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EFFECTS OF ARTISANAL MINING ON GROUNDWATER QUALITY IN ANTANG DISTRICT, JEMA'A LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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ABSTRACT
The study analyzed the effects of artisanal mining activities on groundwater quality in Antang district of Jema'a Local Government Area of Kaduna State, Nigeria. Groundwater samples was collected from ten (10) randomly selected hand dug wells around the mine pits in the peak of the rainy and dry seasons for two years 2018 and 2019, while groundwater samples were collected from two (2) randomly selected hand dug wells in Gidan Waya at the same time period to serve as control. The samples were taken to the laboratory within twenty-four hours for analysis, two basic laboratory techniques were used, that is; the gravimetric and volumetric techniques and a range of water quality parameters were measured and mean values recorded. The results revealed that the level of Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pH, Biochemical Oxygen Demand (BOD), nitrate, iron, magnesium, electrical conductivity, turbidity, and hardness in the water sample were quite high. With the exception of pH and Total Coliform Counts (TCC), all other physico-chemical parameters measured were higher and have exceeded the maximum permissible limits given by the National Standard of Drinking Water Quality (Nigeria) and World Health Organization (WHO).Similarly, the Water Quality Index (WQI) analysis carried out for groundwater samples in Antang revealed that most samples exhibited poor water quality as such considered unfit for drinking. Presence of some pollutants in groundwater at various sampling points in Antang, was observed and level of these pollutants at varying degrees was found largely due to artisanal mining. Since the treatment given to the raw water is disinfection alone, there is tendency of these pollutants to persist in groundwater and its uptake may cause long term health problems.
Keywords: Artisanal mining, Groundwater, Hand dug wells, Physico-chemical parameters, Pollutants, Antang.

INTRODUCTION

The effects of mining activities on water, land and vegetation including forest ecosystems has become a matter of serious concern the world over (Ugya, Ajibade and Ajibade, 2018). Mining which is one of those activities of humans have altered the landscape and has led to a loss in landscape diversity characterizing the land with mined ponds, pilot ponds, reservoirs, mine dumps and mounds thereby losing its aesthetic value. The wastes generated from mining activities are of particular concern due to the large quantities produced and the presence of toxic elements (Kitula, 2006). A common negative effect of excavating minerals from the earth's surface is the destruction of its natural landscape, creating open spaces in the ground and generating heaps of rock wastes that cannot be easily disposed off. The impact due to mining causes rapid and drastic environmental changes. Because of complex problems and frequent changes in the landscape in the mining area, monitoring of these environmental changes is becoming extremely difficult (Kumar, Arivazhagan, and Rangarajan, 2003).

In most developing countries like Nigeria, minerals are extracted using crude mining methods outside the legal and regulatory frame-work.This results into pollution of the air, land and water (particularly groundwater). Also, direct dumping of waste and effluents into rivers, improperly constructed dams and rivers, alluvial areas. All these lead to river siltation, erosion, deforestation, vegetation loss, landscape destruction among others as cited by Hentschel, Hruschka and Priester, (2002). Mining, especially open cast mining has a major impact on landscape, during pre-mining and post-mining operations(Khan and Javed, 2012). However, studies have shown that the environmental costs of artisanal mining are in general higher than those of other types of mining. This means that artisanal mining is dirtier per unit of output than medium-sized or large and modern mining operations, another problem of artisanal mining is the great individual number of polluters, normally concentrated in a specific area, which causes significant local impact. It is also very difficult to control or monitor environmental violations or enforce regulations because of the lack of resources and the inaccessible nature of most operations (Hentschel, Hrusschka and Priester,2003).

Kumi-Boateng, Boye and Issaka, (2012) applied the use of Remote Sensing and Geographic Information Systems (GIS) techniques to assess the impact of mining on vegetation in the Tarkwa Mining Area (TMA) of Ghana. The researchers discovered that there was observable impact of mining on vegetation. Anil and Katyar (2010), also analysed the impact of open cast mines on land-use/land-cover in Chandrapur District of Maharashtra State in India. From the study, the results showed that there were enormous changes especially in vegetation and agricultural area as areas of dense vegetation were converted either into mine land or artificially created mountains of mine overburden.

Within the Jos Plateau, Adekoya (2003) stated that large amount of vegetation was stripped due to the open cast mining method employed by the miners. This has given rise to the destruction of the scenic landscape which is replaced by unsightly large irregular holes and heaps of debris produced by the opencast method of mining. The alteration of the landscape invariably creates a problem of erosion in the mining localities with the result that most of the opencast pits are filled with water.

Lyocks, Tanimu, Olajide, Lyocks and Micah,(2014) analysed the effects of small scale mining activities on agricultural production in Jema'a Local Government Area of Kaduna State Nigeria through the use of structured questionnaire administered to famers/miners and guided interview with community leaders.

According to Ashano and Gyang (2010) the major problem of Jos South still remains the devastated and de-vegetated land and mine spoils; depriving the inhabitants of fertile farmland. The deep mining which is an excavation of underlying sand has created mining pits, man-made lakes, pools and ponds which have great effect on both the people and agricultural practices. Mining ponds have always been death traps for people and animals (Davis, 2001).

From the aforementioned research works, it is eminent that mining has greatly affected several environmental components especially landscape around mine areas. The severity of the effects however depends on the methods used in mining the ores as well as the scale of the mining (Fyles, Fyles and Bell 1985; Mkaanem, 2015). Some of the typical environmental impacts caused by artisanal mining activities include diversion of rivers, water siltation, landscape degradation, deforestation, destruction of aquatic life habitat, and widespread mercury pollution (Kitula, 2006).

Although several literatures exist on the effects of mining ranging from economic to environmental using different methods, none of these studies is concerned with the effects of artisanal mining on groundwater quality in Antang area, Jema'a local government area of Kaduna State. The protection of water quality of the area isof a high importance as this will curb the environmental challenges at mining and mineral processing sites which is quickly eroding and contributing greatly to reducing our water resource base. Therefore, this study determines the impacts of mining activities on ground water resource of the area.

THE STUDY AREA

The study area (Antang) is located along latitudes 9°25'0"N and 9°29'0"N and longitude 8°28'0"E and 8°29'30"E of the Greenwich. It has an altitude of 1850ft above sea level as shown on figures 1,2 and 3.The area is designated Koppen's Aw climate with two distinct seasons: a wet season and a dry season. Rainfall occurs between the months of April to October with a peak in August. The mean annual rainfall is about 1900mm and the mean monthly temperature is about 25°C, while the relative humidity is about 60%. The orographic effects of the Jos Plateaux and Kagoro Hills have positive influence on weather. (Lyocks *et al.,* 2014). Like any other part of the country, the climate of these rural communities is directly under the influence of two dominant air masses; namely; the tropical maritime (mt) or South-west Trade wind which blows across the Atlantic Ocean and the Tropical Continental (mt) or Northeast Trade wind which blows across the Sahara Desert.

The relief is relatively flat and undulating and it influences the drainage pattern of the area. It is lowest in the South and Southwest with a height of 180m rising steadily North and Northeastward to about 450m along the Northern angle of the area sometimes reaching 600m in the extreme Northeast as one is approaching the Jos plateau. Natural resources such as relief, soil, vegetation, minerals among others, of any area are to a large extent determined by the geological setting of such area. Geologically, the area is endowed with basement complex underlies the recent alluvial deposits at the top. Basement complex rocks (igneous and metamorphic) are predominantly granite, although gneiss, migmatites, schist and quartzite are also present.

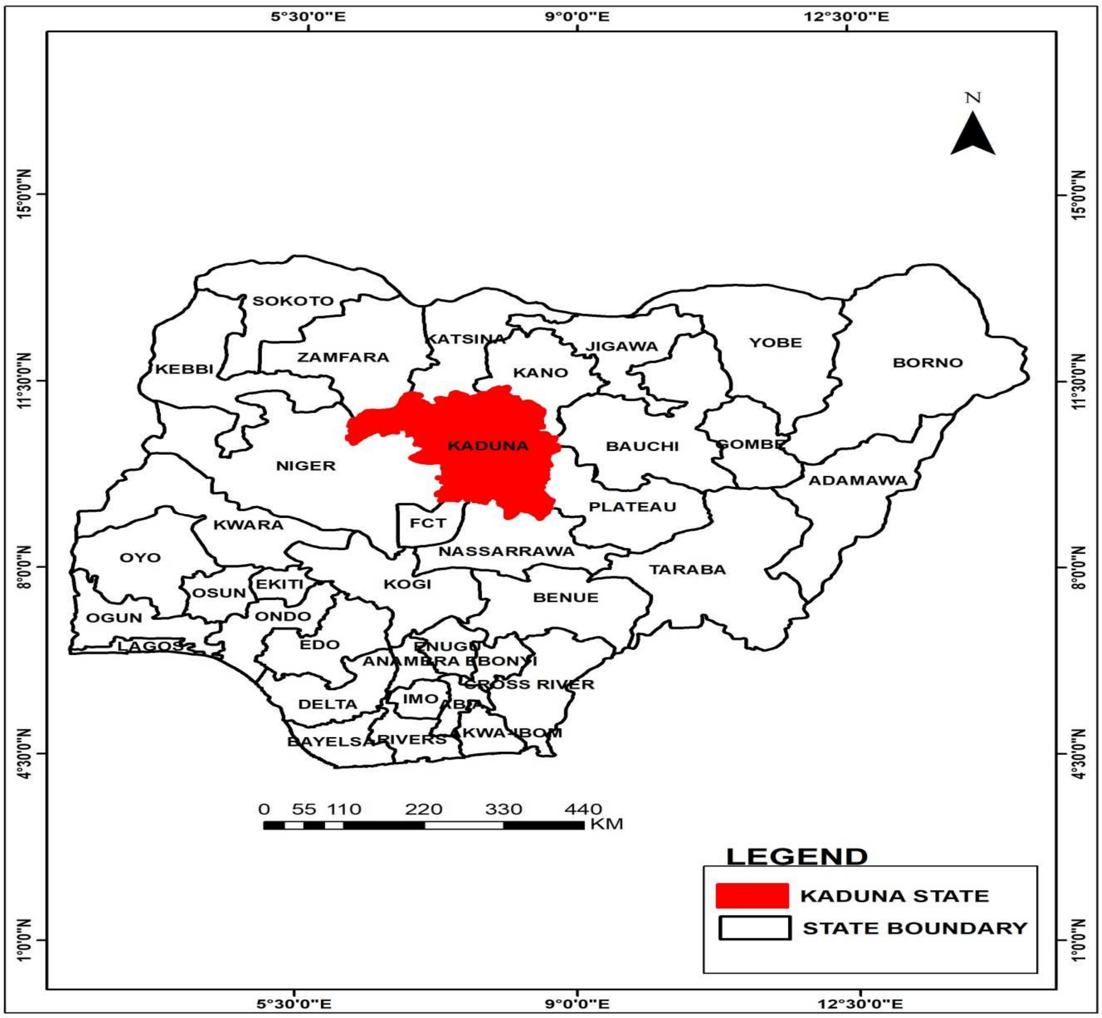

Figure 1: Map of Nigeria Showing Kaduna State
Source: Modified from the Administrative Map of Kaduna

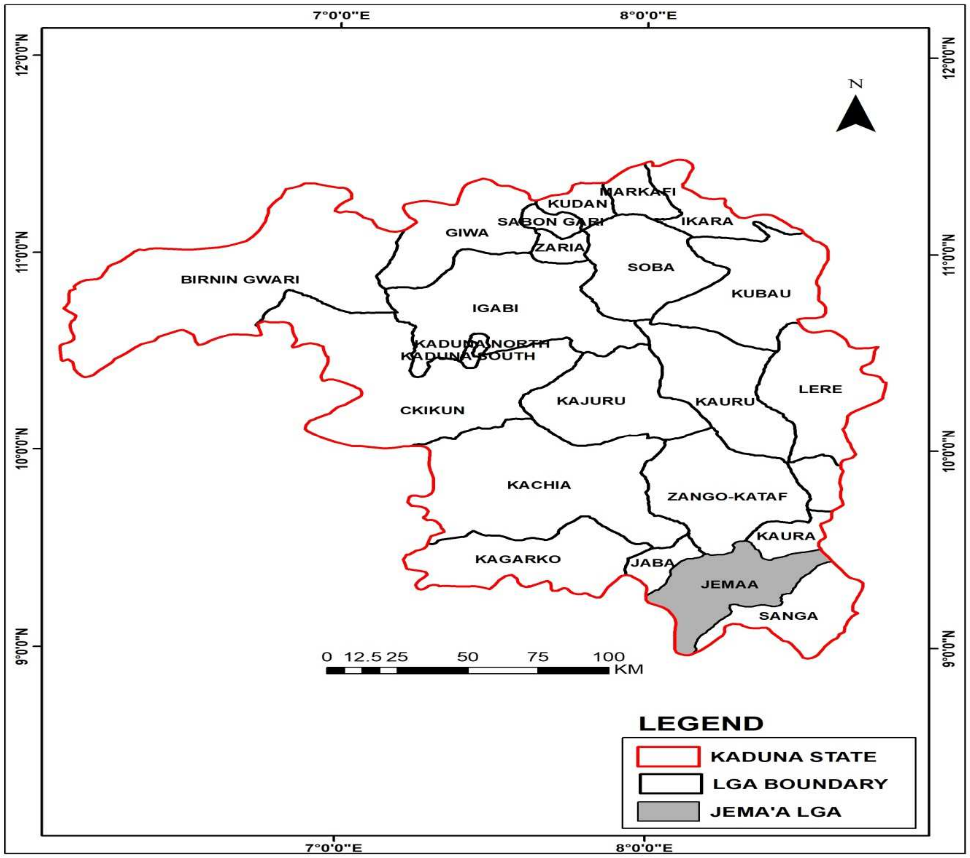

Figure 2: Map of Kaduna Showing Jema'a Local Government Area
Source: Modified from the Administrative Map of Kaduna State, 2017

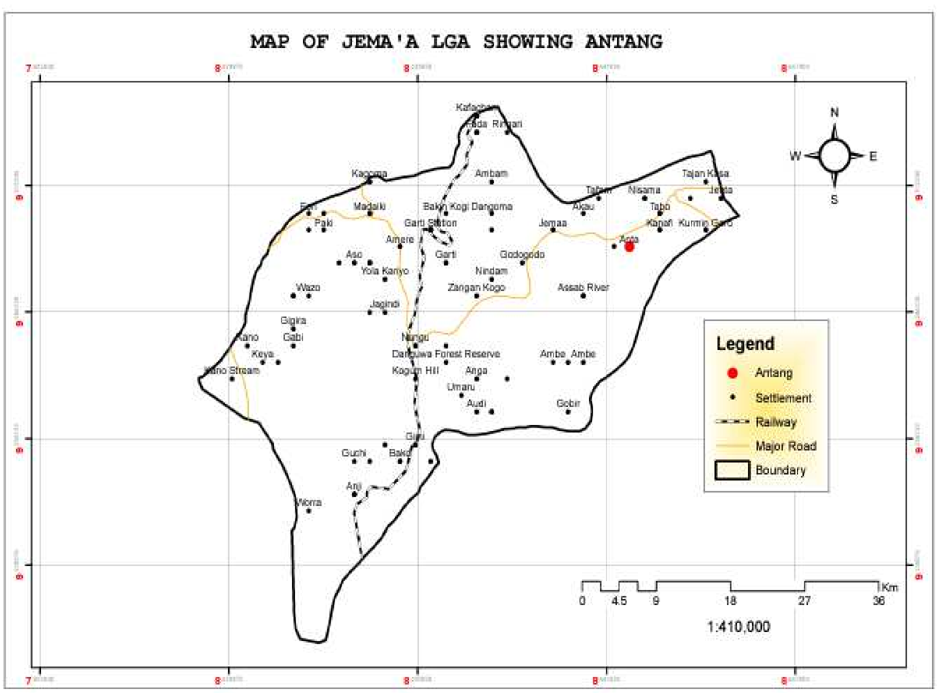

Figure 3: Map of Jema'a Local Government Area Showing Antang

MATERIALS AND METHODS

In the course of this study, reconnaissance survey was carried out by the authors in order to familiarize with the study area and make observations/notes that would aid the process of sample selection. Samples of groundwater was taken from ten (10) randomly selected hand dug wells sources collected for the years 2018 and 2019 during both the peak of dry and rainy seasons of 2018 and 2019 as shown on Table 1. Samples of groundwater were taken from two (2) randomly selected hand dug wells in Gidan Waya to serve as control.

Locations of wells were picked by a hand-held Global Positioning System (GPS) receiver and the coordinates recorded. Groundwater samples was collected from sixty (60)wells in the study area, as ten (10) wells was randomly sampled in each of the settlements that makes up the study area and 10 water samples collected from 10 hand dug wells in the area with the same geological setting as the study area (Gidan Waya area of Jema'a local government area). Collection of water samples was done in the morning between 8am and 9am. Samples were collected into clean 1 litre plastic bottles and stored in an ice box of 4ºC and were taken to the laboratory within twenty-four hours for analysis. Parameters investigated are those physical and chemical parameters indicating effects of artisanal mining on water quality, water samples from Gidan Waya area of Jema'a local government area was used as control sample, because Gidan Waya area with nearly the same geological setting as Antang area with no mining activities taking place is used as control, to help determine that the pollutants in groundwater of Antang area is coming from artisanal mining activities.

Table 1: Number of Wells sampled in Study Area

Area	Sample Code	Number of samples Collected			
		Wet Season 2018	Dry Season2018	Wet Season 2019	Dry Season 2019
Antang	W1	1	1	1	1
	W2	1	1	1	1
	W3	1	1	1	1
	W4	1	1	1	1
	W5	1	1	1	1
	W6	1	1	1	1
	W7	1	1	1	1
	W8	1	1	1	1
	W9	1	1	1	1
	W10	1	1	1	1
Gidan Waya	C1	1	1	1	1
	C2	1	1	1	1

Source: Field Survey 2018 & 2019

The physico-chemical parameters were determined according to procedures outlined in the Standard Method for the examination of water and wastewater (APHA, 1998). As indicated in the sampling, the parameters analyzed are those believed to have effects on water quality and referred to by WHO (2004). These parameters are Electrical conductivity, Suspended Solids, Dissolved Solids, Total Solids, pH, Dissolved Oxygen, Biochemical Oxygen Demand, (BOD), Chemical Oxygen Demand (COD), and Oil and Grease. Two basic techniques were used: Gravimetric, Volumetric techniques. The gravimetric technique was used to analyze Total Solids, Dissolved Solids and Suspended Solids, while the volumetric technique was used to determine the concentration of BOD, COD.Water Quality Index for groundwater samples collected at the peak of the dry and samples collected at the peak of the wet season was calculated using Water Quality Index (WQI).

RESULTS AND DISCUSSION

In the course of this study it was observed that the main source of water for domestic and other uses in the study area is groundwater, which is accessed mainly through hand dug wells.

Table 2: Mean Values of physico-chemical parameters for all sampled wells

Parameter	pH	Conductivity	Hardness	TDS	TSS	BOD	Turbidity	Nitrate	Chloride	Fluoride	Magnesium	Iron	TCC
Unit		µs/cm	Mg/l	Mg/l	Mg/l	Mg/l	NTU	Mg/l	Mg/l	Mg/l	Mg/l	Mg/l	Count/100ml
WHO(2011)	6.5-8.5	1000	100	500	500	5	5	10	250	1.5	0.2	0.3	0
NSDWQ(2007)	6.5-8.5	1000	100	500	25		5	50	250	1.5	0.2	0.3	0
Antang													
W1	5.765	180.5	1.3275	95.61	4.75	0.975	4.4275	0.3175	54.95	0.1225	0.8925	0.095	0.5025
W2	5.8925	114.55	2.7825	75.15	58.75	1.3225	13.3825	0.0775	32.75	0.1375	1.375	0.89	0.0075
W3	5.5075	79.95	1.905	54.6925	9.175	1.1775	8.985	0.2975	53.35	0.195	1.935	1.1225	0.0125
W4	6.25	50.475	3.2925	32.85	10.2575	1.78	22.28	0.2425	55.975	0.1475	1.38	0.255	0.0025
W5	5.978	181.7	1.7532	93.25	4.58	0.991	4.572	0.3888	54.12	0.1432	0.8327	1.565	0.628
W6	5.5075	79.95	1.905	54.6925	9.175	1.1775	8.985	0.2975	53.35	0.195	1.935	1.1225	0.0125
W7	6.67	240.1	2.1	156.6	3.07	2.13	1.76	0.04	25.5	0.17	2.1	0.02	0.01
W8	6.43	77.6	2.84	51.3	7.809	0.54	2.36	0.03	24.2	0.07	2.63	0.247	0
W9	6.61	153.8	0.33	10.04	4	1.7	3.61	0.1	45.6	0.07	0.33	0.28	0.01
W10	6.6	309.1	2.04	201.7	5	0.44	8.88	0.12	62.1	0.12	2.04	0.02	0
Gidan Waya													
C1	5.26	73.9	3.18	49.8	19	1.2	42.4	0.45	57	0.13	1.39	0.4	0
C2	5.46	75.8	4.1	48.9	22	2.42	43	0.18	44.2	0.06	1.42	0.42	0.01

Source: Field Survey &Laboratory analysis 2018 & 2019

* National Standard for Drinking Water Quality (NIGERIA) and World Health Organization maximum acceptable limits

Table 3: WQI of samples collected at the peak in dry season

Parameters	Test Results (Vn)	Standard Permissible Value (Si)	Units	Relative Weight (Wi)	Quality Rating (Qi)	Weighted Value {(Wi) *(Qi)}
Ph	6.8	6.5-8.5		0.04000	88.4	3.54
Turbidity	46.78	50		0.11764	6.66	0.784
Total Hardness	27.32		NTU	0.03333	326.6	10.88
TDS	93		Mg/l	0.00200	24	0.048
Electrical Conductivity	624.7	15000	µs/cm	0.13333	94.36	12.58
CO_2	30.52	50		1.00000	2.8	2.8
Nitrite	Nill	0.2	Mg/l	0.10000	42.1	4.21
Sulphate	30.9	100	Mg/l	1.00000	6	6
Copper	0.912	1.0	Mg/l	0.00000	0	0
Iron	0.626	0.3	Mg/l	0.02500	135	3.375
Cadium	0.502	0.01	Mg/l	0.20000	70.2	14.04
Calcium	1.15	2.0	Mg/l	10.0000	121	1200
Mercury	0.004	2.0	Mg/l	0.00500	4.75	0.0237
Lead	0.039	0.001	Mg/l	1.00000	212	212
Magnesium	0.437	0.01	Mg/l	0.20000	28.6	5.72
Coliform Bacteria	0.00	1.0	Mpn/ml	0.00000	0	0
				= ***13.8563***		***1476.001***

$$WQI = \frac{1476.001}{13.8563} = 106.521$$

Table 4: WQI of samples collected in peak of rainy season

Parameters	Test Results (Vn)	Standard Permissible Value (Si)	Units	Relative Weight (Wi)	Quality Rating (Qi)	Weighted Value {(Wi) *(Qi)}
pH	6.65	6.5-8.5		0.04000	88.4	3.54
Turbidity	23.4	50		0.11764	6.6	0.78
Total Hardness	60		NTU	0.03333	50.0	1.6
TDS	80		Mg/l	0.00200	6.0	0.012
Electrical Conductivity	699.8	15000	µs/cm	0.13333	44.79	5.971
CO_2	33.0	50		1.00000	97	97
Nitrite	Nill	0.2	Mg/l	0.10000	30.1	3.01
Sulphate	44.9	100	Mg/l	1.00000	5	5.0
Copper	1.70	1.0	Mg/l	0.00000	0	0
Iron	0.71	0.3	Mg/l	0.02500	55	1.375
Cadium	0.1	0.01	Mg/l	0.20000	76	15.2
Calcium	0.11	2.0	Mg/l	10.0000	98	980.0
Mercury	2.13	2.0	Mg/l	0.00500	0.415	0.021
Lead	0.1	0.001	Mg/l	1.00000	70	70.0
Magnesium	0.5	0.01	Mg/l	0.20000	2.6	0.52
Coliform Bacteria	0.0	1.0	Mpn/ml	0.00000	0	0
				= ***13.8563***		***1184.029***

$$WQI = \frac{1184.029}{13.8563} = 85.450$$

Table 5: Water quality classification based on Arithmetic WQI method

WQI	Value Water Quality
0-50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

Source: Brown *et al.,* 1972

Plate 1: Miners draining water from a mine pit
Source: Field Survey, 2019

The result of the water quality analysis carried out on the water samples from boreholes and wells from different locations are presented on Table 2. The World Health Organization WHO (2011) and the Nigerian Standard for Drinking Water Quality (NSDWQ 2007) was used as the baseline to compare the water quality from the different sources. pH is one of the important parameters of water whose determination facilitates a quick evaluation of acidic and alkaline nature of water. In this study the mean pH values for groundwater samples collected from Antang ranges from 5.23-7.16 in which some were below the maximum permissible limit of 6.5-8.5 set by World Health Organization and the Nigerian Standard for Drinking water quality (Table 2). While the pH value for groundwater samples collected from Gidan Waya that serves as control ranges from 5.26-5.46 which is below the maximum permissible limit of 6.5-8.5 set by World Health Organization and the Nigerian Standard for Drinking water quality (Table 2). The result for pH in this study concurs with the findings of Aina and Oshunrinade, (2016) in their study which revealed that pH values of borehole samples were very low.

The study revealed the mean electrical conductivity values for groundwater samples in Atang ranges between 5047-309.1ɥs/cm which falls within the maximum permissible limit of 1000ɥs/cm set by World Health Organization and Nigerian Standard for Drinking Water Quality (Table 2). While the mean electrical conductivity values for groundwater samples in Gidan Waya ranges between 73.9-75.8ɥs/cm which falls within the maximum permissible limit of 1000ɥs/cm set by World Health Organization and Nigerian Standard for Drinking Water Quality, the electrical conductivity values for groundwater samples appears to higher than that of the control (Table 2). The result obtained on the level of conductivity in the sampled groundwater concords with the findings of (Eduvie and Olaniyan, 2013) in their work carried out in Southern Parts of Kaduna State, Nigeria. This can also be attributed to the fact that both study area has similar geology.

The mean hardness values for groundwater boreholes ranges between 0.33-3.29 which falls within the maximum permissible limit of 100Mg/l set by World Health Organization and Nigerian Standard for Drinking Water Quality (Table 2).

While the mean hardness values for the control samples ranges between 3.18-4.10 which falls within the maximum permissible limit of 100Mg/l set by World Health Organization and Nigerian Standard for Drinking Water Quality (Table 2). The results for hardness in this study concurs with the findings of Adetunde, Glover and Oguntola (2011) in their work titled "assessment of the groundwater quality in Ogbomoso Township of Oyo State of Nigeria" in which the study revealed that hand-dug well water samples in the Ogbomosho North and South Local Government Areas are generally soft.

Similarly, the Water Quality Index (WQI) analysis carried out for the groundwater of Antang area of Jema'a Local Government, Kaduna State revealed that most samples exhibited poor water quality as such considered unfit for drinking, the results from Water Quality Index on Tables 3, 4 and 5 rates groundwater samples collected at the peak of the dry season as poor with a score of 106.521, as this could be the interaction between water in mining pits and groundwater in the study area as shown on plate 1. Samples collected at the peak of the wet season from rated as fairly good with a score of 85.450. The findings here are in line with a study by Abdulsalam, Zubairu and Hussaini (2017) that analysed water quality of selected wells in Gonin-Gora area of Kaduna metropolis. The study randomly collected samples from nine (9) different wells and concentration levels of ten (10) physico-chemical parameters were determined to ascertain how fit groundwater in the area is for human consumption. Laboratory analysis of samples and inferential statistics was used to determine the difference between the laboratory values of the samples and World Health Organization standards for drinking water. The results revealed that there was significant difference between the levels of concentration of the selected parameters of samples and World Health Organization standards for drinking water. The study recommended that water from open hand dug wells in the area should be treated before human consumption.

CONCLUSION

This study reveals that groundwater in Antang area, Jema'a Local Government Area, Kaduna State has been contaminated by artisanal mining activities, because there is difference of concentration of the pollutants at different sampling points within the study area as compared with the laboratory results of the control samples collected from Gidan waya. Many of the parameters measured in samples collected in Antang area are still higher than the acceptable limit set by National Standard Nigeria and World Health Organization, it was found that these pollutants present in the groundwater has long term health effect on the inhabitants of this area, as groundwater has been found to be the main source for drinking and other domestic uses.

The government should formulate a policy that includes the following:

i. Encouraging and assisting the artisanal miners which are illegal to come together and acquire legal permits, or the government establishing a state owned mining company which takes over the mining site of illegal miners or a joint stock mining company comprising the government and some interested sponsors.

ii. Also, educating them on the effects of their operation and assure them that there are safe methods of mining, discouraging especially the youth and providing financial support for the youth to further their education.

iii. In order to deal with the changing nature of land-use/land-cover of areas within the study area that are associated with such enormous long term effects, an urgent need for the use of Remote Sensing and GIS for proper monitoring and management of land within the state and the study area in particular.

iv. Kaduna Environmental Protection Authority (KEPA) and National Environmental Standards Regulation Enforcement Agency (NESREA)should ensure that Kaduna Refinery complies with Federal Environmental Protection Agency and National Standard Drinking Water Quality guidelines of industrial effluent discharge.

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