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Physiochemical Analysis of Groundwater at Kataeregi Mining Site, Niger State, North Central Nigeria

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Abstract: Groundwater samples were analysed to determine the heavy metals (pH, Cd, Zn, Cu, Cr, Pb, Hg, Ar, Fe and Ni) at Kataeregi mining site, Niger State, Nigeria. Ten groundwater samples were collected. Four samples of groundwater were collected from control site 100 m away from mining site. The results of the analysed water samples are as follows: The concentration level of Cadmium ranges from 0.000 mg/L to 0.003 mg/L while the control site is 0.000 mg/L, Copper ranges between 0.000 mg/L and 0.515 mg/L and that of the control site is 0.055 mg/L, Zinc ranges from 0.000 mg/L to 0.111 mg/L with its control site of 0.095 mg/L, all three analysed samples falls far below the permissible limit. Iron concentration varies from 0.03 mg/L and 13.6 mg/L with control site of 0.15 mg/L, all are above tolerable limit, arsenic ranges from 0.002 mg/L to 0.026 mg/Land the control site is 0.00 mg/L. Nitrate concentration level found is far above the WHO and NSDWQ standard with the values ranging from 16.50 mg/L to 323.7 mg/L with the control well value stands at 29.0 mg/L, $well_1$, $well_3$ and $well_4$ values are all above tolerable limit. Mercury has concentration level ranging from 0.000 mg/L to 0.022 mg/L with $well_2$ been the possible contaminant, the control site remains at 0.000 mg/L while chromium has values ranging from 0.000 mg/L to 0.080 mg/L with $well_1$ having the value above the NSDWQ standard with control site value of 0.00 mg/L and lead concentration value ranging between 0.000 mg/L and 0.001 mg/L having control well value of 0.000 mg/L.

Keywords: Groundwater, Concentration, Mercury, Control Site, Sample

1. Introduction

The sustainable management of waste approach aimed at global environmental quality, and environmental quality is a prerequisite for a rise in per capital welfare over a period of time. Efficient management of waste is a global concern requiring extensive research and developmental work towards exploring newer application for a sustainable and environmentally sound management. The problem of waste management is a primordial one and presents issues in developing countries in Africa, particularly Nigeria [5].

Water and sanitation are among the basic requirements for life [8]. According to United Nations Sustainable Development goals on water and sanitation, about 2 billion people in the world are living in areas classified as water stress. The availability of water resources in quality and quantity is a prerequisite in dealing with the sustainability of the resources. Rapid population increase across the globe has resulted in an increase in food production, thereby putting a lot of stress on water resources [7]. In recent times people have resorted to groundwater for their potable use, especially in developing countries [9]. Observations have shown that the reliance on groundwater resources has risen because of quality issues associated with the use of surface water. The quality of groundwater, however, varies spatially in response to geogenic and anthropogenic factors [3] which warrants an assessment of the water quality to serve the purpose for which it is used.

The earth subsurface has become the safest and most abundant source of potable water in comparison to the earth's surface as it is often shielded from direct human activities.

However, any undetected contamination of this resource poses a threat to the well-being and continuous existence of man in the environment. Contamination is the pollution involving constituents that are hazardous to health because of their nature or quality [1]. Groundwater is transmitted through a deep aquifer comprising unconsolidated weathered materials that form the overlying mantle or regolith [10].

Mining generates a large quantum of tailing otherwise termed as slimes or leach residue, basically a mixture of fine disintegrated mineral particles and fluid, which needs to be disposed safely without causing any environmental hazard like leaching and erosion by wind or water. The global legacy of mining and disposal of tailings had been for more than few centuries. Tailings facilities consist of tailings pond or lagoons, tailings dam and tailings transport systems (generally pipelines). Usually a very large area is required to contain the tailings which is man-made, and is the most critical element of these facilities. The surface disposal site is to be characterised for its sub-surface nature in order to understand its role in mapping the subsurface geological formation in terms of it geophysical parameters in and around the waste disposal site [12]. A mining site is usually a complex industrial system handling huge amounts of rocks in order to extract from them a lower or marginal amount of valuable metals or minerals. It comprises thus two activities: extraction and ore processing. The sheer mass of the handled material implies that the valuable commodity is extracted or concentrated near site, and most of the waste is disposed of nearby. The specificity of mine waste required adapted regulations and standards [2].

1.1. Description of the Study Area

The study area (Kataeregi) is located 39 km along Minna – Bida road, in Katcha Local Government Area of Niger State, North-central Nigeria (Figure 1). The area is part of Bida Sheet 184 NE and is located between Latitudes 09°21'N and 09°25'N and Longitudes 006°17'E and 006°22'E on the scale of 1:25,000 covering a total area of about 68 km^2 [11]. It lies between the geographical co-ordinates of Northing's 811400 – 813200 mN and Easting's 732200 – 733400 mE in the Universal Traverse Mercator (UTM) Minna Zone 31 [4]. The topographic elevation around the site ranges from 335.0 to 365.0 m above mean sea level and generally slopes gently from the north towards the southern part. The area has a climate characterized by two seasons; the wet season and the dry season. The wet season starts from around mid-April and ends in October with an average rainfall of 1500 mm to 2000 mm while the dry season starts around November and ends in March with an average maximum temperature of about 33°C [4].

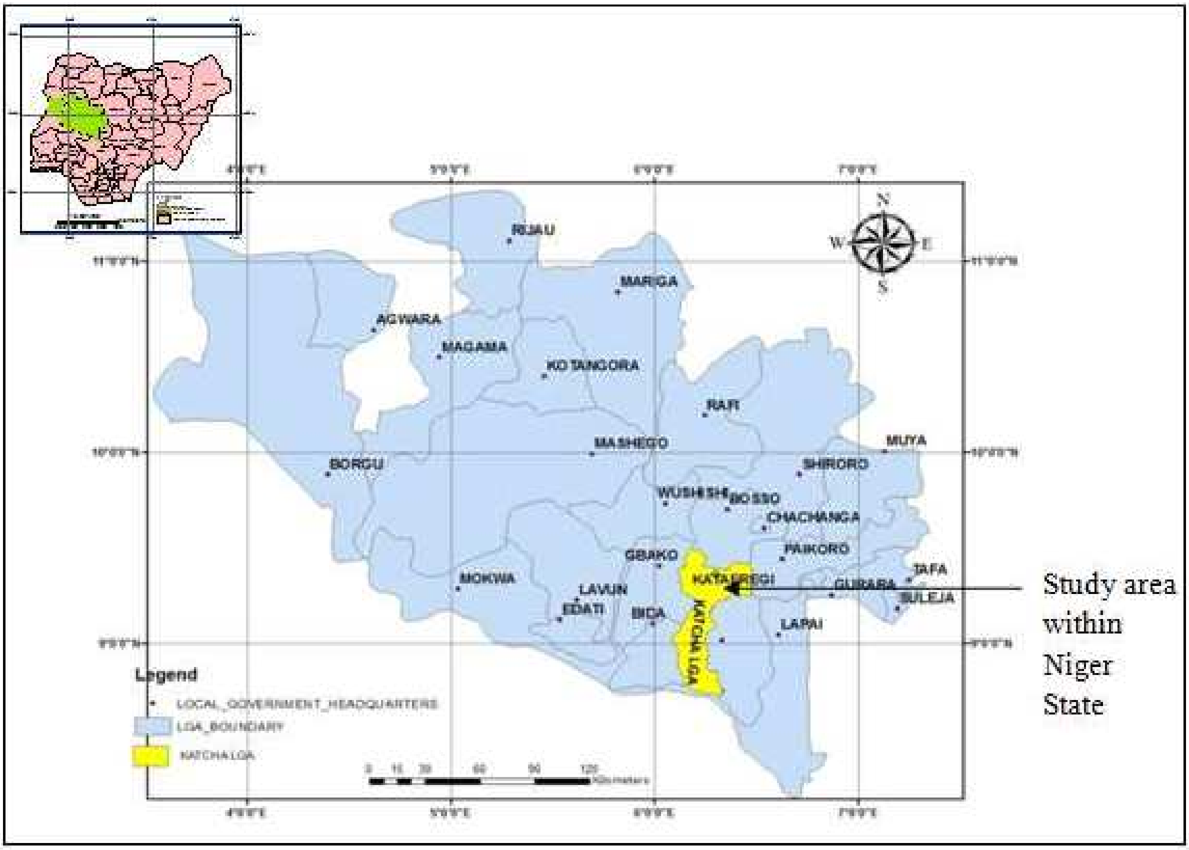

Figure 1. *Location map of Kataeregi, Niger State, Nigeria [11].*

1.2. Geology of the Study Area

The area consists of mixed geology of both basement and sedimentary rocks. The rocks units consist of schists, migmatites, gneisses, granites, quartzite of Precambrian age (> 550 million years old) [6]. The area is dominated by schistose rocks that serves as host to auriferous quartz vein where the mining is taking place. The schists are intercalated with amphibolites observable along the River Chanchaga, the schists had already been mapped and considered as part of the Kusharki Schists. The schists are intruded by plutonic rock and exposed at sabon Eregi and Kataeregi with xenoliths of phyllites. The study area is dominated by migmatites-gneisses complex and granites at the North and South-eastern parts and Bida sandstone to the extreme South-western part [11]. The sedimentary terrain falls within the Bida Basin of central Nigeria and covers the central and southern part of the state. The rocks of the basin comprise of conglomerates, sandstones, siltstones, mudstones and ironstones [6].

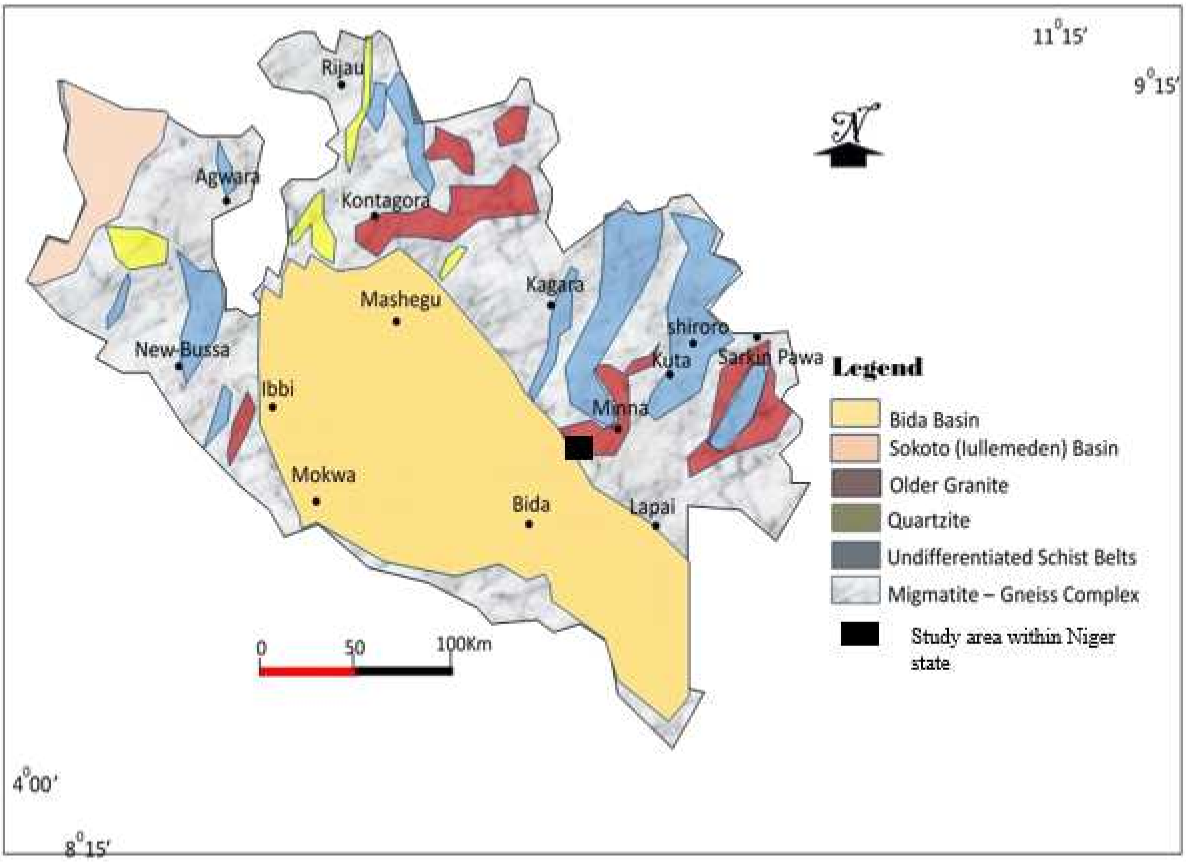

Figure 2. *Geological Map of the Study Area [6].*

2. Methodology

Five water samples were collected from the untreated well and mine pits around the mining site, the groundwater samples from the fetched bucket which was cleansed with distilled water was then transferred into plastic bottles which was capped and clearly labelled. The water temperature, electrical conductivity, and pH of all the water samples were measured and recorded on the field. The concentration of lead, zinc, nitrate, arsenic, iron, copper chromium, mercury and cadmium were determined.

Hydrochemical Analysis

In order to carry out pollution assessment of the study area, hydrochemical analysis of water samples were collected from five wells/pits around the mining site. The sampling wells were designated W_1 to W_5 which stand for well $_1$ to well $_5$. The physiochemical parameters that are indicative of groundwater pollution such as copper, cadmium, zinc, chromium, lead, iron, mercury, nitrate and arsenic were analysed. All samples were analysed using standard methods recommended by the American Public Health Association (APHA 19^{th} edition, 1995). Results were compared with Nigerian Standard for Drinking Water Quality (NSDWQ, 2015). HM 5000 Metelyser and Colorimeter was used to ascertain the concentration of heavy metals in groundwater at the Federal Ministry of Water Resources, Regional Water Quality Laboratory, Minna, Nigeria.

3. Results and Discussion

Physical parameters

Table 1 shows the values of physiochemical parameters determined, the World Health Organisation and Nigerian Standard for Drinking Water Quality standard with their health impact. The temperature ranges from 30.9 to 31.9°C which is lower than the World Health Organisation (WHO) limit. Lower temperature may indicate the presence of pollutants [11].

The pH values ranges from 6.70 to 7.04 which is below the limit and within the allowable consumption limit. Total

Dissolve Solids varies from 210 to 338 mg/L which is normal and fall below the standard and thereby recommended for domestic purposes. Electrical Conductivity varies from 323 to 520 μScm^{-1}, this is also within the prescribed values by World Health Organisation (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ).

Table 2 shows maximum and minimum concentration of determined parameters and percentage compliance for the sampled parameters. The concentration level of Cadmium ranges from 0.000 mg/L and 0.003 mg/L while the control site is 0.000 mg/L, Copper ranges between 0.000 mg/L and 0.515 mg/L likewise the control site is 0.055 mg/L, Zinc ranges from 0.000 mg/L and 0.111 mg/L control site is 0.095 mg/L, all three analysed samples fall far below the permissible limit, and the percentage compliance level is 100%. Iron concentration varies from 0.03 mg/L and 13.6 mg/L with control site is 0.15 mg/L as shown in table 1 with is W_1, W_2, all above tolerable limit and the percentage compliance is 50%, arsenic ranges from 0.002 mg/L and 0.026 mg/L with well $_1$ and $_4$ been the affected, the control site at 0.00 mg/L and the percentage compliance is 50%, nitrate concentration level fall far above the WHO and NSDWQ standard with the values ranging from 323.7 mg/L and 16.50 mg/L with control well stands at 29.0 mg/L, with well $_1$, $_3$ and $_4$ all above tolerable limit and the percentage compliance is 25%. Mercury has concentration level ranging from 0.000 mg/L and 0.022 mg/L with well $_2$ been the possible contaminant, the control site remain at 0.000 mg/L and the percentage compliance is 75% while chromium has values ranging from 0.000 mg/L and 0.080 mg/L with well $_1$ having the value above the standard and the percentage compliance is 75% with control site 0.00 mg/L and lead concentration value ranging between 0.000 mg/L and 0.001 mg/L with control well at 0.000 mg/L and the percentage compliance is 100%.

Table 1. *Summary of Physiochemical parameters of Water Samples and Standards.*

Parameters	Method	Control well	W_1	W_2	W_3	W_4	WHO	NSDWQ	Health **Impact (NSDWQ, 2015, Ezugwu, 2015)**
Temperature (°C)	APHA 2550 B	30.9	31.5	31.5	31.1	31.9	35-40	-	-
Arsenic (mg/L)	APHA 3130 A	0.000	0.026	0.007	0.009	0.019	0.01	0.01	Cancer, Damages Kidney & Liver
Nitrate (mg/L)	APHA 4500 NO_3	29.0	109.2	16.50	288.0	323.7	50	50	Cyanosis and asphyxia
(pH)	APHA 4500H*B	3.70	6.73	6.76	6.70	7.04	7-8.5	6.5-8.5	Bitter taste
TDS (mg/L)	APHA 2510 B	210	338	312	232	312	1000	500	Shorten the life of hot water heaters
Electrical conductivity c	APHA 2510 B	323	520	466	357	480	1000	1000	None
Iron (mg/L)	APHA 3500 -Fe D	0.15	3.00	0.62	0.04	0.03	0.3	0.3	Bitter taste, brownish colour to clothing
Mercury (mg/L)	APHA 3130 A	0.000	0.000	0.022	0.005	0.004	0.006	0.001	Kidney and nervous system
Cadmium (mg/L)	APHA 3130 A	0.000	0.000	0.000	0.000	0.000	0.003	0.005	Toxic to liver & kidney, High blood pressure etc.
Chromium (mg/L)	APHA 3500 –Cr D	0.00	0.08	0.03	0.05	0.05	0.05	0.05	Cancer, respiratory damage
Copper (mg/L)	APHA 3500 Cu-D	0.055	0.515	0.000	0.000	0.000	2.0	1.5	Stomach & intestinal distress, liver & kidney damage
Lead (mg/L)	APHA 3130 A	0.000 mg/L	0.003	0.000	0.001	0.000	0.001	0.001	Cancer, toxic to central & nervous system, red blood cell
Zinc (mg/L)	APHA 3500 Zn-D	0.095	0.111	0.000	0.000	0.000	3.0	3.0	Aid in healing of wounds

Table 2. *Comparison of Physiochemical parameters of Water Samples with percentage compliance to WHO 2004 & NSDWQ, 2015).*

Parameters	Minimum	Maximum	Percentage compliance (%)	WHO	NSDWQ
Temperature (°C)	30.9	31.9	100	35-40	-
Arsenic (mg/L)	0.002	0.026	50	0.01	0.01
Nitrate (mg/L)	16.50	323.7	25	50	50
(pH)	6.70	7.04	100	7-8.5	6.5-8.5
TDS (mg/L)	210	338	100	1000	500
Electrical conductivity μScm^{-1}	323	520	100	1000	1000
Iron (mg/L)	13.6	0.03	50	0.3	0.3
Mercury (mg/L)	0.0000	0.0061	75	0.006	0.001
Cadmium (mg/L)	0.000	0.003	100	0.003	0.005
Chromium (mg/L)	0.00	0.08	75	0.05	0.05
Copper (mg/L)	0.000	0.515	100	2.0	1.5
Lead (mg/L)	0.00	0.017	100	0.001	0.001
Zinc (mg/L)	0.000	0.111	100	3.0	3.0

4. Conclusion

The result of geochemical parameters on analysed groundwater are within the specified limit set by World Health Organisation, Nigerian Standard Drinking Water Quality. However the activity of artisanal mining in the area has impacted on the environment with about 20% of the area directly or indirectly contaminated as shown in Tables 1 and 2 respectively. The possible contamination may be as a result of element migration and extent of migration depth.

Consequently the activities has led to environmental degradation and loss of vegetation, therefore regulations and remediation methods should be in place to checkmate the effect during and after the mining activities. The activity of artisanal gold mining in the area can generated large amount of waste leaving large heaps of excavated soils from trenches and tailings generated during processing creates an artificial barrier for surface run-off. This has led to the modification in the stream channels by disrupting the initial channel and creating new ones.

Omanayin et al stated that mining activities can cause a change in the natural geology of the area promoting geological hazards like erosion and flooding [11].

5. Recommendation

Electrical resistivity method (vertical electrical sounding) be employed to delineate the lateral and depth extent of contaminated leachate plume migration and to map out subsurface structures that could acts as pathway for flow of contaminant.

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