoplankton and zooplankton mass remains stable (Ako et al, 2014).

Water insect and crustacean communities are modified around the mine, resulting in a low trophic completeness and community being dominated by predators. However, biodiversity of macro invertebrates can remain high, if sensitive species are replaced with tolerant ones. When diversity is on the contrary reduced, there is sometimes no effect of stream contamination on abundance or biomass, suggesting that tolerant species fulfilling the same function take the place of sensible species in polluted sites (Uzi, 2009). The pH diminution in addition to elevated metal concentration can also have adverse effects on macro invertebrates' behaviour, showing that direct toxicity is not the only issue. Fishes are also affected by pH, temperature variations and chemical concentrations.

Effect on Soils' Texture and Plant Specie

Soils' texture and water contents were greatly modified in the disturbed sites, leading to changes in the plants communities in the given area. Most of the plants have a low concentration tolerance for metals in the soil, but sensitivity differs among species. Grass diversity and total cover is less affected by high contaminant concentration than forbs and shrubs. Mines waste-material rejects or traces due to mining activity can be found in the vicinity of the mine, sometimes pretty far away from the source. Established plants cannot move away from perturbations, and will eventually die if their habitat is contaminated by heavy metals or metalloids at concentration too elevated for their physiology. It was discovered that some species are more resistant and will survive these levels, and some non-native species that can tolerate these concentrations in the soil, will migrate in the mine surrounding lands to occupy the ecological niche (ICMIHNE, 2008).

Plant species were affected by the mining in the area through direct poisoning, for example arsenic soil content reduces bryophyte diversity. Soil acidification through pH diminution by chemical contamination also led to the diminished species number. Here, contaminants really modified and disturbed the microorganisms specie, thus modifying nutrient availability, causing a loss of vegetation in the area. Some tree roots avoid the deeper soil layer in order to avoid the contaminated zone, and thus miss anchorage and were uprooted by the wind when their height and shoot weight increase (Diehl, 2004). In general, root explorations were reduced in the contaminated areas compared to non-polluted ones. The habitats here were not reclaimed as such plant species diversity is lower than in the undisturbed areas. Cultivated crops too were affected by the mine problem near the mines vicinities. In the area of Maiwayo, most crops can grow on weakly contaminated sites, but yield is generally lower than it would have been in regular growing conditions. Plants also accumulated heavy metals in their aerian organs leading to human intake through fruits and vegetables. Regular consumptions also led to health problems as caused by long-term metal exposure.

Conclusion

Positive economic development is one of the primary advantages for mining gold in contemporary times. Gold mining is a sector of trade and businesses that governments use to improve their nation's economic systems. Gold mining is the process of mining of gold or gold ores from the ground. The current study shows that the water has no copper but other heavy metals like lead, Zinc, manganese and Iron are contained in most of the water samples analyzed and their presence can be tied to the geology of the area and human activities. Result of the soil samples shows that these metals occur in association with gold bearing quartzite. The study was also able to compare values of heavy metals contained in water samples collected from Maiwayo and Gada-Eregi villages in Niger state and the results revealed that the impact of the mining activity is more on Maiwayo village than Gada-Eregi. Copper, mercury, manganese, iron, lead and zinc dusts are carried in the air; therefore it is recommended that a study to determine levels of these metals in the air in the study area to carried out with a view to ascertain their content in the atmosphere. Study can be conducted in different parts of Niger State or mining communities to assess the health impacts of heavy metals in surface and groundwater including the effects of mercury used by the artisanal miners to amalgamate gold and their impact on the health of the inhabitants.

Recommendations

1. It is recommended that increased and continued combined environmental interventions, through public health education by community based health workers, awareness and sensitization campaigns be carried out for improved household and community sanitation in rural areas in the developing countries.
2. Wells located within 50 meters from pollution source should be abandoned and future wells should be constructed beyond 250 meters from pollution source.
3. Adequate solid waste disposal method should be adopted, phasing out open dumpsites to safeguard public health from water borne diseases.
4. The mining sites become nonetheless polluted, and therefore mitigation techniques such as acid mine drainage (AMD) need to be performed.
5. The five principal technologies used to monitor and control water flow at mine sites are diversion systems, containment ponds, groundwater pumping systems, subsurface drainage systems and subsurface barriers. In the case of AMD, contaminated water is generally pumped to a treatment facility that neutralizes the contaminants.

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