

Assessment of the Physicochemical Properties of Water in Tin Mining Ponds on the Jos Plateau, Nigeria: Prospect for Municipal Clean Water Supply

¹Daniel D. Dalyop, ¹Wuyep S. Zitta, ¹Bioltif Y. Edward, ²Selzing P. Musa and ³Larai Beka

¹Plateau State University, Bokokos.

²Montane Forest Research Station Jos, Plateau State Forestry Research Institute of Nigeria, (FRIN).

³National Environmental Standards and Regulations Enforcement Agency (NESREA), Jos.

Corresponding author: wuyepsol@gmail.com

Doi: <https://doi.org/10.5281/zenodo.13769615>

Abstract

The global problem in water resources management is finding new and reliable sources of water. The utility of water is limited by its quality and accessibility, which makes it suitable or unsuitable for a variety of uses. Assessment of water quality is therefore an important aspect of water resource evaluation. Various analytical procedures were used to analyze the appearance, taste, electric conductivity, temperature, turbidity, color, odor, pH, total hardness, total alkalinity, calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), sodium (Na) chloride (Cl), fluoride (F), nitrate (NO₂), microbial, cadmium (Cd), cobalt (Co), nickel (Ni), lead (Pb), zinc (Zn), copper (Cu), chromium (Cr) and arsenic (Ar) contents, which were all measured during the dry season. The results were compared with water quality standards established by the World Health Organization (WHO) and the National Environmental Standards and Regulations Enforcement Agency (NESREA). Based on these findings, the appearance, color, taste, odor, electrical conductivity, turbidity, iron (Fe), lead (Pb), arsenic (Ar), total coliform and E. coli concentrations are above the WHO and NESREA limits. The utilization of mining ponds for a sustainable water supply offers benefits, including increased water security, minimized environmental impact and reduced water costs. It is recommended that mining ponds undergo proper treatment and further purification before being utilized for domestic purposes.

Keywords: Water, Tin Mining, Physicochemical, Mining Pond, Supply

INTRODUCTION

Although 70% of the Earth is covered with water, only a small percentage approximately 0.3% is actually usable by humans, and only a fraction is available for drinking globally (Yan and Bai, 2016; Kausley et al., 2019). This water comprises inland seas (0.008%), groundwater (0.279%), freshwater and lakes (0.009%), soil moisture (0.005%), rivers (0.0001%), the atmosphere (0.001%), and other sources, such as the ocean (97.2%), glaciers, and other ice (2.15%) (Bibi, Khan and Nazir, 2016). Water is necessary for human nutrition, either directly as drinking water or indirectly as a component of food and is used in a variety of other daily activities (Adesakina, et al., 2020). Identifying new and dependable sources of water is a global issue in the management of water resources and is vital in any society (Garba et al., 2019). The demand for water is significantly increasing in many countries across the world for a variety of reasons, including the rise of populations, improvements in

living standards, and prosperous economies (Umeh et al. 2005; Kazi et al., 2009; Mafuyai, Ayuba and Zang, 2020).

Water shortages are among the most pressing problems in the world (United Nations, 2022). Water is an important resource; hence it needs to be protected from pollutants (Megersa, Beyene, Ambelu and Woldeab, 2014; WHO, 2017). Many people in developing nations, mostly in Africa, do not have access to potable water; they are forced to use untreated water for drinking and other household uses from sources such as springs, reservoirs, streams, groundwater, and rivers (Jamielson, Gordon, Joy, and Lee, 2004; Gongden and Lohdip, 2015). Insufficient water supplies in Nigeria are causing problems that endanger the health of approximately 40 million people. Studies indicate that addressing ground and surface water contamination would be quite costly if it continues (Raji and Ibrahim, 2011; Adesakin, et al., 2020).

Water quality is a vital component of human existence that describes the physical, chemical, and biological qualities of water and whether or not it is suitable for a certain use (Jabbo, Gin, Ogezi and Dass, 2011). The quality and accessibility of water determine its usefulness and whether it is appropriate or inappropriate for a certain purpose (Offodile, 2002; Ashraf, Maah and Yusoff, 2011; Bisimwa, Amisi, Bamawa, Muhaya and Kankonda, 2022). When assessing whether water is suitable for drinking, farming, industry, or other household applications, water quality is important (Jabbo, Gin, Ogezi and Dass, 2011). Environmental factors such as geochemistry, geological processes, and hydrological characteristics of water sources have a tremendous influence on water quality (Rahman, Islam, Hossain and Ahsan, 2012; Zhang, et al., 2023). Contaminated water containing heavy metal ions, including Cr, Cd, Pb, As, Hg, Ni and Cu, can lead to human health problems, such as liver failure, kidney damage, stomach and skin cancer, mental disorders, and negative effects on reproductive systems (Orisakwe, 2014; Zhang, et al., 2023). Compared to the water quality set by the Federal Ministry of Water Resources (FMWR) of Nigeria, the physical and chemical parameters of Lake Ogezi have been quantified from the analysis that the values of the three stations (25.6, 27.8°C) are below the Federal standard limit (0.05). The chemical oxygen demand (COD) varied from 24.4 to 26.7 mg/L with only station 3 showing statistically significant month-to-month variations ($P=0.01$). At Stations 1 and 2, potassium levels (2.6–4.3 mg L⁻¹) varied significantly between the months ($P=0.01$). At station 3, there were substantial differences in sodium levels (1.3–2.5 mg L⁻¹), which were below the standard limit (200 mg L⁻¹) ($P = 0.03$; Environment Agency (EA), 2019).

Following tin's discovery in 1903, the Jos Plateau emerged as a significant global leader in tin production and export, with tons of increase recorded annually (Garba, et al., 2019). In addition to tin, solid minerals such as quartz, wolframite, zircon, monazite, and columbite were also mined (National Bureau of Statistics, 2015). This has substantially contributed to the industrial growth of numerous nations worldwide. However, during mining activities on the Jos Plateau, there was need for proper environmental enforcement. Due to the

negligence to do that previously leads to environmental degradation. However, degradation of the environment and the formation of water-filled ponds resulted from this process. These mining ponds have turned into water reservoirs that can supply water from municipal sources when mining has ceased.

It is important to note that historians and academics who have conducted related studies have given great amounts of attention to colonial tin mining exploration and exploitation on the Jos Plateau. Their research has focused a great deal on the larger issues of forced proletarianization, its influence on precolonial religion and customs, its impact on labor migration, the role of women and children in tin mining, and the reclamation of abandoned ponds. However, there are no records on the microbiological content or water quality status of Jos Plateau mining ponds. Therefore, the main goal of this study was to evaluate the water quality of samples taken from various ponds in the study area and to analyze the physicochemical properties of the water as well as the microbiological content of the water in the mining ponds.

MATERIALS AND METHODS

Study Area

The Jos Plateau is in Plateau state, north central Nigeria, between 10°30' and 09°00'N and 09°30' and 08°30'E. It has an estimated population of 1,365,400. Jos city serves as the Capital of Plateau state and is situated at an elevation of approximately 1,280 meters above sea level, with several granite hills and outcroppings that occasionally reach an additional 300 meters above sea level (Garba et al., 2019). Jos is made up of younger granite that was formed by volcanic eruptions. The region is known for its rocky, flat-topped hills.

Jos was a significant hub for tin mining under British colonial control. For about 60 years, tin was mined in Jos (Majekodunmi, et al., 2014). According to Haruna (2012), of the 8,689 km² that Jos covers, the total land area that has been impacted by mining activities is 325 km². The Jos Plateau is now primarily grassland and is a densely populated, heavily farmed region (Majekodunmi, et al., 2014). The area is thought to be the northern Guinea savanna, but because of the abundant tin, columbite, and tantalite resources nearby, numerous, dispersed mining activities have seriously disrupted the natural vegetation (Keay, 1969). There are two

different seasons in the climate: wet and dry. The dry season runs from November to April, whereas the wet season lasts six months, from May to October. With a mean temperature of almost 22°C, the average annual rainfall total is approximately 1200 mm (Binbol, Oche, Eziashi and Choji, 2016; Wuyep, Rampedi and Ifegbesan, 2021). The study covers three (3) local government areas where

colonial tin mining took place for approximately sixty years. The local government areas are Jos South, Barkin Ladi and Bokkos (Figure 1). These areas were carefully selected because they have large deposits of tin ore and columbite, and the majority of tin mining activities were hosted there with widespread abandoned tin mining ponds.

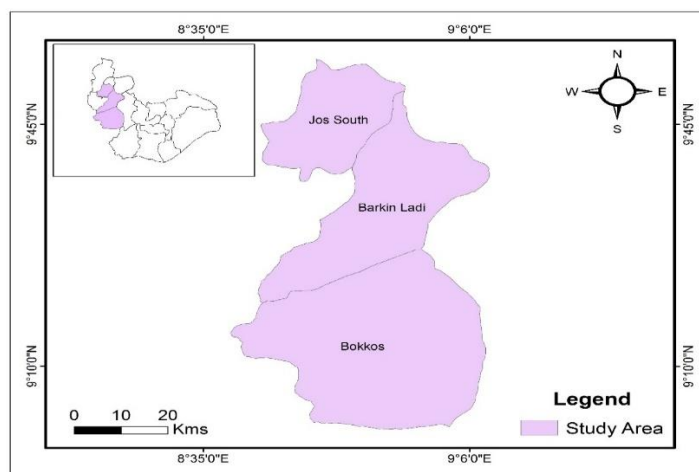


Figure 1 Study Area

Sample Collection

A total of fifteen (15) samples were randomly selected in the study area. A global positioning

system (GPS) device was used to obtain the exact locations of the samples during samples collection (Table 2).

Table 2: Coordinates of Sample Collection Points

Location	Coordinates	Height (m)
Kwang	09.84138N; 008.92425E	1308
Rayfield	09.83881N; 008.92094E	1297
Yelwa club	09.80188N; 008.87444E	1272
Gura Top	09.818880N; 008.90379E	1298
Opposite New Government house	09.82430N; 008.88004E	1247
Butura 1	09.33691N; 008.89108E	1365
Butura 2	09.33657N; 008.89271E	1368
Angwan Kwano	09.40888N; 008.93291E	1364
Mai Dalili	09.40781N; 008.93142E	1372
Kuba 1	09.41731N; 008.92402E	1384
Kuba 2	09.41650N; 008.92503E	1376
Barkin Ladi 1	09.50414 N; 008.91264E	1290
Barkin Ladi 2	09.56480 N; 008.90617E	1295
Barkin Ladi 3	09.53909 N; 008.90207E	1286
Barkin Ladi	09.69492 N; 008.88571E	1239

Several physicochemical properties of water were tested (Figure 2). Samples were collected in 1000 ml sterilized plastic bottles, and

100 ml sampling bottles were used for bacterial analysis. Samples were labeled appropriately, kept in a cooler with an icebox to maintain a stable

temperature of 40°C, and then promptly transported to the laboratory for analysis. All samples were measured using standard techniques and sufficient quality control measures (Table 1).

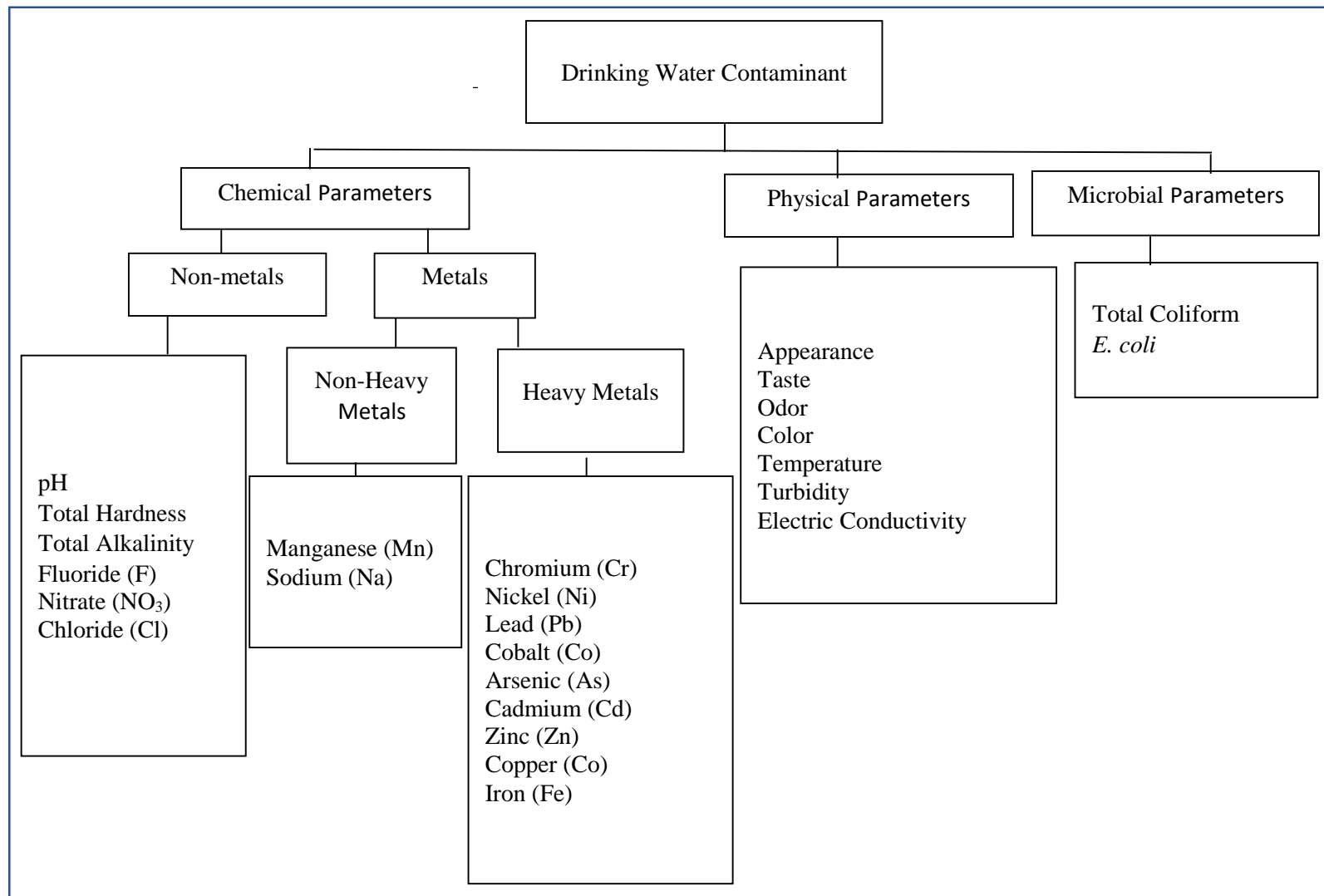


Figure 2 Physicochemical Properties of Water Samples Tested

Table 1: Analytical procedures for physicochemical analysis

Parameter	Unit Measured	Method Used
PHYSICAL		
Appearance	-	Visual
Taste	-	Comparative
Electric Conductivity	µS/cm	Conductivity Meter
Temperature	°C	Thermometer
Turbidity	Ntu	Turbidimeter
Color	Hazen	photometric
Odor	Comparative	-
CHEMICAL		
pH	-	PH Meter
Total Hardness	Mg/l	Titrimetric
Total Alkalinity	Mg/l	Titrimetric
Calcium	Mg/l	Titrimetric
Magnesium	Mg/l	Titrimetric
Iron	Mg/l	spectrometric
Manganese	Mg/l	spectrometric
Sodium	Mg/l	Titrimetric
Chloride	Mg/l	Titrimetric
Fluoride	Mg/l	Spectrometric
Nitrate	Mg/l	Spectrometric
Microbial	CFU/100ML	Culture
Total Coliform		
<i>E. Coli</i>		
HEAVY METALS		
Cadmium	Mg/l	Spectrometric
Cobalt	Mg/l	Spectrometric
Nickel	Mg/l	Spectrometric
Lead	Mg/l	Spectrometric
Zinc	Mg/l	Spectrometric
Copper	Mg/l	Spectrometric
Chromium	Mg/l	Spectrometric
Arsenic	Mg/l	Spectrometric

RESULTS AND DISCUSSION

The study's observations on water quality were compared with the National Environmental Standards and Regulation Enforcement Agency (NESREA) and World Health Organization (WHO) (2011) acceptable levels in the guidelines for drinking water quality.

Physical Parameters of the Water

The results of the appearance presented in Table 3 and Figure 3 show that the water does not appear clean, which indicates that it has impurities. Table 3 shows that the water has a taste and odor, which indicates the presence of dissolved gases, inorganic chemicals, and organic components. This difference may be from domestic, natural or agricultural

sources. The analysis revealed that the color of the water had a mean value of 51 Hazen, which is above the NESREA standard of 15 Hazen. This is due to pollutants from artisanal mining around the ponds, as well as decomposing organic waste (vegetation) or inorganic matter (rocks or soil). Binnie, Kimber and Thomas (2018) stated that the physical characteristics of water are impacted by the presence of suspended solids and physical pollutants such as dirt, silt, clay, or organic matter. These compounds may impact odor, color, and turbidity. Suspended solids include dirt, dust, silt, clay, algae, and any undissolved particles larger than 2 mm. They can cause color and turbidity, and harbor infections and other contaminants hazardous to human health (CDC, 2020).

Table 3: Physical parameters of the water

Parameter	Barkin Ladi	Jos South	Bokkos	Mean Value	NESREA (Permissible Limit)	WHO (Permissible Limit)
Appearance	UO	UO	UO	UO	UO	UO
Taste	UO	UO	UO	UO	UO	UO
Odor	UO	UO	UO	UO	UO	UO
Color	50	52	52	51	15	-
Temperature	27.3	25.1	27.4	26.6	25-30°C	25-30°C
Turbidity	7	12	13	10.7	0-5	5.0
Electric Conductivity	1008	1007	1017	1010	1000	1000

UO = Unobjectionable



Figure 3: Mining ponds on the Jos Plateau

One of the most important physicochemical factors for determining the quality of water for human consumption is temperature. It also affects a variety of activities in water bodies, including the rate at which chemical reactions occur, the solubility of gases, and the amplification of tastes and colors in the water (WHO, 2008). The mean temperature was 26.60°C (Table 3), which shows that the water temperature observed during the period of study was within the standard permissible limits of the WHO (2011) and NESREA. The results obtained

from the mining ponds were similar to those of Kazi et al. (2009), who recorded water temperatures ranging from 26–310°C from surface water bodies in Nigeria.

The mean turbidity value of 10.7Ntu obtained from Table 3 in this study was greater than the recommended standard for both the NESREA and the WHO. High turbidity levels signify increased concentrations of silt, clay, and organic elements inside the ponds. However, higher values might be a sign of particulate matter, such as clay or

silt; organic matter that has broken down; and other pollutants that have lowered water transparency and are caused by artisanal miners' ongoing illicit mining operations in the vicinity. Turbidity levels increase due to runoff into several open ponds carrying impurities (Mafuyai et al., 2019). A high turbidity indicates how well germs are filtered out. Nonetheless, a high level of turbidity could be the source of the bacteria. Moreover, viruses can cause harmful effects when turbidity levels are high (Shah, Arjunan, Baroutaji and Zakharova, 2023). These results further corroborate the findings of Garba et al. (2019) that the turbidity level found in every sample of water taken in Jos is greater than what Nigeria's water quality regulations allow.

The samples analyzed in the study area had a mean electrical conductivity of 1010 $\mu\text{S}/\text{cm}$ (Table 3). This value is above the maximum permissible limit set by the WHO and NESREA standards (1000 $\mu\text{S}/\text{cm}$). Electrical conductivity (EC) measures how well a sample of water can carry or conduct electrical currents. A high conductivity indicates a high pollutant content, which has a profound effect on taste and, in turn, influences the user's acceptance of the water. The conductivity increases with temperature and salinity, which may be detrimental to the quality of the water. This is

because the more contaminants (dissolved materials, chemicals, and minerals) are present in the water, the higher the conductivity. These findings corroborate the findings of Emumejaye and Daniel (2015) in Oleh, Delta State and Gongden and Lohdip (2015) in the Nagani/Wubang Dam in the Langtang South Plateau State, where they discovered that the electrical conductivity of water was greater.

Chemical Parameters of Water Quality

The relevance of the hydrogen ion concentration (pH) in water is clear in the method by which it impacts chemical processes and biological activities that occur only within a restricted range. Table 4 shows that the pH of the water is 7, which is within the permissible limits of NESREA and the WHO (2011) (6.5-8.5). This is an indication that the water is neutral. Any readings below 7.0 are acidic, while those above 7.0 are alkaline. These findings are in agreement with those of Shittu, Olaitan and Amusa (2008), who reported a similar range of pH values for water used for drinking purposes in Abeokuta, Nigeria. A pH less than 6.5 is regarded as excessive acid for human consumption and may lead to acidosis. Additionally, low pH can exacerbate the toxicity of heavy metals in water bodies.

Table 4: Chemical parameters of the water quality

Parameter	Barkin Ladi	Jos South	Bokkos	Mean Value	NESREA (Permissible Limit)	WHO (Permissible Limit)
pH	7.6	6.9	6.5	7	6.5-8.5	6.5-8.5
Total Hardness	260	278	408	315	100-500	100-500
Total Alkalinity	197	189	154	180	20-200	20-250
Fluoride (F)	0.7	1	0.2	0.6	0.5-1.5	0.5-1.5
Nitrate (NO_3)	47	23	39	36.3	0-50	50
Chloride (Cl)	211	192	79	160.7	50-250	250
Iron (Fe)	1.1	0.2	0.2	0.5	0.1-03	0.1-3
Manganese (Mn)	0.001	0.001	0.1	0.03	0.01-0.3	0.1-0.4
Sodium (Na)	113	184	177	158	20-200	200
Microbial						
i. Total Coliform	118	130	124	124	100 ml	100 ml
ii. E. Coli	124	135	112	123.7	100 ml	100 ml

The pH value range was 6.2–6.7 (6.40 0.11), indicating that the water was slightly acidic. Table 4 shows that the mean total hardness is 315 mg/l, which is within the permissible limits of the WHO and NESREA standards (100-500 mg/l).

These findings agree with the results of Lawal, Lohdip and Egila (2014) for the Kampani mining river in Nigeria (317.3 mg/L). Although hard water does not present a health risk, using it for other household tasks constitutes a nuisance, such as

household cleaning. These findings are similar to the results recorded by Ufodike, Kwanasie and Chude (2001) from Dokowa Mining Lake. Hardness is an important factor in lessening the negative effects of toxic substances. Water becomes more contaminated and harder as calcium and magnesium salts pollute it (Bhatt et al. 1999). Total hardness occurs when water contains a high amount of minerals. This is mainly caused by the presence of calcium and magnesium ions, which enter water from soil and rock.

The total alkalinity is a measure of the acid buffering capacity of water. It is the sum of the amounts of bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and hydroxides (OH^-) in water. As shown in Table 4, the total mean alkalinity was 180 mg/l in the study area. This value is within the stipulated permissible limits of the WHO and NESREA for drinking water. These findings agreed with the range documented by Moyle (2009) for natural water bodies. The low alkalinity suggested that anthropogenic runoff and the catchment geology are the primary sources of natural alkalinity and that the alkalinity level is likely low for bicarbonate, hydroxide, and carbonate (Dhameja, 2012). Similarly, the mean concentration found in the mining ponds was 0.6 mg/l (Table 4), which is within the permissible limits of both the NESREA and WHO limits (0.5-1.5 mg/l). The fluoride comes from geologic sources; nevertheless, minimum fluoride level is essential for good teeth. However, a greater quantity of fluoride may cause pitting and staining in teeth, problems in both bones and joints and discoloration of teeth (Kausley, et al., 2019).

Conversely, the mean nitrate (NO_3^-) concentration (36.3) was within the permissible limits of the WHO and NESREA (10-50 mg/l). The water nitrate content could be the result of surface runoff or leaching from nearby farm soils, indicating that farmers are using nitrogen fertilizer. Furthermore, defecation by miners and farmers along water banks may also affect the nitrogen content of water, which could contribute to the high BOD of mining pond water. Blue baby syndrome or methemoglobinemia may result from high levels of these viruses (CAWST, 2009). Additionally, the high consumption of nitrates by infants in water for an extended period of time without treatment may lead to death if not treated (Environment Agency (EA), 2019). Similarly, the mean chloride (Cl) concentration in Table 4 was 160.7 mg/l in the study

area. The chloride concentrations in mine water are within the prescribed limits of the WHO and NESREA 50-250 mg/l. Studies show that kidney function may be affected by excessive chloride in water (CAWST, 2009).

Table 4 shows the amount of iron (Fe) recorded in the study area. A mean value of 0.5 mg/l was obtained from the mining ponds. These values are above the WHO and NESREA standards of 0.1-0.3 mg/l. Although iron is not directly thought to be harmful to human, it is a necessary component of nutrition and does not have any health-related recommendations (CAWST, 2009). A high quantity of iron may cause taste complications (Gray, 1999). This finding agrees with the range documented by Garba et al. (2019), who reported a similar range for Fe in mining ponds around the University of Jos, Nigeria. Iron concentrations of 0.38-0.4 mg/l and 0.31 mg/l are higher than the maximum permissible level of 0.3 mg/l recorded from mining ponds and stream water, respectively.

Manganese is one of the three hazardous essential trace elements, and excessive concentrations of manganese in the human body can be harmful even if they are required for survival. Table 4 shows that the mean manganese (Mn) concentration was 0.03 mg/l. These findings are within the WHO and NESREA ranges of 0.1-0.4 mg/l and 0.01-0.3 mg/l, respectively. According to recent data, children who have high dissolved manganese concentrations have learning impairments (WHO, 2011). Nonetheless, deficiencies as well as excesses can have detrimental effects on people's health (CAWST, 2019). Manganese shortages can also have negative health impacts, such as altered hair color, birth abnormalities, and glucose intolerance. However, as shown in Table 4, sodium (Na^+) has a mean value of 158 mg/l, which is within the permissible limits of 20-200 mg/l for portable water set by the WHO and NESREA. The burnt ashes that are washed and discharged into mining ponds may be the source of the Na^+ in the water. These findings are in agreement with those of Akpan-Idiok et al. (2012), who obtained a mean value of 34.2 mg/l from the Okpauku River in Nigeria.

Microbial Parameters of Water Quality

Table 4 shows the microbial counts in the mining ponds. The total number of coliform bacteria had a mean value of 124 cfu, while the number of *E. coli*

had a value of 123.7 cfu. These values are above the stipulated WHO and NESREA standards of 100 ml permissible limits. Rainfall-induced runoff from the environment, which can increase the microbial burden, particularly coliforms in water, is what causes high counts of bacteria. The main illnesses that can result from mining water being contaminated by bacteria include cholera, cramps, headaches, diarrhea, and typhoid. This study concurs with the findings of Doughari, Elmahmood and Manzara (2007) and Ouma, Ngeranwa, Juma and Mburu (2016). The abnormally high total heterotrophic bacterial load in the water indicated the presence of possibly harmful microorganisms.

The higher pH and increased amounts of biodegradable organics in the water body observed during the dry season may also have contributed to the high microbial load by promoting the growth of the microbial population. These findings coincide with the reports of Shittu Olaitan and Amusa (2008) and Abednego, Mbaruk, John, and John (2013), who recorded a high total coliform count exceeding the permissible limit of the WHO from water sources in the Ogun River. The presence of these bacterial species in the water samples may have

been caused by farming practices and the activities of the inhabitants leaving near the ponds. Open defecation around farmlands increases the likelihood that runoff from these farms will end up in the river. Furthermore, excessive runoff may increase the microbiological load that rainfall carries into the soil, and soil leaching through rain brings additional nutrients (Esharegoma et al. 2018).

Heavy Metal Parameters and Water Quality

Cadmium is a naturally occurring metal that is typically found in the environment in combination with other elements as a mineral (Aboujassoum and Ozeas, 2012). Groundwater and surface water can receive their supply of Cd from geologic deposits, particularly when they contact soft, acidic waters (Shuaibu, et al., 2014). Table 5 shows that the mean cadmium (Cd) concentration in the study area was 0.002 mg/l, and is within the permissible limit (0.23) of WHO and NESREA. An excessive amount of cadmium can cause renal damage, osteoporosis, carcinogenesis, and issues related to development and reproduction (Aboujassoum and Ozeas, 2012; Shuaibu et al., 2014; Kausley et al., 2019).

Table 5: Heavy metal parameters of water quality

Parameter	Barkin Ladi	Jos South	Bokkos	Mean Value	NESREA (Permissible Limit)	WHO (Permissible Limit)
Cadmium (Cd)	0.002	0.001	0.002	0.002	0.003	0.003
Cobalt (Co)	0.04	0.02	0.01	0.02	0.05	0.05
Nickel (Ni)	0.01	0.001	0.02	0.01	0.02	0.02
Lead (Pb)	0.02	0.02	0.01	0.02	0.01	0.01
Zinc (Zn)	2.8	2.3	1.2	2.1	1-3	1-3
Copper (Cu)	1.2	1.07	0.05	0.8	0.05-1	2
Chromium (Cr)	0.12	1.02	0.3	0.5	0.05	0.05
Arsenic (As)	0.002	0.002	0.1	0.03	0.1-0.2	0.01

Cobalt (Co) had a mean value of 0.02 mg/l, which falls within the permissible level of 0.05 mg/l according to the WHO and NESREA Table 5. One element that is naturally present in water is cobalt. High concentrations resulting from absorption may have negative health consequences since vitamin B12 is a major cofactor of vitamin B12 and is essential for healthy brain and nervous system operation as well as blood production. It is among the most important transition metals for humans. On the other hand, consuming too much could be

harmful to people. Furthermore, diarrhea, hypertension, heart disease, hemorrhage, lung disorders, goiter, thyroid damage, nausea, reproductive issues, hyperglycemia, hair loss, bone abnormalities, and mutations in living cells can all result from high amounts of cobalt exposure (Godiya, Cheng, Li, Chen and Lu, 2019; Saad, Alismaeel and Abbar, 2020).

Human health depends on the trace element nickel; however, excessive amounts of nickel can be harmful to the body. Because nickel (Ni) does not

decompose in the environment, pollution from it is becoming a greater problem, especially in developing nations (Pechova, and Pavlata, 2007). The results in Table 5 show a mean value of 0.01 mg/l. This value is below the permissible limits of the WHO and NESREA standards. However, as a result of dissolving nickel ore, nickel may also be found in some groundwater. Numerous health problems, including contact dermatitis, heart disease, asthma, lung fibrosis, and respiratory tract cancer, are caused by high intake of this metal (Seilkop and Oller, 2003; Pechova, and Pavlata, 2007; Zambelli, Uversky and Ciurli, 2016; Chen, Brocato, Laulicht and Costa, 2017).

As shown in Table 5, the mean lead (Pb) concentration was 0.002 mg/l, which is higher than the permissible limits of 0.01 ppm according to the WHO and NESREA. It negatively impacts the nervous system, particularly for young children and expectant mothers (WHO, 2018). In infants and children, high concentrations may impede physical and mental development (CDC, 2020). A high concentration of lead in the body can be fatal or result in irreversible harm to the kidney, brain, and central nervous system. Typically, the damage results in behavioral and academic issues (such as hyperactivity), memory and concentration problems, high blood pressure, headache, slow growth, hearing problems, reproductive problems in men and women, joint pain and digestive problems (CAWST, 2009). These findings are in agreement with those of Shuaibu, Yinusa, Funtua and Akaangee (2014), who reported similar results: urine samples from people in Gwalameji, Bauchi, had the highest Pb concentration, 0.14 mg/l.

Zinc (Zn) had a mean value of 2.1 mg/l Table 5. This value is within the WHO and NESREA limits of 1-3 mg/l in both organizations. Because zinc is found naturally within the Earth's crust, it can naturally find its way into water sources. For instance, strong rains can occasionally cause zinc to leach from natural sources (Sankhla, Kumari Nandan, Kumar and Agrawal, 2016). Similar values of this parameter were observed in Psurow ponds, where the value was below the WHO limit (Gaeka and Iatkowski, 2010). Table 5 shows a copper (Cu) mean value of 0.8 mg/l in the study area. This is within the permissible WHO (2.0) and NESREA (0.05-1 mg/l) levels in water. Copper can have an impact on the gastrointestinal system and is both a nutrient and a pollutant (CAWST, 2009).

Liver and renal issues can result from prolonged exposure (Environment Agency (EA), 2019).

Table 5 shows that chromium (Cr) has a mean value of 0.5 mg/l. This is within the WHO and NESREA limits. Chromium is naturally found in the Earth's crust. Extreme exposure could lead to higher levels of accumulation in humans (Prasad, et al., 2021). It is an essential component that benefits individuals and is important for both regulating and reducing blood sugar levels (Pechova and Pavlata, 2007; Pechova and Pavlata, 2007; Liesch, Hinrichsen and Goldscheider, 2015). Similarly, the mean arsenic (AS) concentration was 0.03 mg/l. This value is above the limits permitted by both the WHO (0.01 mg/l) and the NESREA (0.1-0.2 mg/l). When consumed in excess of the allowable limit, arsenic is carcinogenic and can cause vascular illnesses; birth defects; and lung, bladder, kidney, and prostate cancers, among other conditions. Arsenic was first identified in the Agency for Toxic Substance and Disease Registry (ATSDR) substance priority list (Kausley, et al., 2019).

CONCLUSION

The results of this study showed that the physico-chemical properties of water in tin mining ponds on the Jos Plateau were within safe limits except for appearance, color, taste, odor, electrical conductivity, turbidity, iron, lead, and arsenic, which exceeded the permissible limits of the WHO and NESREA for drinking water. However, the total coliform and *E. coli* concentrations are also above the WHO and NESREA safe limits for drinking water. Changes in physicochemical properties occur as a result of natural and anthropogenic factors. These ponds, created as a byproduct of mining operations, can be utilized as reservoirs for water storage, helping to alleviate water scarcity in the study area. The water in these ponds can become a reliable source of water for drinking water. The utilization of mining ponds for a sustainable water supply offers numerous benefits, including reduced water costs, increased water security, and minimized environmental impact. Additionally, proper management and treatment of the water in these ponds can remove contaminants and pollutants, further enhancing water quality. This approach can help reduce the demand for natural water sources, alleviating pressure on already stressed water resources. It is recommended that mining ponds undergo proper treatment and further

purification before being utilized for domestic purposes.

REFERENCE

- Abednego, M.M., Mbaruk, A.S., John, N.M. & John, M.M. (2013). Water-borne bacterial pathogens in surface waters of Nairobi River and health implication to communities downstream Athi river. *World Appl. Sci. Journal*, 3 (1), 34-40.
- Aboujassoum, H.M.A. & Ozeas, S. C. (2012). *Water contamination: Cadmium in drinking water*. Conference Paper in Qatar Foundation Annual Research Forum Proceedings · October 2012.
- Adesakin, T. A., Oyewale, A.T., Bayero, U., Mohammed, A.N., Aduwo, I.A., Ahmed, P.Z., Abubakar, N.D. & Barje. I.B. (2020). Assessment of bacteriological quality and physico-chemical parameters of domestic water sources in Samaru community, Zaria, Northwest Nigeria. (6), 8,E04773, <https://doi.org/10.1016/j.heliyon>.
- Ashraf, M. A., Maah, M. J. & Yusoff, I. (2011). Analysis of physio- chemical parameters and distribution of heavy metals in soil and water of examining area of Bestari Jaya, Peninsular Malaysia. *Asian Journal of Chemistry*, 23, (8), 3493–3499.
- Ashraf, M.A., Mohammed, J.M. & Ismail, B. Y. (2016). Study of water quality and heavy metals in soil & water of ex-mining area Bestari Jaya, Peninsular Malaysia. *International Journal of Basic & Applied Sciences IJBAS-IJENS*, 10 (3), 7 1-27.
- Akpan-Idiok, A.U., Ibrahim, A. & Udo, I.A. (2012). Water quality assessment of river for drinking and irrigation uses in Yala, Cross River State, Nigeria. *Journal of Environmental Sciences*, 6(6), 210-221.
- Binnie, C., Kimber, M. and Thomas, H. (2018). *Basic Water Treatment*. ICE Publishing, London.
- Bhatt, L.R., Lacoul, H.D., Lekhak, H. & Jha, P.K. (1999). Physicochemical characteristics and phytoplankton of Taudaha lake, Kathmandu. *Pollution Research*, 18 (4), 353–358.
- Bibi, S., Khan, R.L. & Nazir, R. (2016). Heavy metals in drinking water of Lakki marwat district, KPK, Pakistan. *World Appl. Science Journal*, 34 (1), 15–19.
- Binbol, N. L., Oche, C. Y., Eziashi, A. C & Choji, V. D. (2016). Assessment of hydrological drought characteristics on the Jos Plateau, Nigeria. *Jos–Plateau Journal of Environment and Sustainable Development (JPJESD)*, (1)1, 17 – 27.
- Bisimwa, A.M., Amisi, F.M., Bamawa, C. M., Muhaya, B.B. & Kankonda, A.B. (2022). Water quality assessment and pollution source analysis in Bukavu urban Rivers of the Lake Kivu Basin (Eastern Democratic Republic of Congo). *Environmental Sustainable Indicator*, 14, 100183.
- Centers for Disease Control and Prevention (CDC), (2020). *Drinking Water Frequently Asked Questions (FAQs) Drinking Water Healthy Water*. CDC, Atlanta.
- Centre for Affordable Water and Sanitation Technology (CAWST), (2009). *Introduction to Drinking Water Quality Testing*. CAWST, Calgary.
- Chen Q.Y., Brocato J., Laulich F. & Costa M. (2017). Mechanisms of nickel carcinogenesis. In: Mudipalli A., Zelikoff J.T. (2017). *Essential and nonessential metals. Molecular and integrative toxicology*. Springer International Publishing AG; New York, NY, USA. pp. 181–197.
- Dhameja, S.K. (2012). *Environmental Engineering and Management*. S.K. Kataria and Sons Pub, pp. 51–218.
- Doughari, J.H., Elmahmood, A.M. & Manzara, S. (2007). Studies on the antibacterial activity of root extracts of Carica papaya L. *African Journal of Microbiology Research*, 37–41.
- Emumejaye, K. & Daniel. R.A U. (2015). Electrical Conductivity of Water in Some Selected Areas of Delta State, Nigeria. *American Journal of Engineering Research*, 4 (8), 104-107.
- Environment Agency (EA), (2019). *Drinking Water Protected Areas, United Kingdom*. Environment Agency, London.

- Esharegoma, O.S., Awujo, N.C., Jonathan, I. & Nkonye-asua, I.P. (2018). Microbiological and physicochemical analysis of Orogodo River, Agbor, Delta state, Nigeria. *International Journal of Ecological Science and Environmental Engineering*, 5 (2), 34–42.
- Gaeka, B., W & Iatkowski, M. (2010). Heavy metals in water and bottom sediments of a small water reservoir called Psurów. *Ochr. Ćrod. Zas. Nature*, 42,225-232.
- Garba, T., Ilelah, K. G. Gana, B. A., Lukman, S. S. Yusuf, A.I. & Haruna, H. Y. (2019). Analyses of the effects of abandoned mining pond on physio chemical characteristics of water quality. *American Journal of Engineering Research (AJER)*, (8), 5, 242-249.
- Godiya, C.B., Cheng, X., Li D.W., Chen, Z. & Lu, X.L. (2019). Carboxymethyl cellulose/polyacrylamide composite hydrogel for cascaded treatment/reuse of heavy metal ions in wastewater. *Journal of Hazard Material*, 364, 28–38.
- Gongden, J. J. & Lohdip, Y.N. (2015). Seasonal variation of the surface water quality of two dams in Plateau State, North Central Nigeria. *Transactions on Ecology and the Environment*, 196, 291-298. *Water Resources Management VIII* 291.
- Gray, N.F. (1999). *Water Technology: An Introduction for Scientists and Engineers*. Arnold, London.
- Haruna, I. (2012). *Trace elements evaluation for some mine ponds in the tin mining areas of Jos and environs*, Plateau State, Nigeria.
- Jabbo, J, N., Gin, N.S., Ogezi, A.E. & Dass, P.M. (2011). Water quality assessment of mined ponds at The University of Jos, Nigeria permanent site. *Journal of Chemical Society of Nigeria*, 36 (2), 15-20
- Jamielson, R., Gordon, R., Joy, D. & Lee, H. (2004). Assessing microbiology, pollution of rural surface waters: a review of current watershed scale modeling approaches. *Agriculture, Water Management*, 70, 1–17.
- Kausley, S.B., Dastane, G.G., Kumar, J.K., Desai, K.S., Doltade, S.B. & Pandit, A.B. (2019). Clean water for developing countries: Feasibility of different treatment solutions. In: Nriagu, J. (Ed.), *Encyclopedia of Environmental Health*, Second Edition. Elsevier, Amsterdam, pp. 643-652.
- Kazi, T.G., Arain, M. B., Jamali, M.K., Jalbani, N., Afridi, H.I., Sarfraz, R.A., Baig, J.A. & Shah, A.Q. (2009). Assessment of water quality of polluted lake using multivariate statistical techniques: a case study. *Ecotoxicology, Environmental and Safety*, 72, 301–309.
- Keay, R. W. J. (1969). *An outline of Nigerian vegetation*, Lagos, Federal Government Printer.
- Lawal, R.A., Lohdip, Y.N. & Egila, J.N. (2014). Water Quality Assessment of Kampani River, Plateau State, Nigeria. *Asian Review of Environmental and Earth Sciences*, 1(2), 30-34.
- Liesch, T., Hinrichsen, L.T. & Goldscheider, S. (2015). N. Uranium in groundwater—Fertilizers versus geogenic sources. *Science of the Total Environment*, 536, 981–995.
- Majekodunmi, A.O., Fajinmi, A. and Dongkum, C. et al. (2014). Pastoral livelihoods of the Fulani on the Jos Plateau of Nigeria. *Pastoralism* 4, 20. <https://doi.org/10.1186/s13570-014-0020-7>.
- Mafuyai, G. M., Eneji, I. S., Sha’Ato, R. & Nnamonu, L. A. (2019). Heavy Metals in Soil and Vegetables Irrigated with Ex-Tin Mining Ponds Water in Barkin - Ladi Local Government Area Plateau State, Nigeria. *Agriculture and Food Sciences Research*, 6(2), 211-220.
- Moyle, J.B. (2009). Some indices of lake productivity. *Trans. American Fishery Society*, 76, 322–334.
- Mafuyai, G. M., Ayuba, M. S. & Zang, C. U. (2020). Physico-chemical characteristics of tin mining pond water used for irrigation in Plateau State, Central Nigeria. *Open Journals of Environmental Research, (OJER)*, (1) 2, 09-35.
- Megersa, M., Beyene, A., Ambelu, A. & Woldeab, B. (2014). The use of indigenous plant species for drinking water treatment in developing countries: A Review. *Journal of Biodiversity and Environmental Science*, 5(3), 269-281.

- National Bureau of Statistics. (2015). *Summary Report: Nigerian Mining and Quarrying Sector*.
- Olajire, A.A. & Imepeoria, F.E. (2001). Water quality assessment of Osun River studies on inorganic nutrients. *Environmental Monitoring Assessment*, 69, 17-28.
- Orisakwe, O.E. (2014). Lead and Cadmium in Public Health in Nigeria: Physicians Neglect and Pitfall in Patient Management. *North American Journal of Medical Sciences*, 6 (2), 61-70.
- Ouma, S.O., Ngeranwa, J.N., Juma, K.K. & Mburu, D.N. (2016). Seasonal variation of the physicochemical and bacteriological quality of water from five rural catchment areas of lake victoria basin in Kenya. *Journal of Environmental Analytical Chemistry*, 3, 2–7.
- Pechova, A. & Pavlata, L. (2007). Chromium as an essential nutrient: a review. *Veterinarian Medicina*, 52, (1),1–18.
- Prasad, S., Kumar, Y. K., Kumar, S., Gupta, N., Marina, M.S. Pinto,C., Rezania, S., Radwan, N. & Alam, J (2021). Chromium contamination and effect on environmental health and its remediation: A sustainable approach. *Journal of Environmental Management*, (285), 1, 112-174
- Rahman, A.K.M.L., Islam, M. Hossain, M.Z. & Ahsan, M.A. (2012). Study of the seasonal variations in Turag River water quality parameters. *African Journal of Pure and Applied Chemistry*, 6(10), 144- 148.
- Raji, M.I.O. & Ibrahim, Y.K.E. (2011). Prevalence of water-borne infections in North Western Nigeria: a retrospective study. *Journal Public Health Epidemiology*, 3 (8), 382-512 385.
- Saad, D.R., Alismaeel, Z.T. & Abbar, A.H. (2020). Cobalt removal from simulated wastewaters using a novel flow-by fixed bed bioelectrochemical reactor. *Chemical Engineering Process*, 156:108097
- Sankhla, M.S., Kumari, M., Nandan, M., Kumar, R. & Agrawal, P. (2016). Heavy metals contamination in water and their hazardous effect on human health-A review. *International Journal of Current Microbiology Applied Science*, 5(10), 759–766.
- Seilkop S.K & Oller, A.R. (2003). Respiratory cancer risks associated with low-level nickel exposure: An integrated assessment based on animal, epidemiological, and mechanistic data. *Regulation, Toxicology and Pharmacology*, 37,173–190.
- Shah, A, Arjunan, A., Baroutaji, A. & Zakharova, J. (2023). A review of physicochemical and biological contaminants in drinking water and their impacts on human health. *Water Science and Engineering*, 16(4), 333-344.
- Shittu, O.B., Olaitan, J.O. & Amusa, T.S. (2008). Physico-chemical and bacteriological analysis of water used for drinking and swimming purpose in Abeokuta, Nigeria. *African Journal Biomed Research* 11, 285-290.
- Shuaibu, U.O.A. Yinusa, I., Funtua. A.M. & Akaangee, P.A. (2014). Impact of lead and Cadmium in drinking water. *International Journal of Technical Research and Applications*, 2, (6), 31-35.
- Ufodike, E.B.C., Kwanasie, A.S. & Chude, L.A. (2001). On-set of rain and its destabilizing effect on aquatic and physico-chemical parameters. *Journal of Aquatic Science*, 16 (2), 91–94.
- Umeh, C.N., Okorie, O.I. & Emesiani, G.A. (2005). *Toward the provision of safe drinking water: the bacteriological quality and safety of sachet water in Awka, Anambra State*. In: The Book of Abstract of the 29th Annual Conference and General Meeting on Microbes as Agents of Sustainable Development Organized by Nigerian Society for Microbiology (NSM). University of Agriculture, Abeokuta, pp. 14–17.
- United Nations (2022). *Agenda 21: Programme of action for sustainable development*. Rio declaration on environment and development statement of forest Principles. New York, United Nations, 294.
- World Health Organization, (2017) *Guidelines for Drinking-Water Quality*. WHO, Geneva.
- World Health Organization, (2018). *Household Water Treatment and Safe Storage*,

- Treatment Technologies. WHO, Geneva.
- World Health Organization, (2011). *Guidelines for drinking-water quality*, fourth edition. WHO, Geneva.
- Analyses of the effects of abandoned mining pond on physio chemical characteristics of water Quality. *American Journal of Engineering Research*, (AJER), 8 (5), 242-249.
- Wuyep S. Z, Rampedi, I.T. & Ifegbesan, A.P. (2021). The role of urban vegetable production In Jos (Nigeria) as a source of livelihood. *African Journal of Food Agriculture and Nutritional Development*, 21(8), 18533-18551.
- Yan, W., Li, J. & Bai, X. (2016). Comprehensive assessment and visualized monitoring of urban drinking water quality. *Chemometric Laboratory System*, 155, 26e35.
- Zambelli B., Uversky, V.N. & Ciurli S. (2016). Nickel impact on human health: An intrinsic disorder perspective. *BBA Proteins Proteom*, 1864, 1714–1731.
- Zhang, P., Yang, M., Lan, J., Huang, Y., Zhang, J., Huang, S., Yang, Y. & Ru, J. (2023). Water quality degradation due to heavy metal contamination: Health impacts and eco-friendly approaches for heavy metal remediation. *Toxics*, 11, 828.