ASSESSMENT OF ENVIRONMENTAL RISK OF MINING PONDS IN BUKURU, JOS-SOUTH LGC OF PLATEAU STATE

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Abstract: *These days there is increased environmental degradation resulting from mining is caused by inappropriate and inefficient work practices and poor measures of rehabilitation. The different stages of activities in mining have their tendencies to adversely affect the environment, the immediate society, the cultural heritage of the host community and health status of miners. This study is aimed at carrying out an assessment of environmental risk of mining ponds in Bukuru, Jos-South LGC of Plateau State which was achieved through identification and mapping out of the major mining ponds in the study area in relation to land use activities around them and laboratory analysis of water and soil samples of major ponds.*

Keywords: *Environment, degradation, Mining, Remote sensing, Niger State*

1. INTRODUCTION

It has been observed that mining is one of the main economic activities in developing countries (Tauli-Corpuz, 1997; United Nations Environmental programme (UNEP), 1997). Various activities associated with mining be it in small or large scale has inherent tendencies to be devastating to the environment (Makweba and Ndonde, 1996; UNEP, 1997). Environmental degradation resulting from mining is caused by inappropriate and inefficient work practices and poor measures of rehabilitation. The different stages of activities in mining have their tendencies to adversely affect the environment, the immediate society, the cultural heritage of the host community and health status of miners (Akabzaa, 2000; Aitken *et al.*, 2016); PricewaterhouseCoopers (PwC), 2016).

It is the discovery and mining of tin that resulted in the development of the present Plateau State and this activity according to Gwom (2001) is traced to more than a century. Mining operation which was a dominant activity in Jos Plateau can be clearly seen from the way that the southern part of the territory is encompassed by numerous mining and pilot ponds. Mining and processing has resulted in infrastructural and socio-economic development of the territory, with major negative impacts witnessed in hydrological and biophysical environments. The major minerals mined in the Jos Plateau are Tin, Columbite, Tantalum, Magnetite, Iron, Zinc, and Lead among others. The value attached to these minerals makes it irresistible to illegal miners without considering the negative impacts of their mining activities. For instance, the production of Tantalum is highly important to the electronics industries that use it for the manufacture of capacitors. Tantalum, obtained from coltan, is mined on a large scale in Jos South. These mining operations have negative and positive benefits.

The exploitation of mineral resources is considered as among the major causes of environmental pollution in Nigeria, there is an increasing awareness that activities of mining could be embarked upon in a way that financial benefits are optimized, social conditions are enhanced, and destruction of the environment are minimized which is the focus of this study. Relatively few researches have been conducted on risk assessment of mine ponds. Such researches include a study conducted by Edun and Davou (2013) where they carried out an inventory of abandoned mine ponds on the Jos-Bukuru area of Plateau State using GIS and

Remote Sensing application. The study identified 180 mine ponds spread across the study area but did not examine the chemical composition of the water in the mine ponds and its impact on the environment. Also, Gyang and Ashano (2009) focused on the effect of mining on water quality. The impact of mine ponds on the environment and the implications of the usage of the mine ponds for various purposes was also not delved into. This study is aimed at carrying out an assessment of environmental risk of mining ponds in Bukuru, Jos-South LGC of Plateau State which was achieved through identification and mapping out of the major mining ponds in the study area in relation to land use activities around them and laboratory analysis of water and soil samples of major ponds.

1.1 The Study Area

Plateau state is located in the middle belt zone of the country between latitude 8^0 55′ N and 10^0 11′ N and 8^0 21′ E and 9^0 30′ E (Dukiya, 2012). Jos city is bounded by Bassa in the North-West, Riyom at the South, Barkin Ladi at the south-East and Jos East at the North-East. The study comprises of Jos North and Jos south called the greater Jos with a population of 485,040 people (Daspan, 2014). Plateau state is located in Nigeria and the study area is found in the state as shown in Figures 1 and 2.

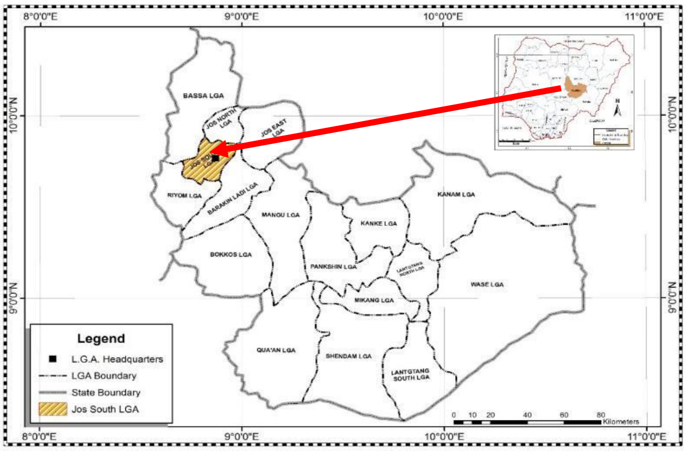

Figure 1: Jos-South Local Government Area in Government Plateau State

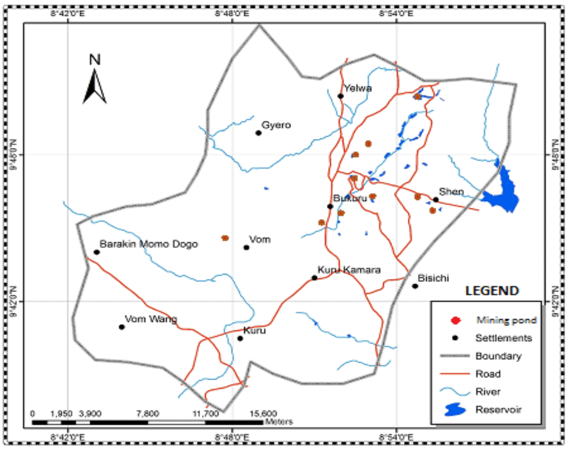

Figure 2: Jos-South Local Area

2. LITERATURE REVIEW

2.1 Mining and types of mining

Mining is extraction of profitable minerals or other geographical materials from the earth generally from a metal body, jackpot, vein, crease, and reef or placer stores. These stores shape a mineralized bundle that is of financial enthusiasm to the mineworker. Minerals recuperated by mining incorporate metals, coal, oil shale, gemstones, limestone, chalk, measurement stone, shake salt, potash, rock, and earth. Mining is required to acquire any material that can't be developed through farming procedures, or made falsely in a research facility or manufacturing plant. Mining in a more extensive sense incorporates extraction of any non-inexhaustible asset, for example, oil, flammable gas, or even water (Heiss and Oeggl, 2008).

2.1.1 Types of mining

Basically, mining activity can be categorized into two basic exhuming sorts: surface mining and sub-surface (underground) mining. Today, surface mining is considerably more typical in comparison with underground mining.

2.1.2 Surface mining method

Gardner and Sainato (2007) described surface mining, including strip mining, open-pit mining and peak expulsion mining, is a general class of mining in which soil and rock overlying the mineral store (the overburden) are evacuated. As opposed to underground mining, in which the overlying rock is left set up, and the mineral expelled through shafts or passages. Surface mining is the principal exploitation procedure globally, accounting for approximately 85% of all mineral production in the United States, apart from natural gas and petroleum. Surface mining can be classified into two groups on the basis of the method of extraction; mechanical extraction, or aqueous extraction.

2.2 General mining operations

Mining exercises cover a differing scope of conditions and the difficulties involved are frequently peculiar and particular to each mine site. Be that as it may, mining exercises constantly affect water conditions through immediate or circuitous contact of either the surface or groundwater. Activities of Mining exercises can likewise create pollution of water through following releases or other immediate or roundabout contacts, blending or utilization of water in the preparing of the metals.

The utilization of water in mining can possibly influence the nature of surface water encompassing an area as well as the groundwater. In light of ecological concerns and government controls, the mining sector overall progressively supervise water released from mine destinations, and has actualized various administrative methodologies to avoid water contamination. Issues of water as well as administration are distinct from one mining site to the other and should be tended to locally, however by and large, the mining sector attempts to limit its effect on water quality and accessibility.

3. RESEARCH METHODOLOGY

The use of primary and secondary data was employed for collection of quantitative and qualitative data. Primary data was collected from selected mining pond sites (see Table 2) for laboratory tests/analysis. Technical information on pollutants was obtained from the laboratory tests of water samples from mining ponds and other water sources in the study area. Also structured questionnaire was randomly administered to residents in close proximity to mining ponds to assess their purpose and extent of use for the mining ponds, so as to determine its impact on residents. The questionnaire survey is further meant to assess the risk perception of the residents to ascertain their level of awareness. The extent at which water sample from the study area were contaminated with trace metal was evaluated with heavy metal pollution index (equation 1). Standards for the different uses were used for calculating HMPI. The metals analysed are lead, manganese, and copper.

$$MPI = \text{Mean} \sum Ci/S \qquad \ldots 1$$

Where Ci = metal concentration & S= standard limit of consumption

Table 1: Metal Pollution Index

Class	Pollution Index (PI)	Status
Class 1	PI<1	No pollution
Cass2	PI: 1-2	Slightly polluted
class3	PI: 2-3	Moderately Polluted
class4	PI: 3-5	Strongly Polluted
class5	PI: >5	Seriously Polluted

Table 2: Sampled location of mining ponds

S/N	Location	Coordinate
1	Rayfield Resort	$09^0$50’31.8”N, $08^0$54’46.6”E
2	Anguwan Doki	$09^0$47’53.73”N, $08^0$51’38.6”E
3	Anguwan Corona	$09^0$48’25.51”N, $08^0$52’40.75”E
4	Shen	$09^0$46’18.98”N, $08^0$54’42.29”E
5	Dorowa	$09^0$46’17.17”N, $08^0$52’13.4”E
6	Bukuru Stadium	$09^0$46’17.17”N, $08^0$51’38.6”E
7	Zawan	$09^0$45’34.40”N, $08^0$51’53.38”E
8	HBC Resort	$09^0$45’24.5”N, $08^0$50’41.0”E
9	NIPSS Kuru	$09^0$44’33.60”N, $08^0$48’21.74”E

Source: Author’s Field Survey (2018).

Glenn (2001) method of calculating sample size was adopted. $\square = \frac{\square}{1+\square(\square^2)}$

This represents the number of questionnaires administered to residents of the settlements within the radius of the selected mining ponds. In order to calculate the sample size per settlement/village, the calculated population for each settlement/village was divided by the total population of the settlements/villages and multiplied by the derived sample size which is 382 (see Table 3).

Table 3: Distribution of sampled units within settlements/villages

S/N	Settlement/Village Name	Population	Sample Size
1	Rayfield Resort	1488	66
2	Anguwan Doki, Rahol-Kanang	1584	70
3	Anguwan Corona	702	31
4	Shen	246	11
5	Dorowa Babuje	1098	49
6	Bukuru Stadium, Gyel	2532	112
7	Zawan	414	18
8	HBC Resort, Kwata	456	20
9	NIPSS Kuru	90	4

Source: Author's Field Survey (2018).

4. RESULTS AND DISCUSSION

The results and discussion are presented in this section according to the objectives of the study. In addressing the first objective of the study which is:

4.1 Identification and mapping of major mining ponds in relation to land use activities around them

The major land use activity identified around the mining ponds located at Rayfield Resort Gut; Anguwan Doki, Rahol Kanang, Shen, Dorowa Babuje, Bukuru Stadium Gyel, Zawan, HBC Resort, Kwata, and NIPSS Kuru is residential as presented in Table 4.

Table 4: Use of Mining Ponds

		Recreational		Construction (Block Industry)		Domestic		Agricultural (Crop Cultivation)		Fish Farming		Watering of Animal		Others (e.g. public water supply)	
SN	Location	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
1	Rayfield Resort	66(100)	-	2(3)	64(97)	-	66(100)	-	66(100)	1(1.5)	65(98.5)	-	66(100)	-	66(100)
2	Anguwan Doki, Rahol-Kanang	31(44)	39(56)	-	70(100)	-	70(100)	-	70(100)	-	70(100)	-	70(100)	-	70(100)
3	Anguwan Corona	-	31(100)	1(3)	30(97)	-	31(100)	-	31(100)	3(10)	28(90)	-	31(100)	-	31(100)
4	Shen	-	11(100)	2(18)	9(82)	3(27)	8(73)	1(9)	10(91)	4(36)	7(64)	1(9)	10(91)	-	11(100)
5	Dorowa Babuje	-	49(100)	2(4)	47(96)	-	49(100)	1(2)	48(98)	-	49(100)	-	49(100)	-	49(100)
6	Bukuru Stadium, Gyel	-	112(100)	2(2)	110(98)	4(4)	108(96)	2(2)	110(98)	23(20.5)	89(79.5)	-	112(100)	-	112(100)
7	Zawan	-	18(100)	1(6)	17(94)	-	18(100)	3(17)	15(83)	2(11)	16(89)	-	18(100)	-	18(100)
8	HBC Resort, Kwata	1(5)	19(95)	2(10)	18(90)	-	20(100)	-	20(100)	-	20(100)	7(35)	13(65)	-	20(100)
9	NIPSS Kuru	-	4(100)	1(25)	3(75)	-	4(100)	4(100)	-	1(25)	3(75)	2(50)	2(50)	-	4(100)

At Rayfield Resort Gut, the mining pond is used for recreation, block industry and fish farming; at Anguwan Doki, Rahol-Kanang it is used for public water supply; the mining **pond at**

Anguwan Corona is used for block industry and fishing; at Shen, it is used for block industry, crop cultivation, fish farming and watering of animals; at Dorowa Babuje, the mining pond is used for block industry, crop cultivation and public water supply; at Bukuru stadium Gyel, it is used for block industry, crop cultivation, and fish farming; the mining pond at Zawan is used for block industry and crop cultivation; at HBC Resort Kwata, it is used for block industry and watering of animals; the mining pond at NIPSS Kuru is used for block industry, crop cultivation and watering of animals.

The study also revealed that the recreational activities in these ponds are restricted to boat sailing and sightseeing, and respondents do not make use of soil (sand) from the mining ponds. This is due to the depth of the ponds which makes it dangerous.

Fishing is one of the activities carried out in the mining ponds. This activity is a source of income for individuals involved directly in fishing and for those involved in the sale. It is also a source of protein for the communities. This implies that it contributes to the economic status of the people. While, ponds with higher concentrations of metals such as lead, copper, and manganese among others, could affect the kidney, liver, nervous system, gastrointestinal and cardiovascular organs of humans directly or indirectly through the consumption of fish or crops from such ponds.

4.2 Laboratory Tests of Mining Ponds

The nine (9) selected mining ponds were sampled in the rainy season whereby the water level was high and the water diluted by run-offs and rains. The water and soil samples collected were analysed for different parameters such as: Temperature, pH, Conductivity, Alkalinity, Chloride, TDS, Sulphate, Hardness, and minerals (Potassium, Calcium, Lead, manganese, Copper and Sodium). The results presented in Figures 3 to 7 are the mean of triplicate analysis conducted for the samples which were compared with recommended standards of EPA 2007 for the following uses: recreation, crop cultivation (irrigation), fish farming (aquatic life), animal watering, and public water supply.

4.2.1 Water temperature in the ponds

The temperature of the mining ponds analysed ranges from 28.70^0C to 29.80^0C. The mining ponds with the highest temperature are located at Anguwan Cororna and Dorowa Babuje with 29.80^0C and the mining pond with the lowest temperature is located at NIPSS with 28.70^0C as shown in Figure 4.3.

4.2.2 pH of water and soil in the selected mining ponds

The pH of water from the mining ponds analysed ranges from 6.80 to 7.18. The mining pond with the lowest pH is located at Zawan with 6.8 and the mining pond with the highest pH is located at Bukuru Stadium with 7.18 as shown in Figure 3. The pH of water in all the mining ponds are within recommended limits. While, the pH of the soil around the mining ponds analysed ranges from 5.20 to 6.91. The location with the highest pH is at Zawan with 6.91 and the soil with the lowest pH is located at Auguwan Doki with 5.20. The pH at Zawan could be attributed to the location of Dana Nigeria Limited a leather tanning company.

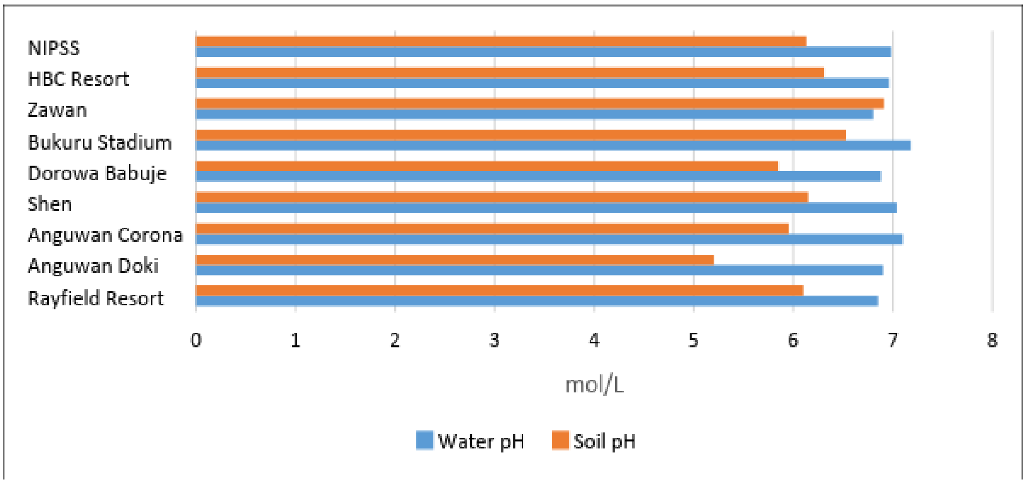

Figure 3: pH of Water and Soil from the Mining Ponds

4.2.3 Total Dissolved Solids (TDS) and conductivity of the water and soil from ponds

The study revealed that the mining pond with the highest TDS is at Dorowa Babuje (531.50mg/L) and the lowest is located at Rayfield Resort (241.50mg/L). TDS of water in all the mining ponds are within recommended limit of 500mg/L (EPA, 2007) except the mining pond at Dorowa Babuje with 531.50mg/L which is higher than the recommended limit. While, the conductivity of the soil around the mining ponds analysed ranges from 5.80 to 26.45. The location with the highest conductivity is at Bukuru Stadium with 26.45 and the soil with the lowest conductivity is located at Dorowa Babuje with 5.80. The highest conductivity at Bukuru Stadium could be attributed to deposits of tailings around the mining pond.

4.2.4 Sulfate concentrations of the water from ponds

Results of the laboratory tests revealed that water in the mining pond with the highest sulfate concentration is at Dorowa Babuje (531.50 mg/L) and the lowest is located at Rayfield Resort (see Figure 4.4). The recommended upper limit for sulfates is 250mg/L (EPA, 2007) which signifies that water in all the mining ponds are within the recommended limit. Analysis of the soil around the mining ponds revealed that the location with the least concentration of sulfate was 35.31mg/kg and the location with the highest concentration of sulfate was Bukuru Stadium with 69.61mg/kg. The highest sulfate concentration at Bukuru Stadium could also be attributed to the deposits of tailings around the mining pond.

4.2.5 Chloride content of the water from ponds and soils around the ponds

The concentration of chloride in the sampled water from the mining ponds ranges from 46.89mg/L to 71.07mg/L, with the highest concentration found at the mining pond located at Bukuru Stadium, Gyel and lowest found at the mining pond at HBC Resort Kwata. While, chloride concentration found in the soil around the mining ponds ranges from 34.56mg/kg to 83.23mg/kg. The location with the highest chloride content was at Bukuru Stadium Gyel with 83.23mg/kg and the location with the lowest chloride content was located at Zawan with 34.56mg/kg (see Figure 4.4). The highest chloride concentration at Bukuru Stadium Gyel could be attributed to the deposits of tailings around the mining pond.

4.2.6 Alkalinity of pond water and soils around the ponds

The alkalinity of the water from the mining ponds ranges from 26.80mg/L to 94.48mg/L. It revealed as shown in Figure 4.4 that the location with the highest alkalinity of 94.48mg/L was located at Bukuru Stadium Gyel and the location with the lowest alkalinity was 26.80mg/L was located at Rayfield Resort, Gut. While, the soil around the mining ponds ranges from 78.45mg/kg to 188.32mg/kg. With the location with the highest alkalinity of 188.32 mg/kg was located at Bukuru Stadium, Gyel and the location with the lowest alkalinity was 78.45mg/kg was located at Zawan (see Figure 4.3). The highest alkalinity level at Bukuru Stadium could be attributed to the deposits of tailings around the mining pond.

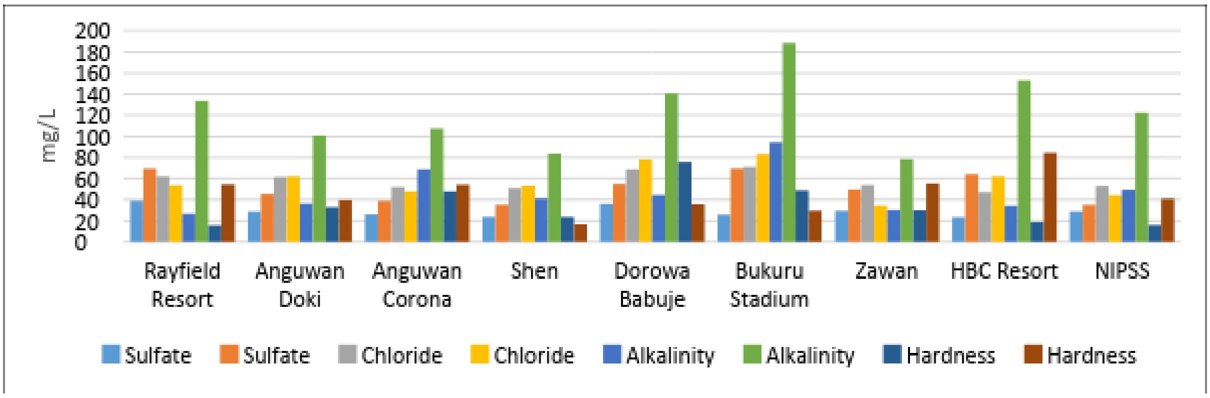

Figure 4: Concentrations of Sulphate, Chloride, Alkalinity, and Hardness of Water and Soil from the Mining Ponds

4.2.7 Potassium content of the water from ponds and soils around the ponds

The concentrations of potassium in the sampled mining ponds as shown in Figure 5 ranges from 10.55mg/L to 115.85mg/L. The lowest concentration was found at the mining pond located at Shen and the highest at Anguwan Corona. While, the potassium concentrations of the soil ranges from 7.39mg/kg to 43.90mg/kg, with the lowest concentration found at the mining pond located at Shen and the highest at Dorowa Babuje.

4.2.8 Calcium content of the water from ponds and soils around the ponds

The concentrations of calcium in the mining ponds as shown in Table 5 ranges from 12.10 to 42.33mg/L. The highest concentration was found at Anguwan Doki (Rahol-Kanang) and the lowest at NIPSS Kuru. Therefore, this gives an indication of a very low amount of the mineral nutrient (Ca) in the soils. While, the concentrations of calcium in the soils around the mining ponds ranges from 0.18 to 0.87mg/kg. The highest concentration was found at Anguwan Doki (Rahol-Kanang) and the lowest at Bukuru Stadium.

4.2.9 Magnesium (Mg) content of the water from ponds and soils around the ponds

The concentration of magnesium in the sampled water from the mining ponds ranges from 25.80mg/L to 74.04mg/L, with the highest concentration found at the mining pond located at Shen and lowest found at Anguwan Doki, Rahol Kanang. While, magnesium concentration found in the soil around the mining ponds ranges from 0.09mg/kg to 0.85mg/kg. The location with the lowest magnesium content was found at NIPSS Kuru with 0.09mg/kg and the location with the highest magnesium content was located at Anguwan Corona with 0.85mg/kg (see Figure 5).

4.2.10 Sodium content of the water from ponds and soils around the ponds

The concentrations of sodium in the mining ponds ranges from 0.11 to 4.08mg/L. The lowest concentration was found at Bukuru Stadium, Gyel and the highest at HBC Resort (Kwata). While, the concentrations of sodium in the soils around the mining ponds ranges from 0.05 to 0.11mg/L. The lowest concentration was found at Anguwan Corona and the highest at Bukuru Stadium, Gyel (see Figure 5). This shows that the concentrations of sodium in the water are relatively higher than the concentrations in the wells.

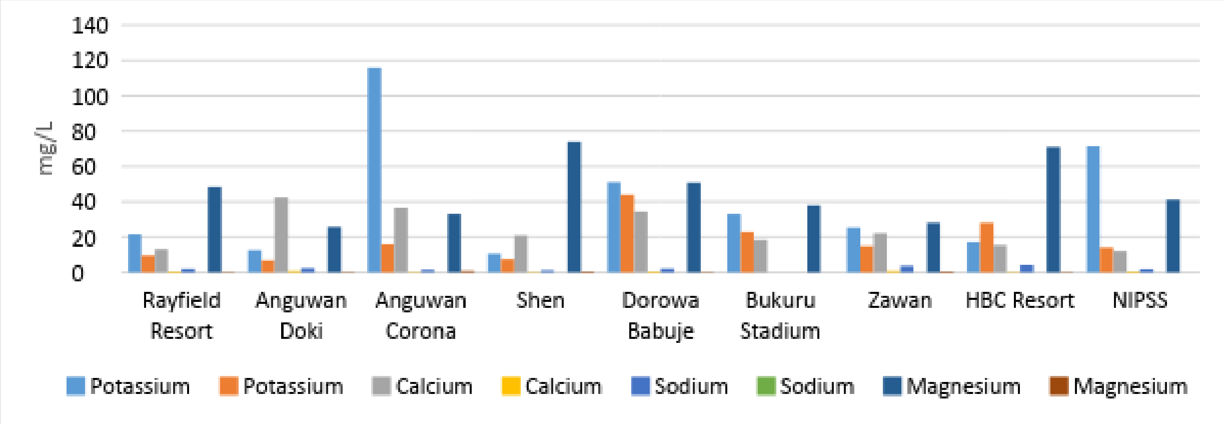

Figure 5: Concentrations of Potassium, Calcium, Magnesium and Sodium of Water and Soil from the Mining Ponds

4.2.11 Lead content of the water from ponds and soils around the ponds

The concentrations of lead in the mining ponds as presented in Figure 6 ranges from 0.06 to 1.87mg/L. The lowest concentration was found at Anguwan Doki, Rahol Kanang and the highest at Zawan. While, the concentrations of lead in the soils around the mining ponds ranges from 0.02 to 0.09mg/kg. The lowest concentration was found at Anguwan Corona and Dorowa Babuje and the highest at Zawan.

4.2.12 Manganese (Mn) content of the water from ponds and soils around the ponds

Though Mn is an essential metal, high concentration may cause serious problems and limit crop yield (Pakade *et al.*, 2014). Manganese (Mn) concentrations in the mining ponds ranges from 0.27 – 0.90 mg/kg. The minimum concentration of manganese was observed in Bukuru Stadium and the maximum at HBC Resort, Kwata. While, the concentrations of manganese in the soils ranges from 8.95mg/kg to 31.55mg/kg. The lowest concentration is found at Zawan and the highest at NIPSS Kuru (see Figure 6).

4.2.13 Concentration of copper in sampled water from ponds and soils around the ponds

The concentrations of copper in the mining ponds as presented in Figure 6 ranges from 0.32 to 2.45mg/L. The lowest concentration was found at Anguwan Corona and the highest at HBC Resort (Kwata). While, the concentrations of copper in the soils around the mining ponds ranges from 8.59 to 28.00mg/L. The lowest concentration was found at Bukuru Stadium, Gyel and the highest at NIPSS Kuru. This shows that the concentrations of copper in the soils are relatively higher than the concentrations in the water.

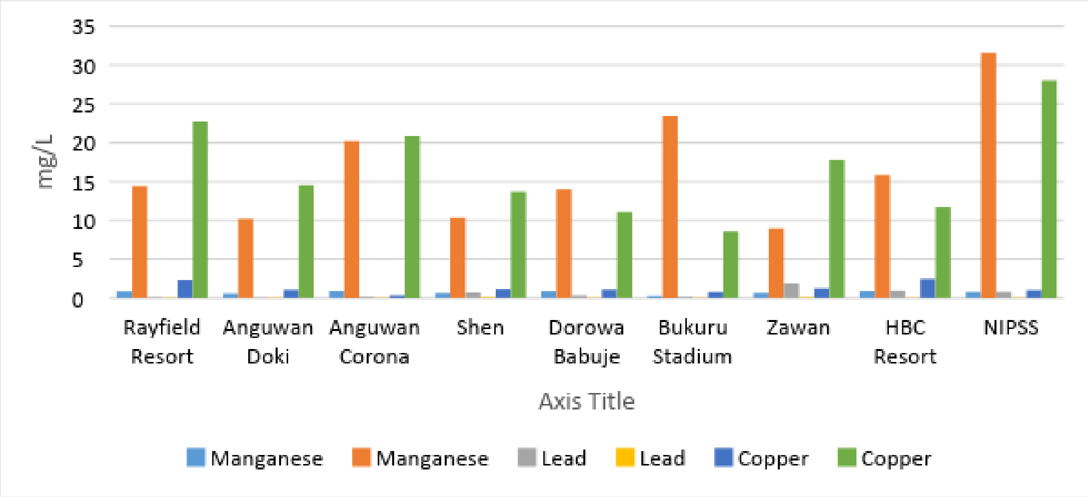

Figure 6: Concentrations of Lead, Manganese and Copper of Water and Soil from the Mining Ponds

4.3 Suitability of Mining Ponds for Different Uses

The results obtained from the laboratory analysis of the water and soil samples, were used to determine the suitability of the mining ponds for the major use(s) of each of the selected ponds based on standards (EPA, 2007).

4.3.1 Rayfield Resort, Gut mining pond

Based on the results from the laboratory analysis (see Figure 3 to 6) and the main uses of the mining pond at Rayfield Resort Gut, which are recreation (boat sailing and sightseeing, see Plate I), fish farming and block industry, standards for this uses were applied. Though, since swimming is restricted in the pond, the standard for recreation was not applied. A temperature of less than or equal to 30^0C, pH of 6.5 to 8.3, TDS of 5,000mg/L (EPA, 2007) and the permissible limit of lead set by WHO (Ekpete, 2013) of between 0.05 - 0.1mg/L is recommended for fish farming. Therefore, it can be stated that the mining pond at Rayfield Resort Gut is suitable for the uses identified.

4.3.2 Anguwan Doki, Rahol Kanang mining pond

The mining pond at Anguwan Doki, Rahol Kanang is mainly used for public water supply. The criteria for water quality for public water supply are the most sensitive. The following criteria is required for public water supply: minimum pH of 6.5, chloride 250mg/l, TDS 500mg/l, sulfate 250mg/l, total hardness 100mg/l, manganese 0.05mg/l and lead 0.015mg/l. Based on these criteria, it can be said that the pond at Anguwan Doki Rahol Kanang is relatively suitable for public water supply

4.3.3 Anguwan Corona mining pond

Fish farming and block making are the major use the mining pond at Anguwan Doki are utilized for. A temperature of less than or equal to 30^0C, pH of 6.5 to 8.3, TDS of 5,000mg/L (EPA, 2007) and the permissible limit of lead set by WHO (Ekpete, 2013) of between 0.05 -

0.1mg/L is recommended for fish farming. Therefore, it can be stated that the mining pond at Rayfield Resort Gut is suitable for the uses identified. Though, the concentration of lead is slightly higher (0.13mg/l) than the recommended limit of 0.015mg/l.

4.3.4 Shen mining pond

The following uses are what the mining pond at Shen is used for: crop cultivation (irrigation), fish farming, watering of animals and block making. For crop cultivation, the sampled test results is within the acceptable limit for all the criteria except for copper (1.12mg/l) which is higher than the standard concentration of 0.2mg/l. For fish farming the results signifies that it is suitable except for the concentration of lead (0.69mg/l) which is higher than the acceptable limit. Likewise, it is suitable for animal watering except for lead (0.69mg/l) and copper (1.12mg/l) which are higher than the standard. Therefore, it can be stated that the mining pond at Shen is suitable for the uses identified. Though, precaution need to be taken for the concentration of lead and copper.

4.3.5 Dorowa Babuje mining pond

The suitability of the mining pond at Dorowa Babuje for public water supply and crop cultivation (irrigation) was compared with EPA criteria for the identified uses. Based on the stated criteria, the pond at Dorowa Babuje meets the other criteria for public water supply except for lead (0.30mg/l) and manganese (0.88mg/l) which are higher than the standard. The pond is suitable for crop cultivation, except for copper concentration (1.08mg/l) which is higher than the criteria of .020mg/l.

4.3.6 Bukuru Stadium Gyel mining pond

Comparison of the laboratory results and standard revealed that the pond is suitable for crop cultivation with only the concentration of copper (0.76mg/l) that is higher than the acceptable limit. While for fish farming, the results are within the acceptable limit except for the concentration of lead (1.57mg/l) which is higher than the standard.

4.3.7 Zawan mining pond

The criteria for crop cultivation, whereby the standard for sensitive crops such as fruit trees and strawberries is adopted are; pH of 4.5 to 9.0, TDS for 500mg/l, copper 0.20mg/l, lead 5.0mg/l, and manganese 10mg/l. Comparison of the laboratory tests results and standards at the mining pond at Zawan revealed the suitability of the pond for the identified use except for copper concentration (1.22mg/l) which is higher than the acceptable limit.

4.3.8 HBC Resort Kwata mining pond

The suitability of the mining pond at HBC Resort Kwata for animal watering was compared with EPA criteria for the identified use. The criteria for animal watering are: sulfate 2500mg/l, TDS 2860mg/l, copper 0.5mg/l, and lead 0.1mg/l. Based on the stated criteria, the pond meets the other criteria for animal watering except for lead (0.94mg/l) and copper (2.45mg/l) that exceeds the standard requirements.

4.3.9 NIPSS Kuru mining pond

Crop Cultivation and animal watering are the major uses the mining pond at NIPSS Kuru are utilized for. Based on criteria, it can be said that the pond at NIPSS Kuru is suitable for crop cultivation, though the concentration of copper (1.01mg/l) exceeds the standard measure. While for animal watering, the pond is suitable except for the concentration of lead (0.78mg/l) which is higher than the recommended limit of 0.1mg/l.

Table 5: Heavy Metal Pollution Index (HMPI) (Manganese) for Selected Uses

Location	Fishing		Public Water Supply		Irrigation		Animal Watering	
	HMPI	**Remark**	**HMPI**	**Remark**	**HMPI**	**Remark**	**HMPI**	**Remark**
Rayfield Resort Gut	0.51	No Pollution	0.10	No Pollution	0.05	No Pollution	1.02	Slightly Polluted
Anguwan Doki, Rahol Kanang	0.32	No Pollution	0.65	No Pollution	0.03	No Pollution	0.65	No Pollution
Anguwan Corona	0.53	No Pollution	1.62	Slightly Polluted	0.05	No Pollution	1.06	Slightly Polluted
Shen	0.37	No Pollution	0.73	No Pollution	0.04	No Pollution	0.73	No Pollution
Dorowa Babuje	0.52	No Pollution	1.04	Slightly Polluted	0.05	No Pollution	1.04	Slightly Polluted
Bukuru Stadium, Gyel	0.16	No Pollution	0.32	No Pollution	0.02	No Pollution	0.32	No Pollution
Zawan	0.37	No Pollution	0.74	No Pollution	0.04	No Pollution	0.74	No Pollution
HBC Resort, Kwata	0.53	No Pollution	1.06	Slightly Polluted	0.05	No Pollution	1.06	Slightly Polluted
NIPSS Kuru	0.45	No Pollution	0.91	No Pollution	0.05	No Pollution	0.91	No Pollution

Findings from the result of Heavy Metal Pollution Index as calculated and presented in Table 5 ranged from 0.02 to 1.62. According to Caeiro *et al*. (2005), water sample with Pollution Index greater than 1 is termed as contaminated. Therefore, in terms of fishing and irrigation, none of the mining ponds have a HMPI greater than 1; for public water supply, Anguwan Corona, Dorowa Babuje and HBC Resort, Kwata have HMPI greater than 1 representing 33.33% of the mining ponds; and for watering of animals, Rayfield Resort Gut, Anguwan Corona, Dorowa Babuje and HBC Resort, Kwata have HMPI greater than 1 representing 44.44%..This implies that the mining ponds are suitable for irrigation and fish farming, while for public water supply and watering animals the above mentioned ponds are not suitable.

5. CONCLUSION AND RECOMMENDATIONS

Mining can contaminate the surrounding surface and groundwater if protective measures are not taken. The result can be unnaturally high concentrations of some chemicals, such as lead, copper, manganese and mercury over a significant area of surface or subsurface. Runoff of soil or rock debris also devastates the surrounding vegetation. Transport and dissolution of metals by run-off and ground water is an environmental problem caused by mining. Although in this study, water in each of the mining ponds are suitable for the various uses identified, though the concentrations of lead and copper needs consideration and necessary remediation measures adopted. Based on the findings of the research work, the following recommendations are proffered:

i. The high concentrations of lead and copper exceeding the EPA/WHO limits at Anguwan Doki, Shen, Forowa Babuje, Bukuru Stadium Gyel, Zawan, HBC Resort and NIPSS Kuru should be treated through bioremediation which is more economical and eco-friendly when compared with chemical and physical remediation methods. Though, combined remediation is the most economical and effective at large scale.

ii. A viability study should be conducted for the mining ponds for optimal utilization considering their suitability based on laboratory tests. Also, since all the mining ponds studied are within the recommended limit for recreational activities (excluding swimming), recreational activities should be extended to other mining ponds.

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