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AN EVALUATION OF PHYSICO-CHEMICAL CHARACTERISTICS OF WATER FROM ABANDONED TIN MINE PONDS IN BUTURA, PLATEAU STATE, NORTH CENTRAL NIGERIA.

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ABSTRACT
Mining has had a negative impact on the environment including the creation of mine ponds that is detrimental to human health and water quality. This study aims at evaluating the physico-chemical characteristics of water in tin mine ponds in Butura, Plateau State, Nigeria. Water samples were collected during the dry season and analyzed for parameters such as color, appearance, odor, taste, temperature, electric conductivity, turbidity, total hardness, pH, total alkalinity, manganese (Mn), calcium (Ca), sodium (Na), iron (Fe), magnesium (Mg), chloride (Cl), fluoride (F), nitrate (NO_3), and microbial count using various analytical techniques. The results of the physico-chemical analysis revealed that electric conductivity (775 µS/cm), turbidity (196.7Ntu), total hardness (18.5Mg/l), pH (6.7), total alkalinity (265Mg/l), Mn (3.85Mg/l), Ca (58.35Mg/l), Na (6.75Mg/l), Fe (0.015Mg/l), Mg (85Mg/l), Cl (40.25Mg/l), F (0.015Mg/l), NO_3 (7.85Mg/l) are all within the World Health Organization (WHO) water quality permissible limit for consumption, except for parameters such as temperature, color, appearance, odor, turbidity and microbial count, which were over the recommended limits. The study concluded that the physico-chemical characteristics of water from the mine ponds is aberrant for consumption, which could be detrimental to humans. It is recommended that the mining pond water be properly treated before use as some of the contaminants are liable to be harmful to humans.

Keywords: ***B****okkos, Mining Pond, Physico-chemical, Tin Mining, Water quality.*

1. INTRODUCTION
Water is an important element of the environment required for life's survival and socio-economic growth (Ejigu, 2021). Surface and subsurface water systems are essential for domestic, agricultural, municipal, industrial, recreational, and other public purposes; thus, our daily lives depend on the availability and quality of water resources. Water quality determines the suitability of water for a particular purpose by describing the physical, chemical, and biological characteristics of the water (Vasistha & Ganguly, 2020; Chapman, 2021; Ejigu, 2021). Surface water quality is significantly impacted by numerous factors including mining and other forms of mineral exploration (Low, 2016; Awogbami, 2023; Dube, 2024; Suglo, 2024).
Mining, the extraction of naturally occurring minerals from the earth's crust, is regarded as the second oldest and most significant industry in the world after agriculture (Nukpezah, Rahman, & Koranteng, 2017). The World Mining Data annual analytical collection states that mining

activities took place in 171 countries in 2019 (Reichl, Schatz & Zsak, 2021). 17.9 billion tons of minerals were taken in total this year, 6.6 billion tons more than at the start of the twenty-first century. Numerous causes contribute to the annual increase in production growth rates, including the general advancement of technology (Litvinenko, 2020; Sánchez & Hartlieb, 2020) and the rising need for certain raw materials in order to transition to more ecologically friendly energy sources.

Generally speaking, mining is linked to inadequate environmental laws and regulations in most third world nations (Aldinger, 2013; Agboola et al., 2020; Kazapoe et al., 2023), with resultant contamination of both surface and subsurface water (Kumi, Adu-Poku, & Attiogbe, 2023; Dehkordi et al., 2024). Pollutants of concern are increased in organic waste, which is typically linked to crushing and other mining operations, and hazardous metals, which are difficult to remove from the environment (Agboola et al., 2020; Dehkordi et al., 2024).

In Nigeria, especially the Jos Plateau, the history of tin mining dates back to the colonial administration early in the 20th century (Onyeka, Chukwu, & Adebayo, 2024). This saw great success with tin mines, which produced financial gains, significantly aided in the industrialization of other countries and created numerous employment opportunities, particularly, in rural areas where there are limited formal sector jobs. Despite its economic importance for the region, state, and country overall, tin mining had negative social and environmental effects (Worlanyo & Jiangfeng, 2021). Butura district in Bokkos Local Government Area (LGA), is an extensively mined area characterized by deep excavations, high overburden, mine tailings, and slurry wash deposits. The extraction of underlying soil, known as deep mining, has produced abandoned mine ponds, which have become reservoirs of contaminants, posing risks to ecosystems and public health (Adegboye, 2012). Most of the mine ponds often contain high concentrations of heavy metals, suspended solids, and other pollutants, which can leach into nearby water sources. The type of pond and its exposure to different environmental conditions determine the quality of water from the tin mined ponds (Hedayatzadeh, 2024). Several studies (Gyang and Ashano, 2010; Adegboye, 2012; Mangdong et al., 2015; Mafuyai et al., 2020; Dalyop et al., 2024) on the impact of tin mining in Jos Plateau have been conducted. Despite the numerous researches and widespread dependence on these ponds, there is still limited empirical data on their physicochemical properties. Therefore, it is crucial to continually evaluate the water quality of the mine ponds to ensure the safety of humans and sustainability of water resources in mining-affected areas (Yasuor, Yermiyahu, & Ben-Gal, 2020; Amuah, Amanin-Ennin, & Antwi, 2022; Ashie et al., 2024). This study determines the physico-chemical parameters of the water from mining ponds in Butura, Bokkos LGA, Plateau State, Nigeria to ascertain their suitability for a variety of uses.

2. MATERIALS AND METHODS

2.1 Study Area

Butura lies between latitude 9°20′0” N and 9°25′0” N and longitude 8°52′30” E and 8°57′30” E in Bokkos Local Government Area (LGA) of Plateau State, north central Nigeria (Figure 1). The climate of the area is characterized by two distinct seasons (the wet and dry). The dry season which occurs during the Harmattan period (November to March), is characterized by the dry and dusty wind blowing from the Sahara Desert while the wet season starts from April to October. The mean minimum temperature is about 18°C while the maximum mean temperature is roughly 22°C (Wuyep et al., 2023). The area has an elevation of 1324m above mean sea level, and a mean rainfall of 1458 mm annually (Wuyep et al., 2022).

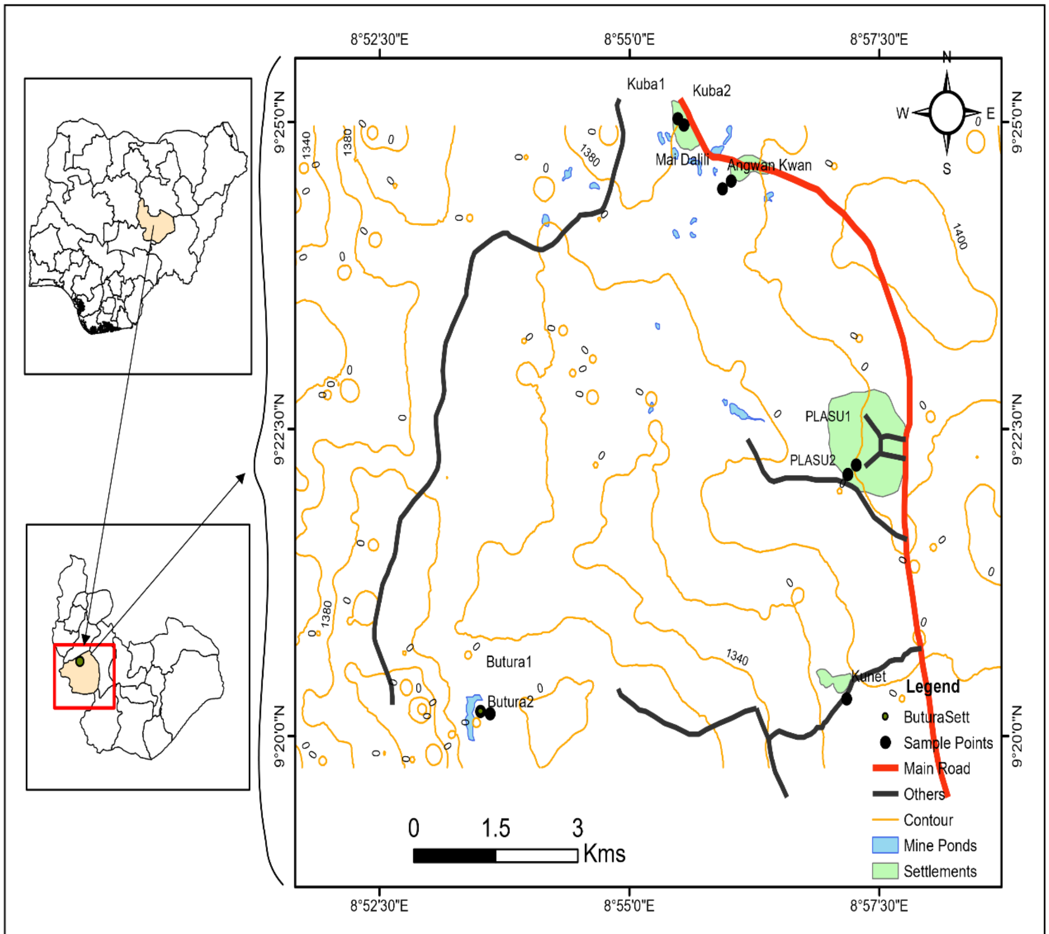

Figure 1: Study Area Map (Butura)

The geology is mostly underlain by basement complex rocks, which are the oldest rocks in the area and appear as small, widely scattered outcrops. It is located in Central Nigeria's granite complexes, which are one of the world's classic sites for ring complex occurrence (Gyang & Ashano, 2009). The geology of the study area is responsible for the deposits of tin ore and columbite, with numerous abandoned mine ponds due to tin mining activities. Soils of Butura are ferruginous with textural clay and subsurface horizon formed over biotype granite or gneiss (Dung-Gwom et al., 2009). The soil has moderate water holding capacity, low organic matter content and is leached intensely (Ogbole, Wuyep, Monday, Boilif, & Ocheri, 2024). The clayey soils have little fertility and are good for crop production. Agriculture is the main economic activity in Butura, with a variety of crops cultivated including tomatoes, cabbage, Irish potatoes, cucumber, and carrots.

2.2 Sample collection

Water samples were collected from the study areas using the standard analytical methods (APHA, 1998; Adefemi & Awokunmi, 2010). Six (6) water samples were collected at random from selected mine ponds, with a Global Positioning System (GPS) device utilized to get the exact locations of the sampling point (Table 1).

Table 1: Geographic Coordinates of Sampling Points

Location	Coordinates	Heights
Butura A	09.33691^{0}N 08.89108^{0}E	1365m
Butura B	09.33657^0 N 08.89271^{0}E	1368m
Kuba A	09.40781^0 N 08.93142^{0}E	1372m
Kuba B	09.41650^{0}N 08.92503^{0}E	1376m
Kuba C	09.41582^0 N 08.92547^{0}E	1375m
Mai Dalili	09.40781^0 N 08.93142^{0}E	1374m

One liter (1L) plastic bottles were lowered at each mine pond to obtain the desired quantity of water sample, samples were properly labeled, kept in ice boxes and afterwards transported to the laboratory for physicochemical analysis. The samples were collected in March 2023 during the dry season from each of the ponds and analyzed for heavy metals and water quality parameters using standard water analysis procedures as shown in Table 2.

Table 2: Analytical Procedures for Physicochemical Analysis

Parameters	Method	Unit of Measurement
CHEMICAL		
pH	PH Meter	
Total Alkalinity	Titrimetry	Mg/l
Total Hardness	Titrimetry	Mg/l
Magnesium	Titrimetry	Mg/l
Iron	Spectrometry	Mg/l
Calcium	Titrimetry	Mg/l
Manganese	Spectrometry	Mg/l
Chloride	Titrimetric	Mg/l
Fluoride	Spectrometry	Mg/l
Sodium	Titrimetric	Mg/l
Nitrate	Spectrometry	Mg/l
PHYSICAL		
Color	Photometry	Hazen
Taste	Comparative	-
Appearance	Visual	-
Turbidity	Turbidimeter	Ntu
Electric Conductivity	Conductivity Meter	µS/cm
Temperature	Thermometer	0C
MICROBIAL		
Total Coliform	Culture	CFU/100ML

2.3 Quality Control and Assurance

Quality control and assurance procedures were meticulously followed to verify that the results were free of mistakes. Analytical grade chemicals and distilled deionized water were utilized throughout the experiment. The precision and accuracy of the analysis were ensured using replicate analyses, which involved running the experiment on each sample three times using conventional analytical techniques.

3. RESULTS AND DISCUSSION

The water quality data from the study were compared to the permissible limits in the drinking water quality criteria established by the World Health Organization (WHO, 2011).

3.1 Chemical Parameters of Water Quality

The results of the chemical parameters for selected mine ponds in Butura, Bokkos LGA, Plateau State north central Nigeria, are all presented in Table 3. The table reveals that the mean pH is 6.7, which falls within the acceptable range of WHO (6.5-8.5). This result indicates that the water is slightly acidic to neutral. Values of pH above 7 are alkaline, 7 is neutral while those below 7.0 are acidic. The mild acidity of the water in the mining pond may result from the surplus minerals present in the geological soil caused by mining activities in the area (Jiya & Musa, 2012). Total alkalinity which measures the acid buffering capacity of water varies between 20 – 32 mg/L with a mean value of 26 mg/L. The highest value was found in Kuba A and the lowest obtained in Butura A respectively.

Table 3: Chemical and Biological Parameters of the Water Quality

Parameters	Butura A	Butura B	Kuba A	Kuba B	Kuba C	Mai Dalili	Mean Value	WHO(Permissible Limit)
pH	6.9	7	6	6.1	6.7	7.5	6.7	6.5-8.5
Total Hardness	22	10	24	21	8	26	18.5	100-500
Total Alkalinity	20	22	32	30	24	28	26	20-250
Calcium (Ca)	55	60	60	61	50	64	58.3	75
Magnesium (Mg)	10	7	7	8	8	8	8	20
Iron (Fe)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.1-0.3
Manganese (Mn)	10	0.01	7	6	0.01	0.01	3.8	0.01-0.3
Sodium (Na)	9	6	0.01	9	8	8	6.7	20-200
Chloride (Cl)	35.45	35.45	42.54	42.54	49.63	35.45	40.2	250
Fluoride (F)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.5-1.5
Nitrate (NO_3)	10	7	7	8	9	6	7.8	0-50
MICROBIAL								
Total Coliform	200/100ml	260/100ml	260/100ml	260/100ml	250/100ml	260/100ml	248.3/100ml	0/100ml
Chemical Oxygen Demand (COD	8.0	7.2	8.2	8.2	8.5	9.5	8.2	20
Dissolved Oxygen (DO)	7.3	7.6	7	7	7.5	7.4	7.3	12
Biological Oxygen Demand (BOD)	1.2	2	1.4	1.4	1.5	1.3	1.5	2

The total alkalinity obtained in this study is slightly higher than the value range (0.8 – 28.3 mg/L) documented by Lawal et al. (2014) at a mining site in Wase, Plateau state, Nigeria. The generally low alkalinity indicates that natural alkalinity is primarily caused by anthropogenic runoff and catchment geology. Bicarbonate, hydroxide, and carbonate levels are all likely low (Adesakin et al., 2017). The alkalinity of the water samples analyzed is within the allowable limit of WHO. The total hardness of tin mine pond water shows hardness ranges from 10 – 26 mg/L with a mean value of 18.5 mg/L (Table 3). The highest value was obtained in Mai Dalili and lowest in Butura B. The values of hardness in the mine water obtained in this study is lower than that reported by Mafuyai, Ayuba, & Zang, (2020) in Jos South Barkin Ladi and Bokkos mine ponds, Plateau State, Nigeria. Total hardness in water is mainly caused by high mineral content due to the presence of calcium and magnesium ions from the rock and soil in the area. The values in this research are thus, lower compared to the prescribed 500 mg/L WHO drinking water standard value. Calcium and Magnesium in the study area ranged between 50 – 64 and 7-10 mg/L with a mean value of 58.3 and 8 mg/L respectively (Table 3). The value of calcium is higher than the value of 83 and 138 mg/L obtained by Leppänen, Luoto & Weckström, (2019) in Talvivaara mine, Finland.

Table 3 shows the value of iron (Fe) obtained in the study area. A value of 0.01 mg/l was obtained in all the studied mining ponds. This result agrees with the range documented by Schaider et al. (2014), who reported a higher iron range of Fe (13 – 59 mg/L) in mining ponds Tar Creek, Lytle Creek. Even though iron is not explicitly regarded to be hazardous to humans, it is a required component of diet and there are no health-related guidelines (Musallam & Taher, 2018). This value obtained in this study is below the WHO permissible limit of 0.01 mg/l. Similarly, Table 3 reveals that Manganese (Mn) ranges between 0.01 and 10 mg/L with a mean value of 3.8 mg/L while Sodium (Na) varied from 0.01 to 9 mg/L with an average of 6.7 mg/L. Manganese, an essential trace element could be dangerous even if they are necessary for living, thus deficiencies and excesses can have negative consequences on people's health (Neculita & Rosa, 2019). On the other hand, burnt ashes that are washed and released into mining ponds could be the cause of the sodium in the water (Mafuyai et al., 2020). The concentration of Sodium (Na) obtained in this research is lower than the value of 48.0 mg/L documented by Low et al. (2016) in Mysore City Karnataka and higher than the value of 1.45 – 5.26 mg/L obtained by Hussain et al. (2010). Thus, sodium concentrations of the studied mine ponds water were far below the WHO allowable limits of 200 mg/L by the WHO.

Nitrate (NO_3) ranges between 7 and 10 mg/L with mean concentration of 7.8 mg/L (table 3). The value falls within the permissible limits of the WHO (50 mg/L). The presence of nitrate in the water bodies could be attributed to surface runoff or leaching from nearby farms' soils, indicating the application of nitrogen fertilizer on farmlands (Nukpezah, Rahman and Koranteng, 2017). Water bodies with high nitrate levels can lead to excessive vegetative growth, poor fruit quality, and delayed maturation in crops (Alam et al., 2021). Similarly, human feces washed into water bodies could also influence the concentration of nitrogen in the water, which may lead to excessive Biological Oxygen Demand (BOD) in the mining pond water (Nartey, Hayford & Ametsi, 2012). Chloride (Cl) and Fluoride (F) had mean values 40.2 and 0.01 mg/L (table 3). The chloride value obtained is lower compared to the 124.4 mg/L and 98.7 mg/L stated by Osuocha et al. (2016) in Ishiagu and Daniel et al. (2014) in Barkin-Ladi mining pond, Nigeria respectively. Chloride contents in the mine ponds are within the WHO acceptable range. All the mining pond water in terms of chloride quality is good and can be considered for use in irrigation together with other satisfactory characteristics without any restrictions. Similarly, Fluoride is derived from geologic sources (Ghosh et al., 2013) nonetheless, a minimum fluoride level is required for healthy teeth. However, a larger amount of fluoride may cause pitting and staining in teeth, difficulties in both bones and joints, and yellowing of teeth (Gupta, Gupta & Chhabra, 2016; Lubojanski et al., 2023). The fluoride value obtained is within the standard limit of WHO.

3.2 Microbial Parameters of Water Quality

The microbial counts in the mining ponds is presented in Table 3. The total number of microbial counts had a mean value of 248.3 cfu. Rainfall-induced runoff from the environment can increase the microbial burden, notably coliforms in water (Tryland et al., 2011), resulting in higher bacterial counts than the WHO permissible amount of 100 ml. This study supports the findings of Rochelle-Newall et al. (2016) and Blaustein, (2014). The excessively high total

heterotrophic bacterial load in the water suggested the existence of potentially hazardous pathogens. Similarly, Biochemical oxygen demand (BOD), which is the amount of oxygen required by bacteria and other microorganisms to digest and change organic materials found in wastewater under aerobic circumstances, ranges between 1.2 and 2 mg/L (Table 4). From the results presented, it is observed that the highest BOD was found in Butura B and lowest in Butura A. A mean value of 1.5 mg/L. High amount of BOD in the mining pond water also suggested that there was an excessive quantity of bacteria in the water, which absorbed the dissolved oxygen (Low et al. 2016; Koki, 2017; Herafi, Lingga & Kurniawan, 2022)
In addition, Dissolved Oxygen (DO) had a mean of 7.3, a value lower than the required 12 mg/L. A suggestion that the water from the mine ponds could cause diseases in crops or might be toxic for aquatic life since DO is important for most chemical and biological processes in water bodies.
Furthermore, Chemical Oxygen Demand (COD) varies from 8 – 9.5 mg/L, with a mean value of 8.2 mg/L. This value is lower than the range of 24.4 to 26.7 mg/L obtained by Dalyop et al. (2024) and also lower than the allowable limit given by WHO. COD is a measure of the oxygen equal to the fraction of organic matter contained in the wastewater sample that is susceptible to oxidation by oxidizing agents.

3.3 Physical Parameters of Water Quality

The result in Table 4 shows the values of the physical parameters of the studied mine ponds. The the appearance and odor of the water samples did not meet the WHO standard. This suggests that the water has impurities and also has dissolved gases, inorganic chemicals, and organic components.

Table 4: Physical parameters of the water

Parameter	Temperature	Taste	Odor	Appearance	Color	Turbidity	Electric Conductivity
Butura A	22.3	UO	O	O	40	96.4	800
Butura B	22.3	UO	O	O	16	8.50	750
Kuba A		UO	O	O	50	489	750
Kuba B	22.3	UO	O	O	50	489	750
Kuba C	22.3	UO	O	O	30	21.7	850
Mai Dalili	22.3	UO	O	O	25	75.5	750
Mean Value	22.3	UO	O	O	35.1	196.7	775
WHO	25-30	UO	UO	UO	15	5	1000

UO = Unobjectionable
O = Objectionable

Average temperature of the study area was 22.30°C (Table 4), this falls within the standard allowable limits of the WHO. This value is lower than that reported by Kazi et al. (2009) and Dalyop et al., (2024), who obtained temperatures ranging from 26–310°C and 24-27^{0}C respectively from surface water bodies in Nigeria. The sample had color values ranging from 16 – 40 Hazen with a mean value of 35.1 Hazen, which is above the WHO allowable limit of 15 Hazen. This could be caused by contaminants from mining activities in the area, as well as decomposing organic waste (vegetation) or inorganic debris. Electrical Conductivity (EC) values of mining pond water vary between 750 and 800 μScm^{-1}), with a mean value of 775 μScm^{-1}. Several research (Low et al., 2016; Mafuyai & Ayuba, 2020; Terakulsatit et al., 2024; Aluwong et al., 2024; Dalyop et al., 2024) found significant variation in electrical conductivity compared to the values observed in this work. Difference in the EC obtained by the scholars may be attributable to the parent rock materials (Parkhomenko, 2012). The values of EC obtained from the study area are slightly lower than the findings of Dalyop et al., (2024). The EC values obtained show that the water from the mine ponds will not cause soil salinity problems in the future, and they are within the safe limit established by WHO/FAO. The mean turbidity value of 196.7 Ntu obtained from Table 4 in this study was greater than the recommended standard for WHO. High turbidity levels indicate higher amounts of particulate matter such as silt, clay, and organic components and other contaminants in the mine pond that have reduced water clarity and are mostly caused by artisanal miners' continuous illegal mining operations in the surrounding area.

4. CONCLUSION

This study evaluated the physicochemical characteristics of water from the mine ponds in Butura, Bokkos LGA, Plateau State, Nigeria, providing information on the water quality of the ponds and its suitability for human consumption. The results revealed that some of the physical, chemical and biological parameters of all the analyzed water samples are within WHO guideline limit for water consumption and irrigation except for color, appearance, odor, turbidity and microbial count, which were over the suggested limits. Overall, the study concluded that the physicochemical characteristics of water from the mine ponds is aberrant for consumption, which could be detrimental to humans.

5. RECOMMENDATIONS

The study therefore recommends that the mining pond water should be used with caution as some of the water quality parameters are liable to be harmful to the humans' health.

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