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Assessment of Physiochemical Qualities of Soil at Kataeregi Mining Site, Niger State, Nigeria

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Abstract: Soil samples were analysed to determine the heavy metals (pH, Cd, Zn, Ar, Cr, Cu, Pb, Hg, Fe and Ni) at Kataeregi mining site, Niger State, Nigeria. Ten soil samples were collected from four soil pits and control site were collected 100 m away from mining site. The results of the analysed soil samples are as follows: Soil pH values of various locations ranged from 6.08 to 8.12 which is indicative of moderately alkaline, Ar values ranged from 4.23 mg/kg to 12.05 mg/kg, Ni values ranged between 4.00 mg/kg and 70.0 mg/kg and is above the standard set for agricultural and human health, Fe ranged from 0.72 mg/kg to 16.03 mg/kg, Hg values ranged between 0.11 and 1.01, Cd values ranged from 4.76 mg/kg to 9.32 mg/kg which is indicative of high concentration of chemical parameters and Cr ranged between 9.89 mg/kg and 27.00 mg/kg. Cu values ranged from 99.78 mg/kg to 111.9 mg/kg while Pb values ranged between 1.0 mg/kg and 6.07 mg/kg and Zn values ranged from 9.91 mg/kg to 13.0 mg/kg. It is observed that concentrations of Ar, Ni, Hg, Cd and Cr are above the CSQG standard while that of Fe is found to be below the standard set by CSQG & WHO and Cu, Pb, and Zn are within the permissible range.

Keywords: Soil, Human Health, Cadmium, Alkaline and Mining

1. Introduction

A healthy soil is always the foundation of the food production system. Soils help to produces healthy crops. Plants obtain nutrients from two natural sources of soils. They are 1) organic matter and 2) the minerals. Both are present in soils. The organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process. In addition to providing nutrients and habitat to organisms that are living in the soil, the soil organic matter also binds the soil particles to form soil aggregates and improves the water holding capacity of soils. Soils are the bases for survival of life on earth [3].

Soil is the main source of nutrient for crops. Soil also provides support for plant growth in various ways. Knowledge about soil health and its maintenance is critical to sustaining crop productivity. However, this is a general assessment made by farmers. A scientific assessment is possible through detailed geophysical and chemical analysis of the soil which the research established.

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].

Waste rock is hence durably unused extraction products that is generally stored indefinitely in a landfill site which, for economic reasons associated with transport costs, is located in the immediate vicinity of the main mining centre. The quantity of mining waste that can be stored at a mining centre varies considerably and mainly depends on the selectivity of the mining method. As a rule opencast pits and quarries generate much more mining waste than an underground mine [11].

The main type of waste rock is generated by surface (or barren rock) stripping to expose the shallow ore. This is rock that is weathered to varying degrees, although increasingly fresh with depth and showing the geological characteristics of the local surrounding material. Its composition is similar to the rocks of the sector. The largest (in tonnage) quantity of barren rock comes from stripping for opencast mines. In underground mines, these barren rocks are generated by the passages (shafts, crosscuts) [7].

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]. The heavy metals essentially become contaminants in the soil environments because (i) their rates of generation via man- made cycles are more rapid relative to natural ones, (ii) they become transferred from mines to random environmental locations where higher potentials of direct exposure occur, (iii) the concentrations of the metals in discarded products are relatively high compared to those in the receiving environment, and (iv) the chemical form in which a metal is found in the receiving environmental system may render it more bioavailable [16].

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 09º21'N and 09º25'N and Longitudes 006º17'E and 006º22'E. It lies between the geographical co-ordinates of Northing's 1038000 – 1037700 mN and Easthing's 206030 – 206455 mE in the Universal Traverse Mercator (UTM) Minna Zone 31. 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].

The vegetation of the area consist of broad leaved Savannah woodland with some of the trees reaching about 10 meter in height. The predominant vegetation consist of shrubs and grasses [1]. Basically, the study area consist of low-lying terrain and gentle hills.

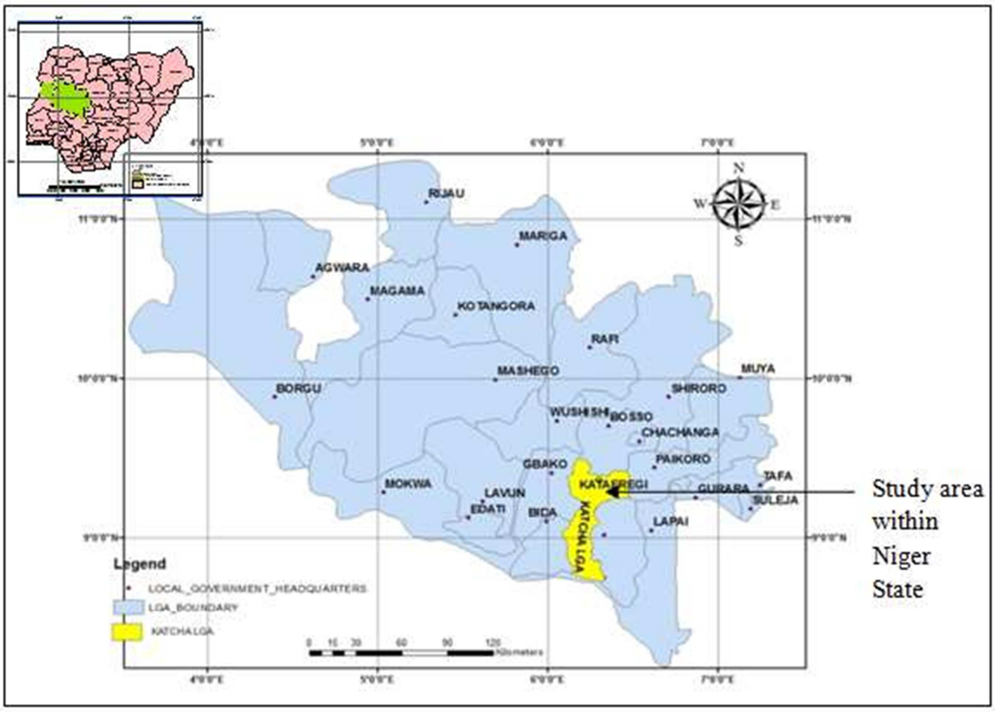

Figure 1. Location map of Kataeregi, Niger State, Nigeria [10].

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) [8]. 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 [10]. 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 [9].

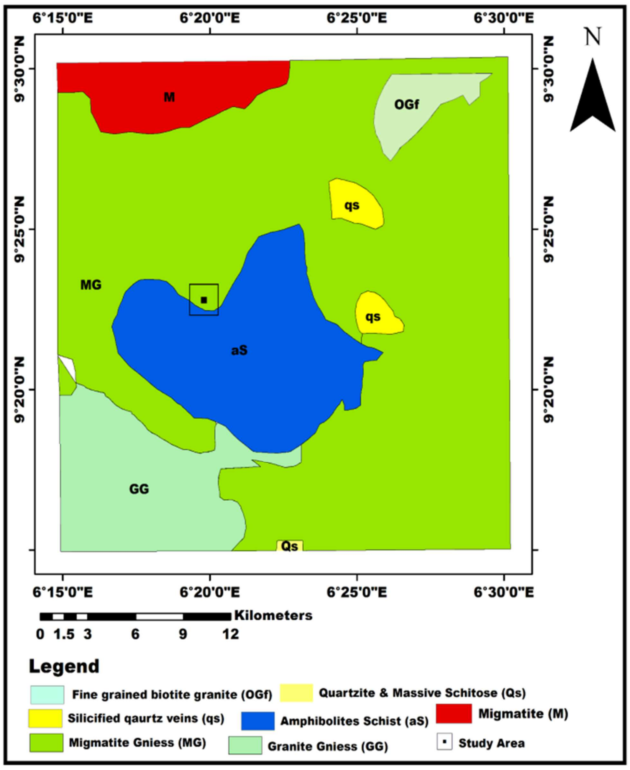

Figure 2. Geological map of the study area.

2. Methodology

Five soil samples within and around the mining waste site were collected from five profile pits dug. This pit size is necessary for easier and clear observation of all soil horizons from the bottom to the top of the pit. The samples were randomly collected at a depth interval of 0 – 2 m. The soil samples were poured into prepared plastic bottles which were capped and lebelled properly. The samples were subjected to air and oven dried to ensure constant weight, gently crush and sieved. The samples (1.5 g) were placed in 100 cm^3 flask and treated with a mixture of solvent, the mixture were swirled gently and digested for fifteen minutes. The mixture was allowed to cool and diluted to 50 cm^3, heated gently and then filtered. The filtered was then diluted to 100 cm^3 and analysed.

3. Soil Chemical Analysis

Chemical analysis was done on the soil sample collected close to and away from the mining site. Preliminary assessment of the extent pollution with respect to exchangeable metals was carried out at the Federal Ministry of Water Resources, Regional Water Quality Laboratory, Minna. Soil samples from five sampling points at about horizon C were obtained and analysed for their chemical concentrations in mg/L. The sample point were designated as S_1 to S_5 with each sampling point separated with a distance of 10 m and S_5 serves as the control point and distanced of 100 m away from S_4.

Table 1. Maximum permissible concentration of constituents in soil [15].

Constituents	WHO/EU/CSQG (mg/Kg)
Hydrogen iron (pH)	6 – 8
Arsenic	9.8
Iron	20
Cadmium	1.4
Chromium	6.4
Copper	270
Acidity	NS
Total Hardness	NS
Mercury	0.18
Lead	70
Zinc	200
Nitrate	35
Chloride	NS

NS* = Not specified, CSQG = Canadian Soil Quality Guideline

4. Results and Discussion

Chemical Properties of Soil

Table 2 shows the results of analysed soil samples within the vicinity of Kataeregi mining site compared with the control site and the standard set up by the Canadian Soil Quality Guidelines [6, [14] World Health Organisation (CSQG/WHO) for the protection of the agricultural and human health values for each metal. Descriptive statistics using computed mean and standard deviation were employed to interpret the measured soil parameters (pH, Zn, Pb, Fe, Cu, Cr, Cd, Ni, Hg, and Ar) concentration. The results indicates that the measured soil pH for both the control site and the mining site are within the CSQG standard signifying a moderately alkaline soil type with normal distribution. Some parameters with high concentration as observed in Table 2 (S_1 for pH, S_1, S_2, and S_4 for Ar,, S_1, S_2, for Ni, S_1, S_3, and S_4 for Hg, S_1, S_2, S_3 and S_4 for Cd, S_1, S_2, S_3 and S_4 for Cr) were above the limit thereby causing harm to soil, crop and human health. For the parameters that have insignificant level of concentration, the contaminants may have been seeped down the soil to ground water (Yusuf *et al*., 2018).

Soil pH values of various locations ranged from 6.08 to 8.12 which is indicative of moderately alkaline, Ar values ranged from 4.23 mg/kg to 12.05 mg/kg which is above the standard, Ni values ranged from 4.00 mg/kg to 70.0 mg/kg is also above the standard set for agricultural and human health, Fe ranged from 0.72 mg/kg to 16.03 mg/kg is below the standard set by CSQG, Hg values ranged from 0.11 to 1.01 which is above the standard, Cd values ranged from 4.76 mg/kg to 9.32 mg/kg is also indicative of high concentration of chemical parameters and Cr ranged from 9.89 mg/kg to 27.00 mg/kg is above standard.

Cu values ranged from 99.78 mg/kg to 111.9 mg/kg while Pb values ranged from 1.0 mg/kg to 6.07 mg/kg and Zn values ranged from 9.91 mg/kg to 13.0 mg/kg all those parameters are within the standard.

***Table 2.** Chemical properties of soil Samples.*

Parameters (mg/Kg)	Control site	S1	S2	S3	S4	Min.	Max.	Mean	S. D.	CSQG/WHO (mg/Kg)
Temperature (°C)	25.2	25.0	25.0	25.0	25.0	25.0	25.2	25.0	0.1	-
pH	2.27	8.12	7.57	6.08	6.62	6.08	8.12	7.13	0.79	6 – 8
Arsenic	4.23	9.89	12.05	9.92	11.00	4.23	12.05	9.42	3.03	9.8
Nitrate	7.01	49.41	70.0	8.60	4.00	4.00	49.41	33.8	27.8	35
Iron	3.6	3.00	0.72	16.03	5.05	0.72	16.03	7.68	6.75	20
Mercury	0.10	0.20	0.12	0.19	1.01	0.11	1.01	0.33	0.49	0.18
Cadmium	0.76	9.32	6.00	8.70	6.50	4.76	8.70	7.06	1.91	1.4
Chromium	1.89	20.10	18.43	27.00	12.00	9.89	27.00	17.5	6.82	6.4
Copper	86.00	100.1	111.1	99.78	111.9	86.00	111.9	102	10.6	270
Lead	1.04	4.44	1.00	1.50	6.07	1.00	6.07	2.40	0.81	70
Zinc	9.91	13.0	11.55	11.01	10.00	9.91	13.0	11.1	1.27	200

5. Conclusion

The results of geochemical parameters on analysed soil are within the specified limit set by World Health Organisation and Canadian Soil Quality Guidelines. However the activity of artisanal miners in the area has impacted on the environment with about 20% of the area directly or indirectly contaminated as shown in Table 2. Consequently the activity has led to environmental degradation, loss of vegetation and soil erosion among others.

6. Recommendation

Regulations and remediation methods should be in place to checkmate the effect during and after the mining activity. Some of the remediation technologies for contaminated soil into (i) source control and (ii) containment remedies [13].

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