International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Assessment of the Suitability of Abandoned Tin Mine Ponds for Irrigation Agriculturein Bukuru - Jos, North Central Nigeria

Kwaghe, E. J.*[1], Akamigbo, F. R. O[2]., Igwe, C. L. A.[3]

[1] Raw Materials Research and Development Council Abuja, Nigeria

[2] Department of Soil Science, University of Nigeria, Nsukka, Nigeria

[3] Department of Soil Science, University of Nigeria, Nsukka, Nigeria
* Corresponding Author email: *ekwaghe16[at]gmail.com*

Abstract: ***Samples of water were collected from the abandoned tin mine ponds in each of the three locations of Bukuru study area and were used to characterize the abandoned tin mine ponds and also to determine heavy metal concentrations. Analyses of the water samples were done using standard laboratory procedures. Results of water quality analysis revealed that the mean values of all the parameters analyzed were below their respective WHO (1993) and FEPA (2001) critical limits, except for total dissolved solids (TDS) which averaged 2, 198 mgkg^{-1} above the WHO and FEPA critical limits of 500 mgkg^{-1}, and Turbidity which had mean values of 33.67 NTU above the WHO and FEPA critical limits of 5 NTU. The results of the water analyses further revealed four heavy metals identified in the abandoned tin mine ponds, namely, Zn, Fe, Cu and Mn. The safety in the use of the abandoned tin mine ponds were established for irrigation by relating their heavy metal contents to the Food and Agricultural Organization/World Health Organization (FAO/WHO) critical limits. The concentrations of these heavy metals were found to be low in the abandoned tin mine ponds as they were below the WHO) critical limit for drinking water, FAO permissible limit for irrigation and FEPA guidelines for land application. Therefore Bukuru abandoned tin mine ponds were not contaminated with any of the heavy metals determined. However, the use of the water from the abandoned tin mines for both domestic and irrigation purposes will require treatment as the total dissolved solids (TDS) and turbidity values were far above WHO and FEPA threshold values and also due to salinity hazards in the long run.***

Keywords: impact assessment, water quality, abandoned tin mine ponds, heavy metals, Bukuru - Jos, Nigeria

1. Introduction

The use of tin mine water for irrigation of agricultural crops could be a promising technology which could solve the problems relating to both shortage of irrigation water and disposal of effluents mine drainage (Annadale*et al.*2001), but the use of such water for irrigation exposes consumers as well as producers to various health risks. With regard to the quality of water for irrigation, the major parameters of concern are salinity denoted by dissolved solids, conductivity, potential toxic trace elements, herbicides and the presence of Na^+. According to Daniel *et al.* (2014) [a], the results of the average temperature, pH, organic C, total suspended solids, electrical conductivity, total hardness and turbidity determined in an untreated tin mine waters used for irrigation at Hiepang, BarkinLadi Local Government Area of Plateau State, were 27.5^{o}C, 5.71, 6.78 mgkg^{-1}, 723 mgkg^{-1}, 317.27 mgkg^{-1} and 5.98 NTU respectively. The quality of water by these parameters was suitable for irrigation but long term irrigation will pose serious problem due to salinity. Cd was not detected, but the total mean (±SD) concentrations of Cr, Ni and Pb sediment were 44.51 mgkg^{-1}, 14.33 mgkg^{-1} and 29.35 mgkg^{-1} respectively. The concentrations of the heavy metals were above the FAO/WHO limits (Daniel *et al.*2014) [b].

In Bukuru, farmers use water from dams from abandoned tin mines for irrigation (Plate 1). Whilst support for increase production and consumption of fresh vegetables is an important goal, citizens have a right to safe food and to ensure food available to them are not contaminated beyond safe acceptable limits. The aim of this paper is to assess the suitability of abandon tin mine ponds in Bukuru - Jos, North Central Nigeria for both domestic use and irrigation purposes.

2. Materials and Methods

The study area (Bukuru town) lays between longitudes 8° 50′ E and 9° 00′E and latitudes 9°45′N and 9°50′N (Figure 1). It was formerly dominated by mining activities in areas such as Maiadiko. Mean monthly temperature varies between 19.4^{0}C and 29^{0}C in the hottest month. It has a cool climatic condition due to its high altitude. Between November and February, average mean daily temperature is 18^{0}C, while it is warm between March and April before the onset of the rains. The mean annual temperature is about 22^{0}C. The rainy season which is between themonths of May and October has its peak in August. Weather Travel (2012) reported that the soil temperature regime is inferred to be isothermal and about 1, 400 millimeters (55 inches) of rainfall annually, the precipitation arising from bothconventional and orographic sources, owing to the location of the city on the Jos Plateau. It has an average elevation of about 1, 150 meters above above mean sea level. According to Gwom (1992), the people of Jos South (Bukuru inclusive) were predominantly farmers and hunters, but with the coming of mining activities and the location of mining camps in

Plate 1: Farmers at Bukuru using water from an abandoned tin mine pond for irrigation

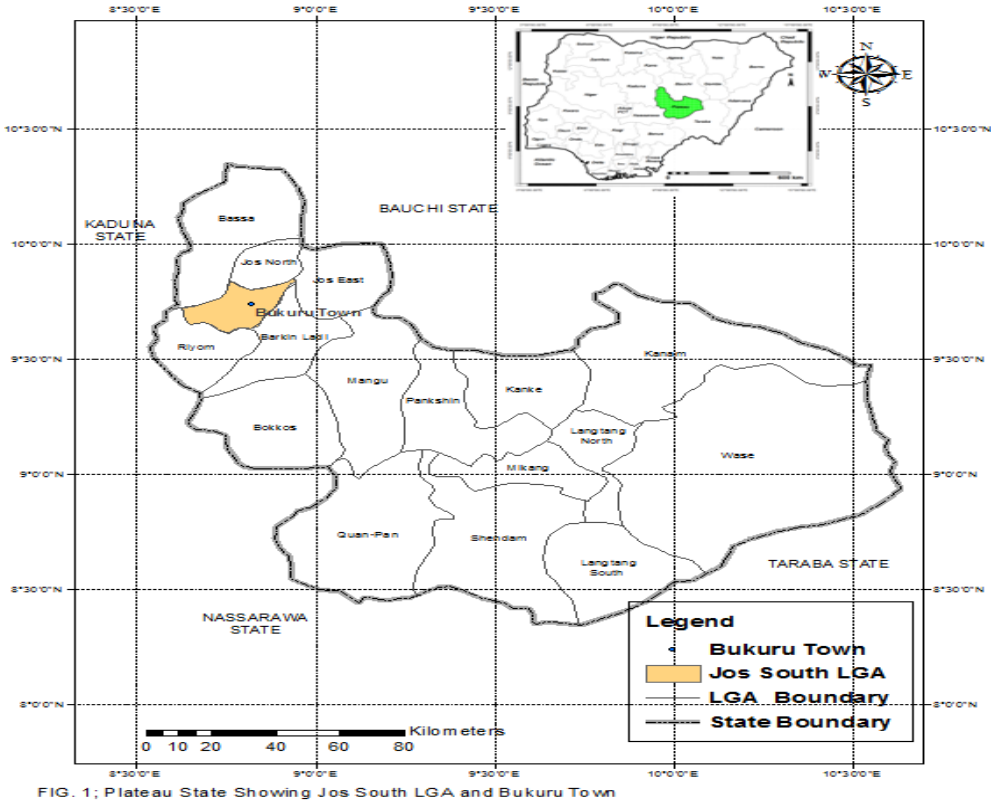

FIG. 1; Plateau State Showing Jos South LGA and Bukuru Town
Source; Adapted from Plateau State Ministry of Land Survey and Town Planning

many areas within the local government, the early occupation of the inhabitants has been overtaken by these mining activitie sweet - potato (*Ipomeabatatas*), maize (*Zea - mays*), millet (*Sorghum bicolor*),. Common food crops grown in the area include irish potato (S*olamumtuberum*), cabbage (*Brassica spp*) tomato (L*ycopersiumesculentum*) and many other varieties of vegetables. On the three locations of the study area, major crops grown were sweet - potato (*Ipomeabatatas*), maize (*Zea - mays*), millet (*Sorghum bicolor*), cabbage (*Brassica spp*) and tomato (L*ycopersiumesculentum*).

In the study area, three locations where active tin mining have been going on for several years were identified as sampling points, namely, Gyel, Rabi and Fwarti (Figure 2). Three) liters of water samples were collected in a sterilized plastic container from the abandoned tin mined ponds (Plate 2) in each location of the study area for determining: turbidity, hardness, nitrates ($NO_3^{-)}$ carbonates ($CO_3^{-)}$, electrical conductivity ($E_{C),}$ sodium ions (Na^+) available phosphorus (P), Nitrogen (N), sulphates (SO_4^+), chloride (Cl, calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and heavy metals concentrations. The water samples were taken immediately to the laboratory for analysis. Physicochemical properties such as; Turbidity, Sodium ($Na^{+),}$ Phosphorus (P), Nitrogen (N), Sulphates ($SO_4^{-)}$, and Chemical Oxygen Demand (COD), were determined by spectrometric techniques, using DR - 2071. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined using the AAS Model ICE 3000 series. Hardness and Chloride were determined by titrimetric method, while Biological Oxygen Demand (BOD) was determined by incubation for 5 days. Nitrates ($NO_3^{-)}$, Total carbonates ($CO_3^{-)}$, electrical conductivity (E_C), of the abandoned mine pond water in each location were determined using standard methods described by AOAC, (1984). Also Lead (Pb), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Nickel (Ni), Copper (Cu), Manganese (Mn), Cobalt (Co), and Iron (Fe) concentrations in the water samples were determined using the Atomic Absorption Spectrophotometer Model: AAS FS 240 plus Varian Spectra.

3. Results and Discussions

The physicochemical characteristics of Bukuru abandoned tin mine ponds are presented in Tables 1. The average temperature of 23.27^0C was recorded for the three locations of Gyel, Rabi and Fwarti (Table 1). Ejila and Daniel, (2011) reported that water temperature may affect water chemistry, metals solubility and uptake by plants and plant growth. Higher temperatures result to greater biomass production. The pH of the abandoned tin mine pond at Gyel, Rabi and Fwarti were 7.84, 7.80 and 7.63 respectively. Its permissible level in both drinking and irrigation water is 6.5 - 8.5.

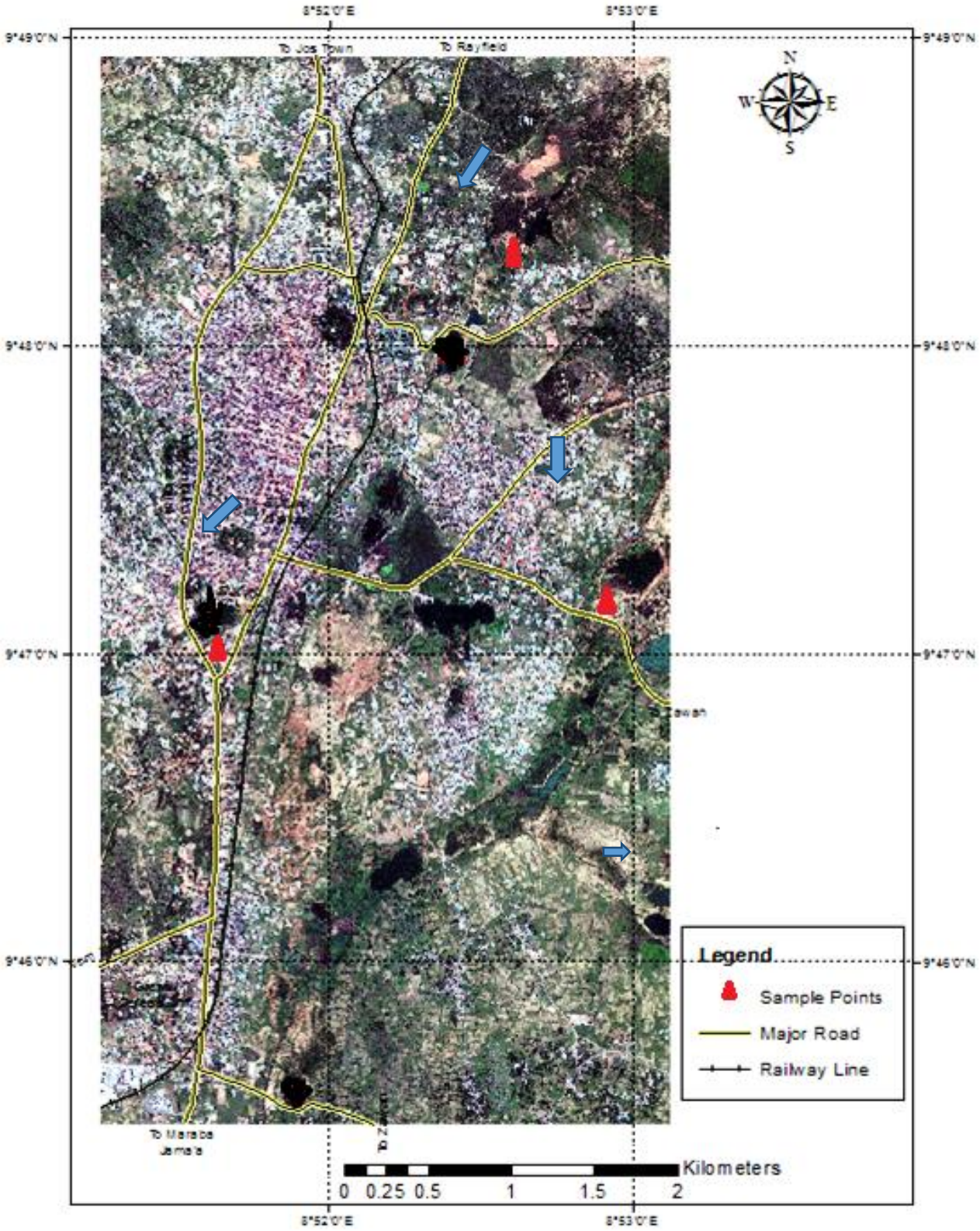

Figure 2: Bukuru Town showing water samples collection points
Source: Adapted from Google imagery (2014). Scale 1: 100, 000

Plate 2: Abandoned tin mine pond at Fwarti, Bukuru

The average pH recorded for Bukuru abandoned mine ponds was 7.75 and is within both the WHO (1993) and FEPA (2001) permissible pH range of 6.5 - 8.5 (Table 1). The values of organic carbon in Gyel, Rabi and Fwarti abandoned tin mine ponds were 1.28%, 1.71% and 0.02% respectively. Therefore mean value of Org. C for Bukuru abandoned tin mine ponds from the study was 1.0% (Table 1). The concentrations of dissolved solids in Gyel, Rabi and Fwarti abandoned tin mine ponds were 400 mgl^{-1}, 4200 $mgl^{-1}$and 1980 mgl^{-1}respectively. TDS value in Gyel abandoned tin mine pond was below WHO (1993) and FEPA (2001) permissible limits of 500 mgl^{-1}, while TDS for Rabi and Fwarti abandoned tin mine ponds have exceed the WHO (1993) and FEPA (2001) permissible limits of 500 mgl^{-1} (Table 1). The average Total Dissolved Solids (TDS) for Bukuru abandoned tin mine ponds was 2, 198 mgl^{-1}, which was above WHO (1993) and FEPA (2001) permissible limits of 500 mgl^{-1} (Table 1). Consequently Bukuru abandoned tin mine will require treatment for continuous irrigation and other domestic uses. The turbidity values for Gyel, Rabi and Fwarti abandoned tin mine ponds were 66 NTU, 23 NTU and 12 NTU respectively. The mean suspended particles in the

Table 1: Physicochemical Characteristics of Bukuru Abandoned Mine Ponds

Characteristics	Gyel (CTM)	Rabi	Fwarti	Mean	WHO (1993)	FEPA (2001)
Temperature (^{0}C)	23.3	22.9	23.3	23.27	NA	27-28^{0}C
pH	7.84	7.80	7.63	7.75	6.5-8.5	6.5-8.5
Organic C (%)	1.28	1.71	0.02	1.0	NA	NA
TDS (mgl^{-1})	400	4200	1980	2198	500	500
Turbidity (NTU)	66	23	12	33.67	5.0	5.0
Ec (mmhos/sec)	73	71	64	69.33	400-600	1000
Total Co_3^+ (mgl^{-1})	72	48	64	61.33	NA	100-200
Hardness (mgl^{-1})	1.4	10	1.5	4.3	50-250	500
P (mgl^{-1})	0.22	0.65	10.07	0.31	NA	NA
Total N (mgl^{-1})	0.02	0.02	0.12	0.05	NA	NA
Na^+ (%)	2.03	1.92	1.01	1.65	20	200
Ca^{2+}(mgl^{-1})	0.93	0.667	1.07	0.89	75	75
$N0_3^+$ (mgl^{-1})	7.53	4.87	2.21	4.87	45	50
$S0_4^+$ (mgl^{-1})	35	75	136	82	200	500
Cl^- (mgl^{-1})	48.85	35.53	22.65	35.67	200	100-200

WHO=World Health Organization; FEPA= Federal Environmental Protection Agency; Organic C=Organic Carbon; TDS=Total Dissolved Solids; NTU= Unit of measurement of Turbidity; Ec= Electrical Conductivity; CO_3^+=Carbonate; P=Phosphorus; =Na sodium; Ca=Calcium; $N0_3^+$=Nitrate; $S0_4^+$= Sulphate; Cl^- = Chloride; NA= Not available and mg/l= milligrams per liter

turbid waters of the three locations was 66 NTU. These turbidity values were higher than the established critical value of 5 NTU in all the three locations of Bukuru study area. (Table 1). The very high turbidity values for Bukuru abandoned tin mine ponds is attributed to the daily domestic use of the ponds for irrigation (Plate 1), fishing (Plate 3), and recreation (swimming), purposes. According to Nguen*et al.* (2010), suspended particles in turbid water higher than the 5 NTU critical

Plate 3: A fisherman checking his hooks at Rabi abandoned tin mine pond

limit becomes warmer thereby reducing the concentration of oxygen as a result of which some organisms cannot survive in the water. Bukuru abandoned tin mine ponds were not therefore, fit for domestic use because of high level of suspended solids. Electrical conductivity (EC) in Gyel, Rabi and Fwarti locations of Bukuru abandoned tin mine ponds were 73 mmhossec $^{-1}$, 71 mmhossec $^{-1}$ and 64 mmhossec $^{-1}$ respectively. Mean EC for the three locations was 69.33 mmhossec $^{-1}$. These EC values were below the WHO (1993) and FEPA (2001) permissible limits of 400 - 600 mmhossec $^{-1}$ and 1000 mmhossec $^{-1}$ respectively (Table 1). Therefore, irrigation with Bukuru abandoned tin mine ponds with Ec of less than 70 mmhossec $^{-1}$ from were considered non - problematic. The hardness of Gyel, Rabi and Fwarti locations of Bukuru abandoned tin mine ponds were 1.4 ml $^{-1}$, 10 mgl $^{-1}$ and 1.5 mgl $^{-1}$ respectively (Table 1). Hardness mean value for the three locations of the study area was 4.3 mgl $^{-1}$. These values were below the WHO (1993) and FEPA (2001) permissible limits of 50 - 250 mgl $^{-1}$ and 500 mgl $^{-1}$ respectively (Table 1). Toxicity of heavy metals and subsequent standards for aquatic life are said to be a function of hardness. In general as hardness increases, toxicity decreases (Alshaebi*et al.*2009). Therefore Bukuru abandoned tin mine ponds toxicity is low due to its low hardness. The values of total carbonate in Gyel, Rabi and Fwarti water samples from abandoned tin mine ponds were 72 mgl $^{-1}$, 48 mgl $^{-1}$ and 64 mgl $^{-1}$ respectively with a mean value of 69.33 mgl $^{-1}$ which was below FEPA (2001) critical limit of 100 - 200 mgl $^{-1}$ considered suitable for land application (Table 1). Therefore, Bukuru abandoned tin mine ponds when used for irrigation will not be problematic for drip or micro spray irrigation systems since total carbonate is low, consequently, low calcite or scales build up that could have reduced flow rates through orifices or emitters. The mean concentrations of Sodium ions ($Na^{+)}$ and Calcium ions ($Ca^{2+)}$ ions in Bukuru abandoned tin mine ponds were 1.65 mgl $^{-1}$ and 0.89 mgl $^{-1}$ respectively. These values were below the WHO (1993) and FEPA (2001) permissible limits of 200 mgl $^{-1}$ and 75 mgl $^{-1}$ respectively (Table 1). Similarly the mean concentrations of nitrates (NO_3^+), sulphates (SO_4^+) and chloride ($Cl^{-)}$ ions were 4.87 mgl $^{-1}$, 82 mgl $^{-1}$ and 35.67 mgl $^{-1}$ respectively, below WHO (1993) and FEPA (2001) permissible limits of 50 mgl $^{-1}$, 500 mgl $^{-1}$ and 100 - 200 mgl $^{-1}$ respectively (Table 1). This

implies that even though the use of Bukuru abandoned Tin mine water for irrigation will not pose immediate problem however, long term irrigation may be problematic due to salinity hazeards.

The values of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) in Bukuru abandoned tin mined ponds are presented in Table 2. Biochemical oxygen demand (BOD), measures the amount of oxygen consumed by microorganisms in decomposing organic matter in water. BOD also measures the chemical oxidation of inorganic matter i. e., the extraction of oxygen from water via chemical reaction (Swistock, 2017). Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen. Dissolved oxygen is reduced by the biological decay of organic material such as decaying plants and animals or animal and human wastes. BOD directly affects the amount of dissolved oxygen in water bodies, the greater the BOD, the more rapidly oxygen is depleted in the water bodies. This means less oxygen is available to higher forms of aquatic life. Therefore the consequences of high BOD are the same as low DO. The amount of oxygen that is dissolved in the water is critical for fish and other pond life. According to Swistock (2017), dissolved oxygen levels below about 6 mgl^{-1} can begin to have detrimental effects on pond life, suffocate and die. For Gyel and Fwarti locations the DO were 7.01 mgl^{-1} and 6.21 mgl^{-1} respectively, determined at 23.3 (^{0}C) for Gyel and 23.6 (^{0}C) for Fwarti. For Rabi location the DO was 10.12 mgl^{-1}determined at 22.9 (^{0}C). While DO was below their maximum critical limit of 8.56 mgl^{-1} for Gyel and 8.40 mgl^{-1} for Fwarti locations, it was above the maximum DO limit of 8.56 mgl^{-1} for Rabi (Table 2). Since DO of the three locations of Gyel, Rabi and Fwarti were greater than 6 mgl^{-1}critical limit. There was therefore, no threat to aquatic life due to insufficient oxygen in the abandoned tin mine pondsin the three locations of the study area.

Table 2: Dissolved Oxygen (DO) concentrations in Bukuru abandoned tin mine ponds

Location	Gyel	Rabi	Fwarti	Mean
Temperature (^{0}C)	23.3	22.9	23.3	23.27
BOD (mgl^{-1})	0.27	1.20	7.20	3.70
COD (mgl^{-1})	4.05	1.80	10.80	9.45
DO (mgl^{-1})	7.01	10.12	6.21	7.94
Max. DO (APHA, 1992)	8.56	8.56	8.40	
Min. DO (Swistock, 2017)	6	6	6	

BOD=Biochemical Oxygen Demand; COD=Chemical Oxygen Demand; DO = Dissolved oxygen; mg/l= milligrams per litter

Heavy metals concentrations in the Bukuru abandoned tin mine ponds are presented in Tables 3 and Figure 3. Nine heavy metals (Cu, Cd, Pb, Cr, Ni Co, Zn, Mn and Fe) were analyzed from the water samples collected for analysis, ouf of which only four were detected namely: Zinc (Zn), Copper (Cu), Manganese (Mn) and Iron (Fe). Their mean concentrations for the three locations were as follows: At Gyel location of the study area, Zn was 0.15 mgl^{-1}, Fe was 0.13 mgl^{-1} and Mn was 0.04 mgl^{-1}. Cu, Cd, Pb, Cr, Ni and Co were not detected in the pond water sampled from Gyel location. For the three metals detected their concentration were below WHO (2003) critical limit for drinking, FAO (1976) permissible limit for irrigation and FEPA (1999) guidelines for land application (Tables 3). Therefore, the abandoned tin mine pond at Gyel location was not found to be contaminated with any of these heavy metals.

At Rabi location Zn concentration in the abandoned tin mine pond was 0.03 mgl^{-1}, Cu was 0.002 mgl^{-1}, Fe was 0.67 mgl^{-1} while Mn was 0.002 mgl^{-1}. Pb, Cd, Cr, Ni and Co were not detected in the water samples analysed for this location. The mean values of all the heavy metals were also below their respective WHO (2003) critical limits for drinking, FAO (1976) critical limit for irrigation and FEPA (1999) guidelines for land application (Tables 3). Therefore, the abandoned tin mine pond at Rabi location was not found to be contaminated with any of the heavy metals analyzed.

At Fwarti location, the mean concentration of heavy metals determined in the abandoned tin mine pond were, Zn, 0.04 mgl^{-1}; Cu, 0.004 mgl^{-1}; Fe, 0.39 mgl^{-1} and Mn was 0.18 mgl^{-}. Therefore, Pb, Cd, Cr, Ni and Co were not detected in the water samples analysed, however, the mean values of all the heavy metals detected at this location were also below their respective WHO (2003) critical limit for drinking, FAO (1976) critical limit for irrigation and FEPA (1999) guidelines for land application (Table 3). Therefore, the abandoned tin mine pond at Fwarti location, was not found to be contaminated with any of the heavy metals analysed.

Table 3: Heavy Metals Concentrations of Bukuru Abandoned Tin Mine Ponds

Location /Heavy metal	Zn	Cu	Fe	Mn	Cd	Pb	Cr	Ni	Co
Gyel	0.15	0.00	0.13	0.04	0.00	0.00	0.00	0.00	0.00
Rabi	0.03	0.002	0.67	0.002	0.00	0.00	0.00	0.00	0.00
Fwarti	0.04	0.004	0.39	0.01	0.00	0.00	0.00	0.00	0.00
Grand Mean	0.073	0.002	0.39	0.017	0.00	0.00	0.00	0.00	0.00
WHO (2003)	2.00	0.20	1.00	0.10	0.01	0.05	0.10	0.20	NA
FAO (1976)	2.00	0.20	5.00	0.20	0.01	5.00	0.10	0.20	NA
FEPA (1999)	5.00	1.50	0.1 - 01.0	0.20	0.01	0.05	0.10	0.20	NA

WHO= World Health Organization; FAO = Food and Agricultural Organizations, FEPA=Federal Environmental Protection Agency; NA=Not Available

The highest mean concentration of heavy metal in Bukuru abandoned tin mine ponds was 0.67 mgl^{-1} for Iron (Fe) from Rabi abandoned tin mine pond followed by 0.15 mgl^{-1} for Zinc (Zn) from Gyel abandoned tin mine pond, and the order

from the highest concentration to the lowest was therefore, Fe>Zn>Mn>Cu (Figure 3). The total mean values of the four metals detected for the three locations of the study area were 0.03 mgl $^{-1}$ for zinc (Zn), 0.002 mgl $^{-1}$ for copper (Cu), 0.04 mgl $^{-1}$ for iron (Fe) and 0.18 mgl $^{-1}$, for manganese (Mn) (Table 3 and Figure 3). These mean values of the identified heavy metals in the abandoned tin mine ponds at Bukuru were below the WHO (2003) critical limit for drinking water, FAO (1976) permissible limit for irrigation and FEPA (1999) guidelines for land application (Tables 3). The results of this study have shown that the concentration of Fe, Zn, Mn and Cu were low, while Pb, Ni, Cr, Cd and Co were not detected in Bukuru abandoned tin mine ponds. The low metallic levels could be attributed to these factors:

1) low level of contaminants released to the environment
2) as a result of nearly absence of tin mining activities in Bukuru study area over the years.
3) low concentrations or absence of some of the heavy metals in the parent materials from which the soils were originally formed.

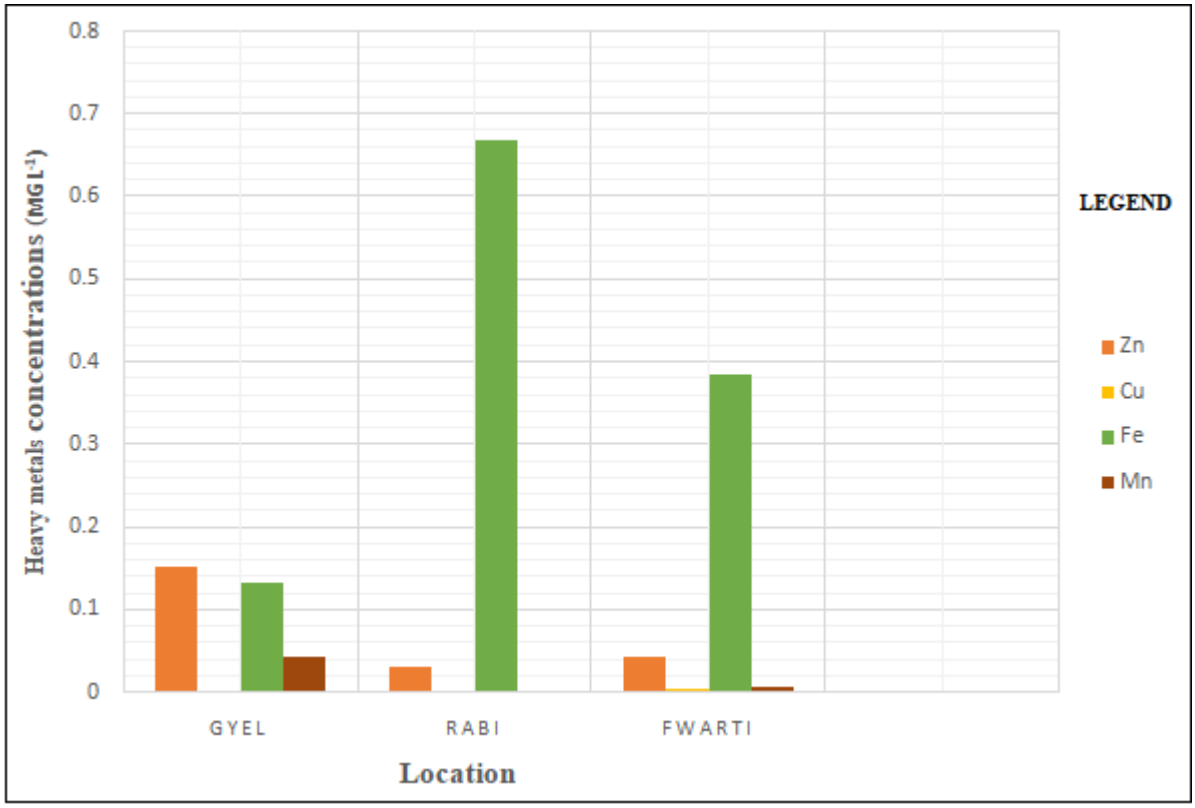

Figure 3: Heavy metals concentrations of Bukuru abandoned tin mine ponds

The result of this study is at variance with reports of previous studies by (Daniel *et al*.2014[a]), who reported that the concentrations of Pb, Cr, Ni and Cd exceeded FAO and WHO critical limits in waters of abandoned tin mine at Hiepang, Barkin - Ladi, NorthCentral Nigeria

4. Conclusion

This study investigated and assessed the suitability of Bukuru abandoned Tin mine ponds for irrigation agriculture in the three locations of Bukuru - Jos, North - Central Nigeria. . Water samples were collected in a sterilized container which was used for physicochemical characteristics and for determination of heavy metal concentrations using standard laboratory procedures. Results of water quality analysis revealed that the mean values of all the physicochemical properties analysed viz: Organic C, Ec, Total Co_3^{+-}, Hardness, P, Total N, Na^+, Ca^{2+}, NO_3^-, So_4^-, Cl^-, BOD, COD and DO values were all below their respective WHO (1993) and FEPA (2001) critical limits except for total dissolved solids (TDS) averaged 2, 198 mgkg $^{-1}$, above the WHO and FEPA critical limits of 500 mgkg $^{-1}$, and Turbidity had mean values of 33.67 NTU above the WHO and FEPA critical limits of 5 NTU. Dissolved Oxygen for Bukuru abandoned tin mine ponds determined at temperature of 23.3^{0}C was below the maximum DO limits of 8.35 mgl - 1 and above the minimum the critical DO limits of 6 mgl - ^{1}for aquatic life. Since the DO of the three locations of Bukuru study area were above the minimum critical DO limit of 6 mgl - ^{1}, there was therefore, no threat to aquatic life due to insufficient oxygen in the abandoned tin mine ponds of the Bukuru study area.

Results of heavy metal analyses from water samples of the abandoned tin mine ponds revealed only four of the heavy metals identified namely, Zn, Fe, Cu and Mn. However, the concentrations of these heavy metals were relatively low in Bukuru abandoned tin mine ponds, as they were below the WHO (2003) critical limit for drinking water, FAO (1976) permissible limit for irrigation and FEPA (199) guidelines for land application. Therefore Bukuru abandoned tin mine ponds were not contaminated with any of the heavy metals determined in the water samples. The result of this study is at variance with reports of previous studies on the abandoned tin mine ponds at Hiepang, BarkinLadi Local Government, and Plateau State.

Although Bukuru abandoned tin mine ponds were not contaminated with these heavy metals, however, the use of the water from the abandoned tin mine ponds for both domestic and irrigation purposes will require further treatment as the total dissolved solids (TDS) and turbidity values were far above WHO (1993) and FEPA (2001) threshold values and also due to salinity hazards in the long run.

5. Recommendations

Based on the results of this study, the following recommendations are made:

1) Although Bukuru abandoned tin mine ponds were not contaminated with any of the heavy metals determined, however, the use of the water from the abandoned tin mines for both domestic and irrigation purposes will require treatment as the total dissolved solids (TDS) and turbidity values were far above WHO (1993) and FEPA (2001) threshold values and also due to salinity hazards in the long run.
2) Government agencies responsible for monitoring activities of companies involved in mining operations should ensure that subsequent tin mining operations in Bukuru by such companies must adhere to international standard best practices in the exploitation and processing of tin in order to reduce to the barest minimum the negative impacts of their activities on the environment.

References

[1] Alshaebi, F. W., Yaacob, W. Z. W. and Samsudin, A. R. (2009). Risk assessment at Abandoned Tin Mine in Sungai, Lembing, Pahang, Malaysia/ *EGJE*.
[2] Annadale J. G., Jovanovic N. Z., Pretorious J. J. B,, Lorentz S. A. Rethman N. F. & Tanner P. D. (2001). Gypsiferous Mine Water Use in Irrigation on Rehabilitated Open Cast Land crop production, Water and Soil Balance. *Ecological Engineering* Vol.17, pp153 - 164
[3] APHA. (1992). *Standard methods for the examination of water and wastewater.18*th ed. American Public Health Association, Washington, DC.
[4] Association of Official Analytical Chemists: AOAC (1984). Official Methods of Analysis. Washington, DC.
[5] Brady and Weil (2010). Elements of the nature and properties of soils. Pearson Education Inc. New Jersy, pp.59, 94, 147 and 148.
[6] Daniel, V. N, Chudusu, E. S., Chup, J. A, and Pius, N. D. (2014) a. Variations of Heavy Metals in Agricultural Soils Irrigated with Tin Water in Heipang District of Barkin - Ladi, Plateau State, Nigeria. *International Journal of Science and Technology* Volume 3 No.5, IJST Publications UK. pp255
[7] Daniel, V. N, Chundusu, E. S and Chup, L. A. (2014) b. Heavy metals accumulation in Agricultural soils irrigated with Tin - Mine Water in B/Ladi Plateau State, Nigeria. *International Journal of Engineering and Technology IJET - IJENS*Vol: 14, (4), pp.69
[8] Ejila, J. N. and Daniel, V. W. (2011). Trace metal accumulation in fresh water and Sediments liberty Dam, Jos, *Plateau States International Journal of Dapia and Applied Sciences;* Vol. II (6), pp.128 - 140
[9] FEPA (1999). Federal Environmental Protection Agency. National Guidelines and Standards for water quality in Nigeria
[10] FEPA (2001). Guidelines and standards for Environmental Pollution control in Nigeria. Federal Environmental Protection Agency (FEPA) Nigeria
[11] Google Earth Imagery (2014). National Center for Remote Sensing, Jos, Nigeria
[12] Gwom S. L. (1992). The Berom Tribe of Plateau State Nigeria. First Edition. Jos. FabAnieh Nigeria Ltd., pp15
[13] Nguyen, L. T. H, Ohtsubo, M, Li Higeshi, T. and Kanagana, M. (2010). Heavy metal concentrations and availability of organic matter Rich River Sediment in Hanoi
[14] Swistock, B. (2017). (Interpreting water test for Ponds and Lakes). *PennState Extension*. The Pennsylvania State University, University Park, PA 16802. Retrieved; 4th November, 2017 ww. https: //extension. psu. edu/
[15] Weather Travel. (2012). Jos Climate and Weather Averages, Nigeria: *Journal of Soil Science and Environmental Management* Vol.3 (4), pp.77 - 83.
[16] WHO/UNEP. (1997). Water Pollution Control. A guide to the use of water Quality Management Principle, Case study IV - Nigeria, pp.14
[17] World Health Organization: WHO. (2003). Guidelines for Drinking Water Quality, (3rd Edition) WHO, Genera, Rome