Lapai Journal of Science and Technology Vol. 3, No. 1 (2016)

IMPACTS OF ARTISANAL GOLD MINING ON SURFACE AND GROUNDWATER QUALITY AROUND MAIWAYO AND GADA-EREGI MINIG SITES, NORTH-CENTRAL NIGERIA

[1]Abdullahi Suleiman, [2]Idris-Nda, A., [2]Amadi, A. N. and [3]Kuti, I. A.

[1]Centre for Disaster Risk Management and Development Studies, FUT, Minna, Nigeria
[2]Department of Geology, Federal University of Technology, Minna, Nigeria
[3]Department of Agricultural and Bio-Resources Engineering, FUT, Minna, Nigeria
***Corresponding author's emails:** geoama76@gmail.com, or an.amadi@futminna.edu.ng
Phone Number: +234-8037729977

ABSTRACT

A study on the impacts of artisanal gold mining on water quality around Gada-Eregi and Maiwayo gold mining sites, North-central Nigeria was undertaken. Geological mapping of the area was conducted and the major rock types in the area are granites and schists. The area is drained by River Chanchaga and its tributaries, which flows in northeast-southwest direction. It corresponds with the main joint direction in the area. Twenty water samples were collected from streams, hand-dug wells and mine-pits located in the study area. The samples were analysed for cations, anions and heavy metals. Physical parameters such as temperature, pH and conductivity were measured in-situ using standard instruments. The samples were analyzed using Atomic Absorption Spectrometer (AAS). The recorded average values for the major ions: chloride, nitrate, phosphate, sodium, potassium and bicarbonate are: 29.27mg/l, 1.74mg/l, 0.08mg/l, 20.02mg/l, 11.65mg/l and 151.32mg/l respectively. The heavy metals such as manganese, copper, zinc, iron and lead had the following respective mean values: 0.65mg/l, 0.05mg/l, 0.10mg/l, 5.70mg/l and 2.70mg/l. These results show that the major cations and anions are presently within safe concentration limits while concentrations of lead, manganese, zinc and iron are higher than their respective WHO maximum permissible limits. This implies that the water sources in Gada-Eregi and Maiwayo are not suitable for domestic and drinking purposes. Treatment of the water before use is recommended due to the toxic nature of the heavy metals. A regular follow up study to determine the level of heavy metals in soils in the area is recommended to avert danger of heavy metal poisoning.

Keywords: Assessments, Artisanal gold mining, Water sources, Maiwayo and Gada-Eregi North-central Nigeria

INTRODUCTION

Artisanal gold mining is the use of rudimentary methods to extract and process gold. It is a subsistent type of mining which is largely driven by low income and plays a large role in boosting the economic base of the poor rural communities. This type of gold mining operation impacts negatively on the environment as the gangue are disposed on the nearby soil and surface water without any precaution. Heavy metal bearing rocks containing gold are mined, crushed and liberated into any available environment and this poses a lot of health and environmental hazards. According to Adekoya (2003), artisanal mining has caused a lot of negative impacts on 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 are women and children (Garba, 2000; Adler and Rascher, 2007).

In Nigeria, gold mining started in 1913 and got to the peak in 1945 with a total production of about 1.4 tons of gold and thereafter, declined due to first and Second World Wars (Garba, 2002). The Nigerian Mining Corporation commenced gold exploration in the early 1980s but could not continue due to lack of funds (Salau, 2000). The absence of organized mining techniques for gold despite the great potentials, coupled with the high rate of unemployment and poverty, led to the invasion of the Nigerian gold fields by artisanal gold miners. The main target of the artisanal gold miners was the primary and alluvial gold deposits with little or no consideration for the environment thereby expelling a lot of heavy metals associated with quartz as gangue and other sundry poisonous by products into the environment and any available water source.

Similar situation is what led to the detrimental health and environmental consequences on Baggega and Daretta villages in Zamfara State where gold mining and processing is a main occupation of the people. The United Nations Centre for Disease Control (2010) reported the death of over four hundred children in these communities due to neurological complications suffered as a result of harmful gold processing practices. Though mining has a lot of economic benefits to the miners and their host communities, its environmental and health effects in terms of land degradation, air pollution and heavy metal contamination of the soil, surface and groundwater could be devastating if not properly handled (Aigbedion and Iyayi, 2007).

All over the World, gold mining is usually accompanied by series of environmental and health hazards with far reaching health implications (Amadi *et al.*, 2014). These hazards could set in during the gold exploitation process itself either from the tailings generated which has a lot of heavy metals in them or from the dangerous trenches created during mining (Fig. 1). The process of getting gold out of the crushed rocks brings it into contact with people and water (both ground and surface water) where heavy and poisonous metals contained in the rocks as gangue are deposited. Maiwayo village now host thousands of artisanal miners as a result of the discovery of a viable gold deposit about 2km east of the Village (Fig. 2). Gada-Eregi is also strategic to the miners because of the availability of electricity and a large water body for processing their milled gold dust. These unsafe activities are capable of contaminating the soil, surface and groundwater system in the area (Garba, 2002; Garba, 2003). Such activities are capable of enriching the ecosystem (soil, water and air) with heavy metals contained in the host rocks discarded into the nearby environment thereby posing a great health risk to humans, aquatic life and livestock within the surrounding and downstream environment (Fig. 3). Gold mining is an economically profitable venture and a major point source of soil and water contamination. Recent studies around the world and Nigeria in particular have shown that gold is often associated with heavy metals like lead, copper, mercury and arsenic (Amadi *et al*., 2014; Okunlola *et al*., 2016). These metals can either be liberated from the rocks hosting them in the process of extracting the gold. Sometimes mercury is used to extract fine gold particles from crushed rocks leading to the pollution of soil and water sources by heavy metals. The present study is aimed at evaluating the pollution status of soil, surface and groundwater due to artisanal gold mining activities in the area.

Fig. 1: Trenches created by Artisanal gold miners

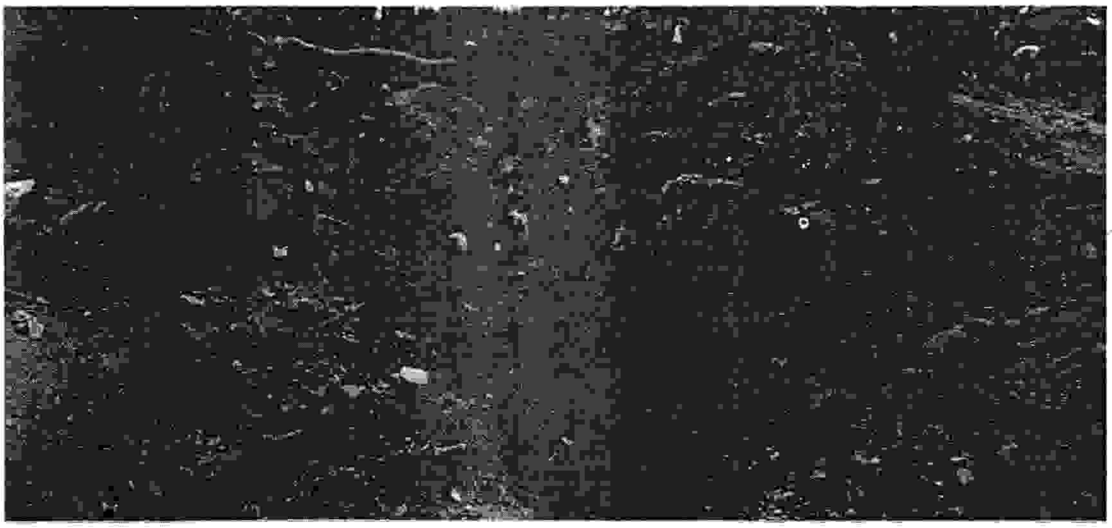


Fig. 2: Environmental degradation associated with artisanal gold mining operations

Fig. 3: Damage to the soil and topography due to artisanal gold mining activity

MATERIALS AND METHODS

Location of the Study Area

The study area is part of sheet 184 NW (Bida) and lies between latitudes 9°20'00"N to 9°26'6.55"N and Longitudes 6°17'40.55"E to 6°23'24.36"E (Fig. 4). About 90% of the area falls within Katcha Local Government Area while the remaining 10% falls within the northern portion in Bosso Local Government Area. The study area is accessible through Minna-Bida road. It is about 45km away from Minna and Bida respectively. The gold mining site is about 900m from Maiwayo village and 120m from the Minna-Bida road.

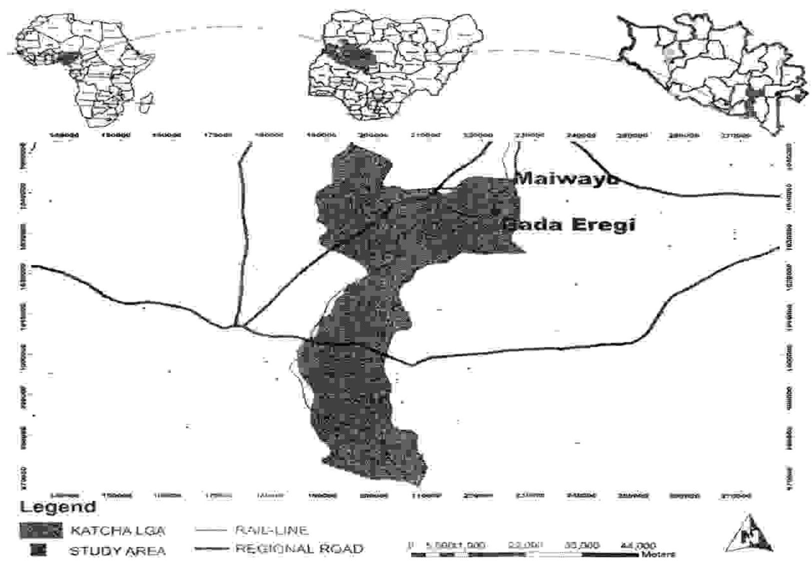


Fig. 4: Map of Katcha Local Government showing the Study Area

Geological, Hydrogeology and Structural Geology of the Area

Rock types identified in the study area are Biotite granite and schist with intrusions of pegmatites, quartz veins and aplites (Fig. 5). The static water level inventory data obtained from the area was used to construct the groundwater flow direction in the area (Fig. 6). The groundwater flow direction is parallel to the principal joint direction which implies that the groundwater movement in the area is structurally controlled. Granites form an approximately N-S trending ridge on the eastern corner of the studied area and are fine grained mainly dominated by quartz, biotite and feldspars. The schists are weathered and deformed in response to stress which makes the rock split in parallel when a force is applied. Schist exposures covers more than half of the study area stretching from the northwest and southeast and along the rail track behind the mining site at Maiwayo village. The joint directions on both the granites and schist were measured and used to construct a rosette diagram which shows a preferred joint direction of NE-SW and NW-SE (Fig. 7). The NE-SW joint system is the axis that is exploited by the artisanal miners while active mining is yet to commence on the NW-SE arm.

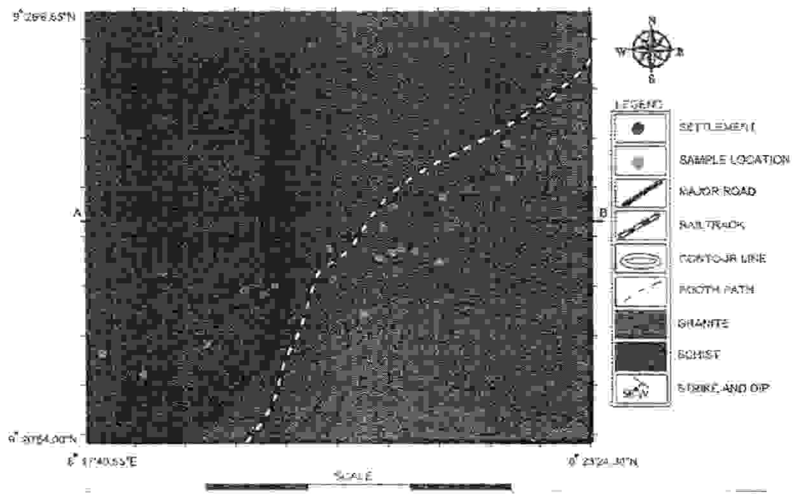


Fig. 5: Geological map of the study area

Sample Collection and Analysis

Sampling points were strategically located with the aid of a GPS along River Chanchaga (Fig. 8), the main river flowing across the entire study area. Water samples were also collected from shallow hand-dug wells in the area as well as the mine pits and hand dug wells mainly along the NE-SW portion of the area where active mining is going on presently (Fig. 3). At each sampling point, two set of samples were collected using glass and plastic containers and 2 drops of HNO3 (ultra-pure grade) to pH < 2 were added to plastic containers for cation analyses in order to prevent loss of metals, bacterial and fungal growth and then stored in a refrigerator. Physical parameters temperature, pH and colour were measured in the field using portable HACH meters. All sampling and analytical procedures met the APHA (2008) standard.

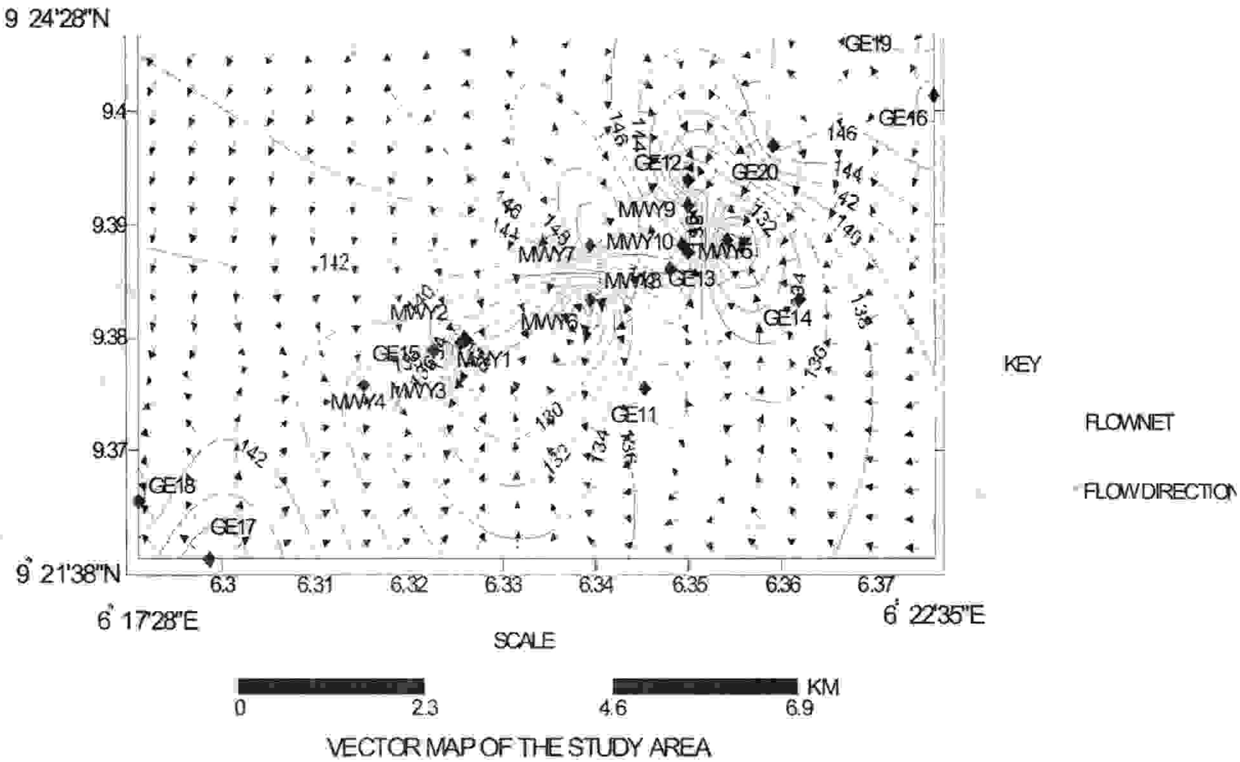


Fig. 6: Groundwater flow map of the study area

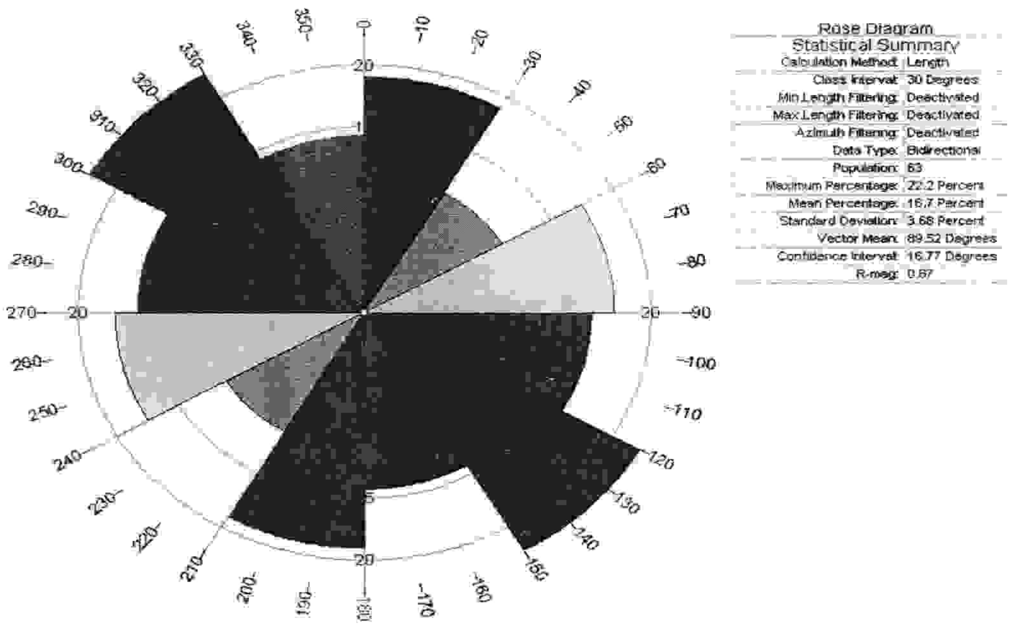


Fig. 7: Rosset diagram showing the principal joint directions

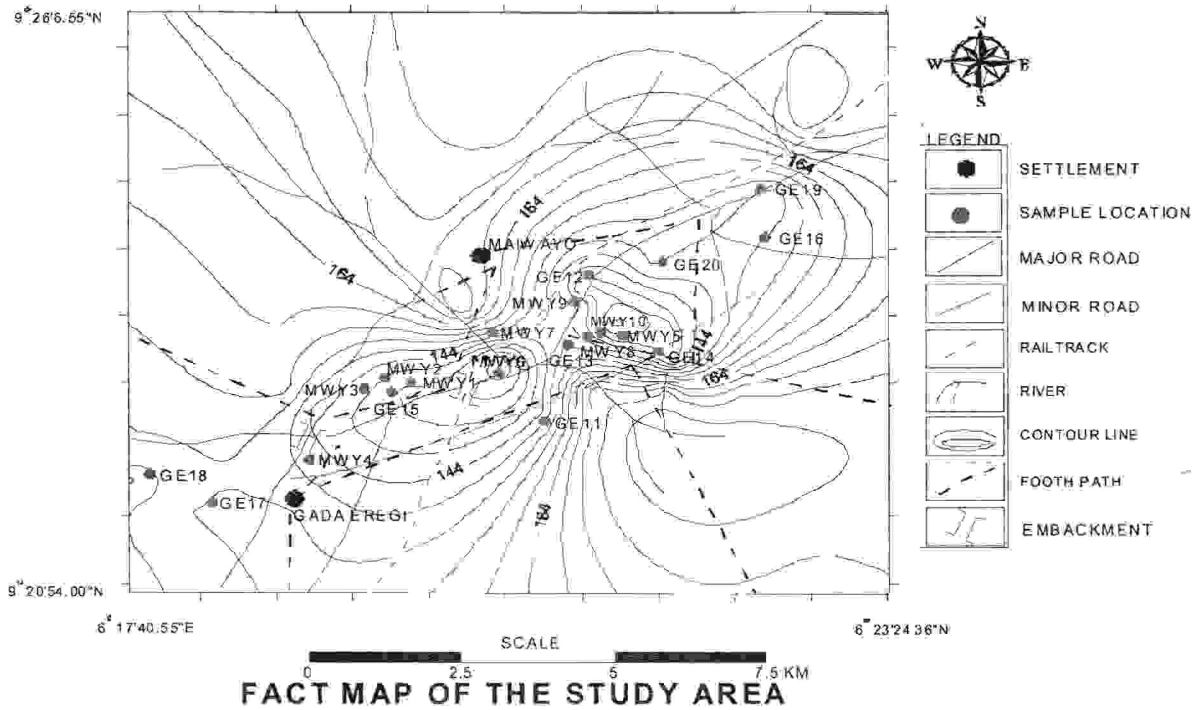


Fig. 8: Map of study area showing the sampling locations

RESULTS AND DISCUSSION

The pH value of the water range from 6.1 to 7.43 with an average value of 7.01 (Table 1). The acceptable pH values ranged from 6.5 to 8.5 according to World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ). The pH of water is an indicator of the water quality and extent of pollution. The gold mining activity going on in the area may be responsible for the pH of <7.0 in some locations, an indication of mild acidity. The temperature values ranged from 28.00 °C to 30.00 °C and an average temperature of 28.95 °C (Table 1). Water temperature is also a crucial aspect of aquatic habitat, as aquatic organisms are adapted to live within a certain temperature range. As the upper and lower temperature limits are approached, the organism becomes more susceptible to diseases. Also, fish that spend extra energy searching for cool areas may be at a disadvantage when competing for food (EPA, 1991). The electrical conductivity (EC) is a valuable indicator of the amount of material dissolved in water. Its value ranged between 71.00 µs/cm to 775.00 µs/cm with an average value of 256.60 µs/cm (Table 1).

Table 1: Statistical summary of the Physico-chemical parameters analyzed

Parameters (mg/l)	Mean.	Min.	Max.
Temp. (0^0C)	28.95	28.0 0	30.0
pH	7.01	6.10	7.43
Conductivity (µS/cm)	256.60	71.00	775.0
Total Hardness	162.00	68.00	480.0
Alkalinity	156.60	50.00	376.0
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	56.0	396.0
Copper	0.05	0.01	1.15
Zinc	0.10	0.01	0.56
Lead	2.76	0.05	41.0
Manganese	0.69	0.02	7.41
Iron	5.70	0.36	62.0
Total Dissolved Solids	208.89	45.44	604.6

The wide range of EC is a testimony that there are substantial differences in the quality/composition of the surface water within the study area. Total hardness (TH) is the summation of total suspended solids (TSS) and total dissolved solid (TDS). The concentration varied from 68.00 mg/l to 480.00 mg/l with a mean value of 162.00 mg/l. The presence of calcium, magnesium and sodium ions in water is responsible for water hardness. The amount total dissolved solid (TDS) is an indication of the general nature of water quality or salinity. Water samples containing >500 mg/l of TDS is considered undesirable for domestic use (WHO, 2010).

In the present investigation (Table 1), the value of TDS varied from 45.44 mg/l to 604.60 mg/l with a mean value of 208.89 mg/l. The high TDS values may be a reflection of anthropogenic interference in the area which is an indicator of pollution. The alkalinity content ranged from 50.00 mg/l to 376.00 mg/l with a mean value of 165.60 mg/l while bicarbonate concentration varied from 56.00 mg/l to 396.00 mg/l with an average value of 151.32 mg/l. These values in most locations are higher than the accepted 250.00 mg/l and 100.00 mg/l for alkalinity and bicarbonate respectively. Bicarbonate is fundamental for all biological fluids in the body. Bicarbonates play a central role in maintaining the body's internal acid-base balance and in stomach secretions and essential to the process of digestion. One of the few adverse effects of bicarbonate is irrigation as it can decrease the lime requirement for plant production thereby causing adverse plant growth by excessively raising the pH of the soil. Sodium concentration in this study ranged between 0.80 mg/l to 42.10 mg/l and a mean value of 20.02 mg/l. This concentration is below the recommended limit of 200.00mg/l (WHO, 2010; NSDWQ, 2007).

The concentration of potassium in the water samples from the study area ranged from 0.00 mg/l to 36.36 mg/l and a mean value of 11.65 mg/l. Potassium occurs in many rocks from where it could be dissolved through weathering procedures. It is also sourced from fertilizers and plants (Hansen, 2000). Being an essential element, potassium is present in the tissues of all plants and animals. Potassium is applied in many industrial processes such as in alloy and organic synthesis, fertilizer production, glass making, soap making. Waste materials generated from gold production processes are very hazardous any time they are discharged into surface water making it difficult and expensive to purify such water. Potassium is a dietary nutrient with critical functions associated with nerve movement, muscle contractions, bloodstream pressure regulation and proteins dissolution. In addition, it protects the heart and arteries and could even prevent cardiovascular ailments. Potassium shortages are usually rare but can result in depression, muscles weakness, cardiovascular rhythm dysfunction and distress. High concentration of potassium can be hazardous as potassium chloride interferes with nerve impulse, which interrupts with virtually all bodily operations and mostly affects cardiovascular functioning (Amadi *et al*., 2013).

The concentration of Chloride in this study ranged from 11.34 mg/l to 119.13 mg/l and a mean value of 29.27 mg/l and these values falls below the maximum limit of 250mg/l (WHO, 2010; NSDWQ, 2007). Since high chloride in groundwater indicates pollution by sewage or industrial waste, the possibility of groundwater in the study area been polluted by sewages was therefore ruled out. Nitrate concentrations in the water samples are generally low with values ranging from 0.11 mg/l to 3.88 mg/l and an average value of 1.75 mg/l. In all locations the value falls below the permissible limit of 50mg/l. High nitrate concentration in water causes gastric methemoglobinemia or blue baby syndrome, a problem found especially in infants less than six weeks which decreases oxygen supply to crucial tissues such as brain (Dan-Hassan *et al*., 2012). The phosphate content in the water is below the permissible limit which is a further attestation to the fact that the area has not witnessed urban pollution arising from mechanized farming and industrialization (Amadi and Nwankwoala, 2013; Amadi *et al*., 2015).

Heavy metal concentrations in geomaterials such as soil and water are of great concern because of their toxicity, persistence and bio-accumulative nature as this have serious effects on both plants and animal health through food chain (Amadi *et al*., 2012). Iron is among the earth's most plentiful elements. Rainwater dissolves it mainly because it infiltrates the soil perfectly to the underlying geological formations. Although iron is not hazardous to health, it is considered a secondary or aesthetic contaminant. It is essential for good health as it helps transport oxygen in the blood. Iron causes taste and odour problem in water and may result in water colouration when it exceed the maximum permissible limit of 0.3mg/l (WHO, 2010; NSDWQ, 2007). The concentration of iron in all the water samples analyzed is generally high while anomalous values are found in the active mining pits areas of Maiwayo and Gada-Eregi villages. The explanation for the anomalous concentration of iron in all the water samples could be attributed to the geology of the underlying rocks in the study area which are mostly schistose in nature, highly weathered and rich in iron bearing minerals. The concentration map of iron in the area is shown in Figure 9.

The concentration of lead in all the water samples ranged between 0.00mg/l to 41.0 mg/l with a mean value of 2.76mg/l as against the maximum permissible limit of 0.01mg/l (WHO, 2010). It was observed during the field work that the hand-dug well with lead concentration of 41.0mg/l was used by the miners for washing the rocks. The buckets used in excavating the host rock were used to fetch water from the well and this unhealthy practice may be responsible for the anomalous concentration of lead. The central portion of the study area has the highest concentration and it correspond to where mining is currently been done.

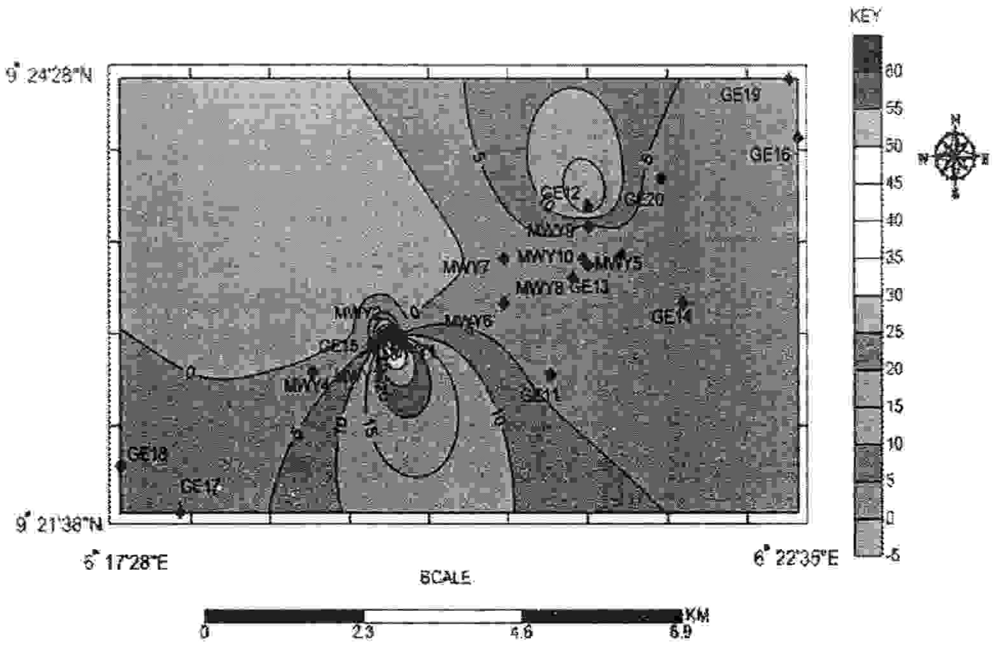


Fig. 9: Concentration map of Iron in the study area.

These values are by far higher than the permissible limit. Water samples with high lead values were collected from the mining pits at Maiwayo village and from river Chanchaga at Gada-eregi where gold washing was done. The high concentration of lead in the water system in the area can be traced to the active gold mining operation on-going in the area. It is interesting and as well disturbing that the miners use the shallow hand-dug wells in the village as their source of drinking water and for other domestic purposes. Investigations in the course of this research revealed that the artisanal miners use the same instruments (buckets, bowls, knifes and plates) used in mining gold for cooking and eating. The miners also crush their gold bearing rocks in shades close to water wells where wind action is very much prevalent. All these unhygienic measures enhance the contamination threshold in the study area. The highest concentration of lead is at the eatern part of the area where the hand-dug well used by miners in washing and bathing is located (Fig. 10). Studies revealed that high concentration of lead in water causes cancer, gastrointestinal tract infections, interference with Vitamin-D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems (NSDWQ, 2007; WHO, 2010).

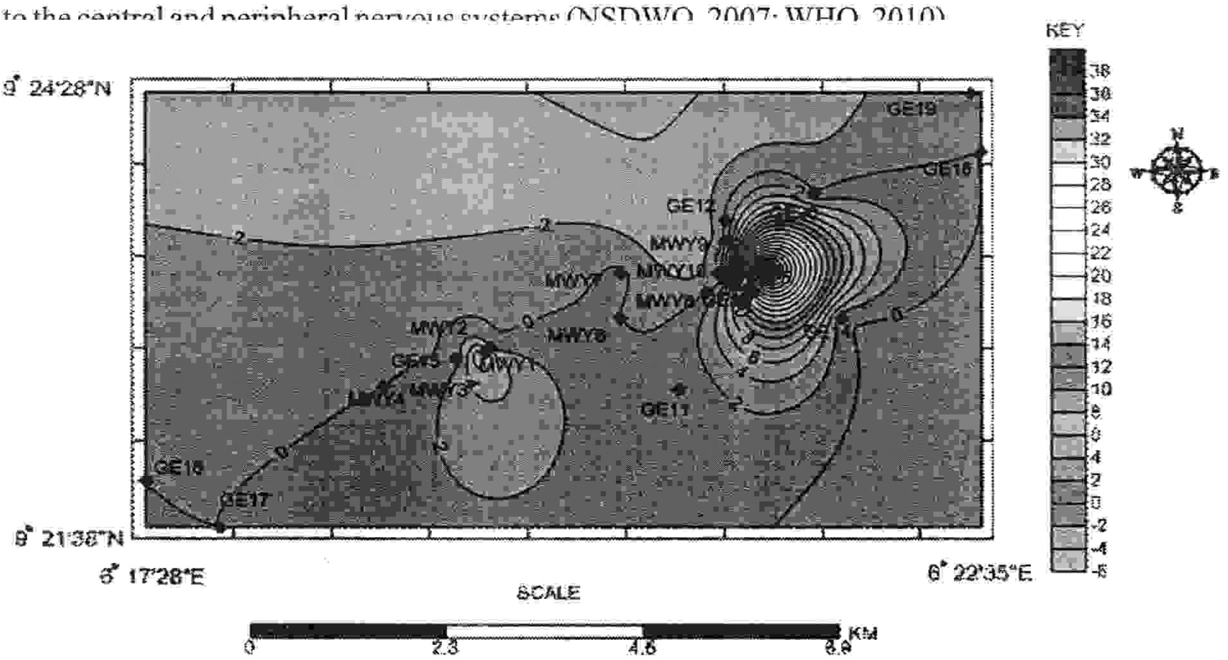


Fig. 10: Concentration map of Lead in the study area.

Manganese is an abundant metal which occurs in various oxidation states both as oxides and hydroxides. It is principally found in Pyrolusite (MnO_2) and Rhodochrosite ($MnCO_3$). The water samples analysed shows Manganese concentration ranged from 0.00 mg/l to 7.41 mg/l with average value of 0.69 mg/l (Table 1) as against the maximum permissible limit of 0.2mg/l (NSDWQ, 2007). Majority of the water samples collected from Maiwayo and Gada-Eregi wells have higher Manganese concentration. High concentration of Manganese in water causes neurological disorder as well as weakness in the legs, staggering gait and also behavioral disorders. Children confronted with high concentration of manganese demonstrate low IQs. The concentration of manganese in the area is significant along the observed NE-SW axis of the study area (Fig. 11). Although manganese is not mined in the area, the occur as pathfinder elements with gold and mining of gold exposes it into the environment. The form part of the gangue that is often discarded by the miners and through surface run off and or infiltration, they find their way into the surface and groundwater system thereby enriching their concentrations. The concentration of zinc ranged from 0.00 mg/l -0.56 mg/l with a mean value of 0.10 mg/l (Table 1). These values falls below the acceptable limit of 3.00 mg/l (NSDWQ, 2007) The World Health Organizations recommends for an addition of 15mg/day of zinc to the diets for men, 12 mg/day for women and 10mg/day for children while the infants zinc intake per day should be 5mg/day (WHO 2010). The concentration map of zinc is reflected in Figure 12

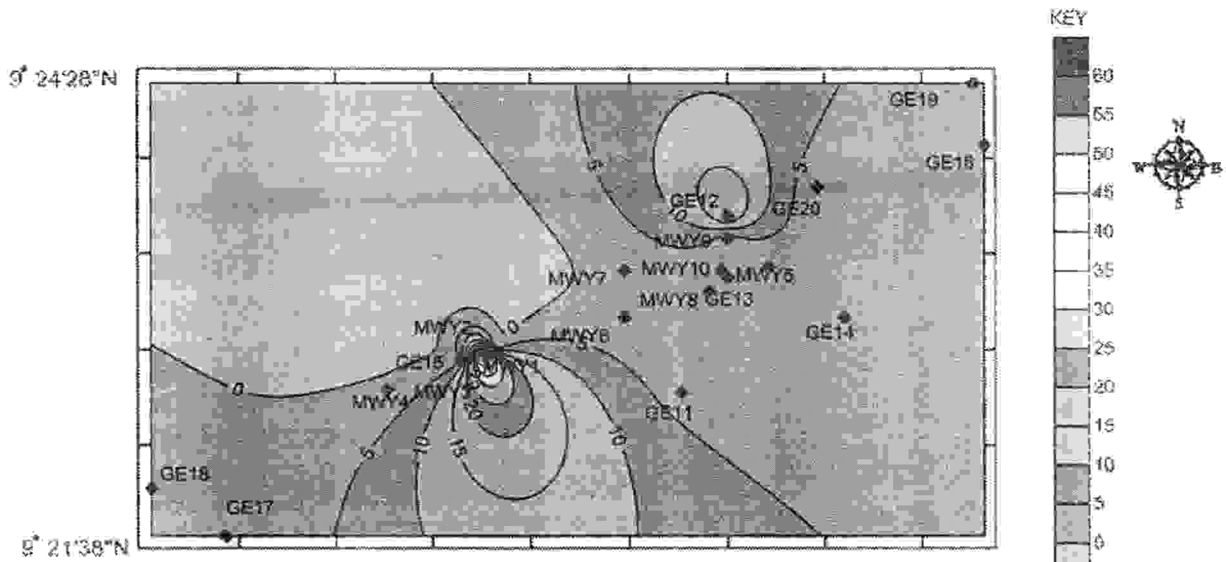


Fig.11: Concentration map of Manganese in the study area

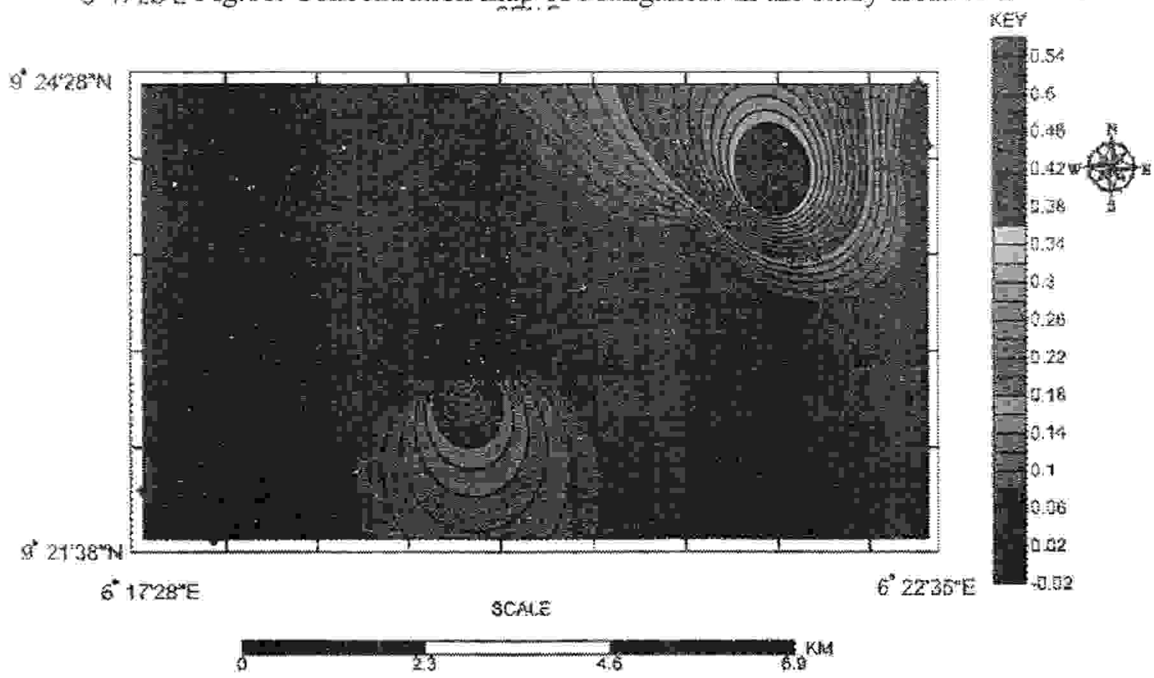
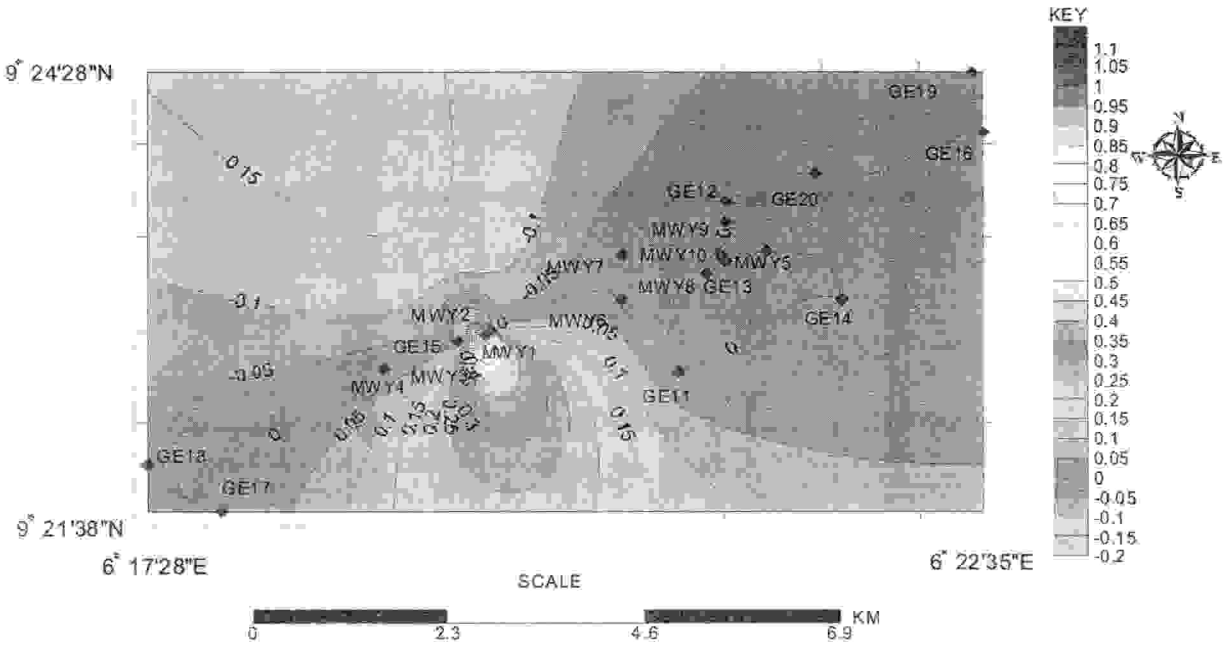


Fig.12: Concentration map of Zinc in the study area

Copper is an essential substance to human life, but in high concentrations it can cause anemia, liver and kidney diseases in addition to stomach and intestinal disorders. The concentration of copper varied from 0.00 mg/l to 1.15 mg/l with an average value of 0.05 mg/l (Table 1) as against the permissible limit of 1.0 mg/l (NSDWQ, 2007). High concentration of copper causes gastrointestinal disorder. A map showing the distribution of copper is shown in Fig.13.



CONCLUSION AND RECOMMENDATION

The impact of artisanal gold mining on water quality was evaluated in this study. Artisanal gold mining is beneficial in terms of income generation but has very serious negative effects on surface and groundwater contamination. The present study shows that the water in the area is highly contaminated with lead, iron and manganese and moderately contaminated with zinc while there is no contamination arising from copper at all. The enrichment of these heavy metals in water is a signature of the location geology as well as the gold mining activity going on in the area. A similar study should be conducted in different parts of Niger State where gold mining is going on in order to determine the level of soil and water contamination in the host communities.

REFERENCE

Adekoya J.A. (2003). Environmental Effect of Solid Minerals Mining. *Journal of Physical Science*, 11: 625–640.

Adler, R. and Rascher, J. (2007). A Strategy for the Management of Acid Mine Drainage from Gold Mines in Gauteng. Report No: CSIR/NRE/PW/ER/2007/0053/C.CSIR, Pretoria.

Aigbedion, I. and Iyayi, S.E (2007). Environmental Effects of Mineral Exploitation in Nigeria. *International Journal of Physical Science*, 2(2): 33 – 38.

Amadi, A.N., Olasehinde, P.I., Okosun, E.A., Okoye, N.O., Okunlola, I.A., Alkali, Y.B.and Dan-Hassan, M. A. (2012). A Comparative Study on the Impact of Avu and Ihie Dumpsites on Soil Quality in Southeastern Nigeria. *American Journal of Chemistry, 2(1): 17-23.*

Amadi, A. N., Olasehinde, P. I., Yisa, J., Okosun, E. A., Nwankwoala, H.O.and Alkali, Y. B. (2013). Geostatistical Assessment of Groundwater Quality from Coastal Aquifers of Eastern Niger Delta, Nigeria. *Geosciences, 2(3): 51-59.*

Amadi, A. N. and Nwankwoala, H. O. (2013). Evaluation of Heavy Metal in Soils from Enyimba Dumpsite in Aba, Southeastern Nigeria Using Contamination Factor and Geo-Accumulation Index. *Energy and Environment Research*, 3(1): 125 – 134. doi:10.5539/eer.v3n1p125.

Amadi, A. N., Nwankwoala, H. O., Jimoh, M. O., Dan-Hassan, M. A. and Aminu, T. (2014). Modeling the Groundwater Quality in parts of Eastern Niger-Delta, Nigeria using Multivariate Statistical Techniques. *American Journal of Water Resources*, 2(5), 118–125, doi:10.12691/ajwr-2-5-3.

Amadi A. N., Tukur, A., Okunlola, I. A., Olasehinde, P. I. and Jimoh, M. O. (2015). Lithologic Influence on the Hydrogeochemical Characteristics of Groundwater in Zango, North-west Nigeria. *Natural Resources and Conservation*, 3(1): 11–18. doi:10.13189/nrc.2015.030103.

APHA, (2008). Standard methods for examination of water and waste water (20th Ed.). Washington DC: American Public Health Association.

Dan-Hassan, M. A., Olasehinde, P. I., Amadi, A. N., Yisa, J. and Jacob, J. O. (2012). Spatial and Temporal Distribution of Nitrate Pollution in Groundwater of Abuja, Nigeria. *International Journal of Chemistry 4 (3)*: 39-48.

EPA, (1991). *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska.* U. S. Environmental Protection Agency, Region 10, Seattle, Washington.

Garba, I. (2000). Origin of Pan African mesothermal gold mineralization at Bin Yauri,Nigeria *Journal of African Earth Sciences*, 31: 433 - 449.

Garba, I. (2002). Geochemical characteristics of the gold mineralization near Tsohon Birnin Gwari, northwestern Nigeria. *Chemie de Erde*, 62: 160-170.

Garba, I. (2003).Geochemical characteristics of mesothermal gold mineralization in the Pan African basement of Nigeria.*Applied Earth Science (Transaction of the Institution of Mining and Metallurgy, Section B)*, 112: 319-325.

Hansen, J. (2000). Phytoremediation as an alternative to traditional soil and groundwater remediation techniques. *Geo-environmental Engineering*, 4: 1-13

NSDWQ, (2007). Nigerian Standard for Drinking Water Quality. Nigerian Industrial Standard, NIS: 554, pp. 13-14.

Nwankwoala, H. O., Amadi, A. N., Oborie, E. and Ushie, F. A. (2014). Hydrochemical Factors and Correlation Analysis in Groundwater Quality in Yenagoa, Bayelsa State, Nigeria. *Applied Ecology and Environmental Sciences, 2(4):* 100 – 105, doi:10.12691/aees-24-3.

Olasehinde, P. I., Amadi A. N., Dan-Hassan M. A., Jimoh M. O. (2015). Statistical Assessment of Groundwater Quality in Ogbomosho, Southwest Nigeria. *American Journal of Mining and Metallurgy, 3(1): 21 – 28,* doi:10.12691/ajmm-3-1-4.

Sala,. S. L. (2000). The geology, geochemistry and possible origin of gold mineralization at Duki old mine, Maru ,Zamfara State, Nigeria. M.Sc. thesis, Ahmadu Bello University, Nigeria.

US Environmental Protection Agency (1996). *A citizen's guide to bioremediation.* office of solid waste and emergency response, technology innovations office. Technology fact sheet. clu-in.org/products/citguide/biorem.htm

World Health Organization (WHO, 2010). Guidelines for Drinking Water Quality, 4th Ed., Geneva.