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# Metal Pollution Assessment of the Abandoned Mine Ponds and Ground Water of Parts of the Jos Plateau, North Central Nigeria

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**Abstract:** The study area also known as tin city is popular for its historic tin mining activity which left behind several heaps of mine spoil (waste) and abandoned mine ponds which today are used to meet domestic water needs. This study is carried out with a view to determining the level of heavy metal contamination of the mine ponds and ground water of the study area. Twenty one water samples were systematically collected from mine ponds and ground water of the study area including the GPS reading of every point were samples are collected. Concentration of the heavy metals lead, zinc, copper, iron and manganese were determined using inductively coupled plasma optical emission spectroscopy(ICP OES), while the level of contamination was determined using the contamination factor(CF). The results revealed low contamination (CF<1) for most of the study area (93.33%), moderate contamination (1≤CF<3) for 4.76% of the area with respect to Fe, Pb, and Zinc, and considerable contamination (3≤CF<6) for 1.9% of the area with respect to Pb.

**Keywords:** Contamination Factor (CF), Mine Spoil, Mine Pond

## 1. Introduction

Mining areas are characterized by high concentration of potentially harmful elements in water and soils related not only to weathering of naturally enriched parent rocks and pathogenesis, but also to human activities of mining, farming, waste disposal and metal processing.

The identification of water pollution by toxic elements in such instances is important because the localized disturbance of the ground through human influence e.g. mine waste, farming, mineral processing etc. may cause increased dispersion and exposure of contaminants derived from natural sources.

Formal mining started on the Jos Plateau as far back as 1902 with tin and columbite as the major targets[1]leaving behind a post mining environment characterize by numerous mine ponds and dams, surrounded by heaps of mine spoils and a devastated landscape [10]. The disrupted landscape, the soil surface and ground water as well as the air, which are needed to sustain the renewable agricultural resources as well as make for a safe and healthy living stand at risk of these activities [3]. Mine tailings which were presumed useless in the past were disposed in mine ponds which today are being used for irrigation and other domestic purposes with its attendant health hazards. Similarly, some of the mine spoils are disposed of in heaps around the mine ponds from which excavations were made thereby altering the landscape and destroying the scenic beauty.

The study area and indeed most urban areas within the Jos –Bukuru urban has witnessed population growth from about 650, 839 in 1991 to over 1 million in the year 2006, with new settlements springing up around mine ponds. This is because it is believed that the urban areas have plenty of economic opportunities and services that will make for a better quality of life [2]. On the contrary however, the local and National Governments seemed unprepared and ill equipped to provide the influx with adequate water and other needed infrastructure, resulting in the use of mine pond water, construction of shallow wells and boreholes without regards to its suitability for municipal use, while also disposing industrial waste and effluents into the ponds.

Heavy metals are natural constituents of natural waters and some of them are biologically essential for life at minute quantities while others are toxic. They heavy metals are induced from several sources including natural geological weathering of rocks and the soils as well as by anthropogenic factors such as mining operations, disposal of industrial wastes and application of biocides for pest [12].

The activities of man in urban cities is fast becoming a threat to the quality of urban environment and in this case there may exist the possibility of leachates from mine waste contaminating pond water used for irrigation and production of most of the vegetables on the plateau today, with possible risk of bioaccumulation of heavy metals, and human and domestic waste polluting the waters with great consequence on the health and safety of population exposed to them [see fig. 1 and 2]. It is worth noting that to produce a single gold ring generates 20tons of mine waste (www.scribd.com/03246/issue-analysis-mining-and -its effect-on-the-environment

***Figure 1.*** *Abandoned Mine Pond Used For Reworking Of Mine Tailings.*

***Figure 2.*** *Abandoned Mine Pond Used for Irrigation.*

***Figure 3.*** *Abandoned mine pond used as source of public water supply.*

The study area is located within latitude 09°30"N and 10°00"N and longitude 08°40"E and 9°00"E covering parts of the Jos- Bukuru Complex. It is located on topographical sheet 168 on a scale of 1:100 000.

Most parts of the study area are easily accessible by road, some of which are tarred, and by foot paths leading to the nooks and crannies of it. The study area falls within the granite complexes of central Nigeria and represents one of the classical areas of occurrences of ring complex in the world. The main geological units are the basement rocks and the younger granite complex [5]; [12], [7].

The basement rocks are the oldest in the area and occur as highly metamorphosed and folded masses in contrast to the surrounding younger granite complex. It is composed of Gneiss, Granite-gneisses and Migmatites.

The younger granite formations consist of various types of rocks ranging from Biotite granite, Quartz-fayalite porphyry, and Hornblende-porphyry and Basaltic rocks [7]. Figure 4 is the administrative map of Nigeria showing Plateau State and the project area, while figure 5 is the geological map of the study area showing the sample collection points.

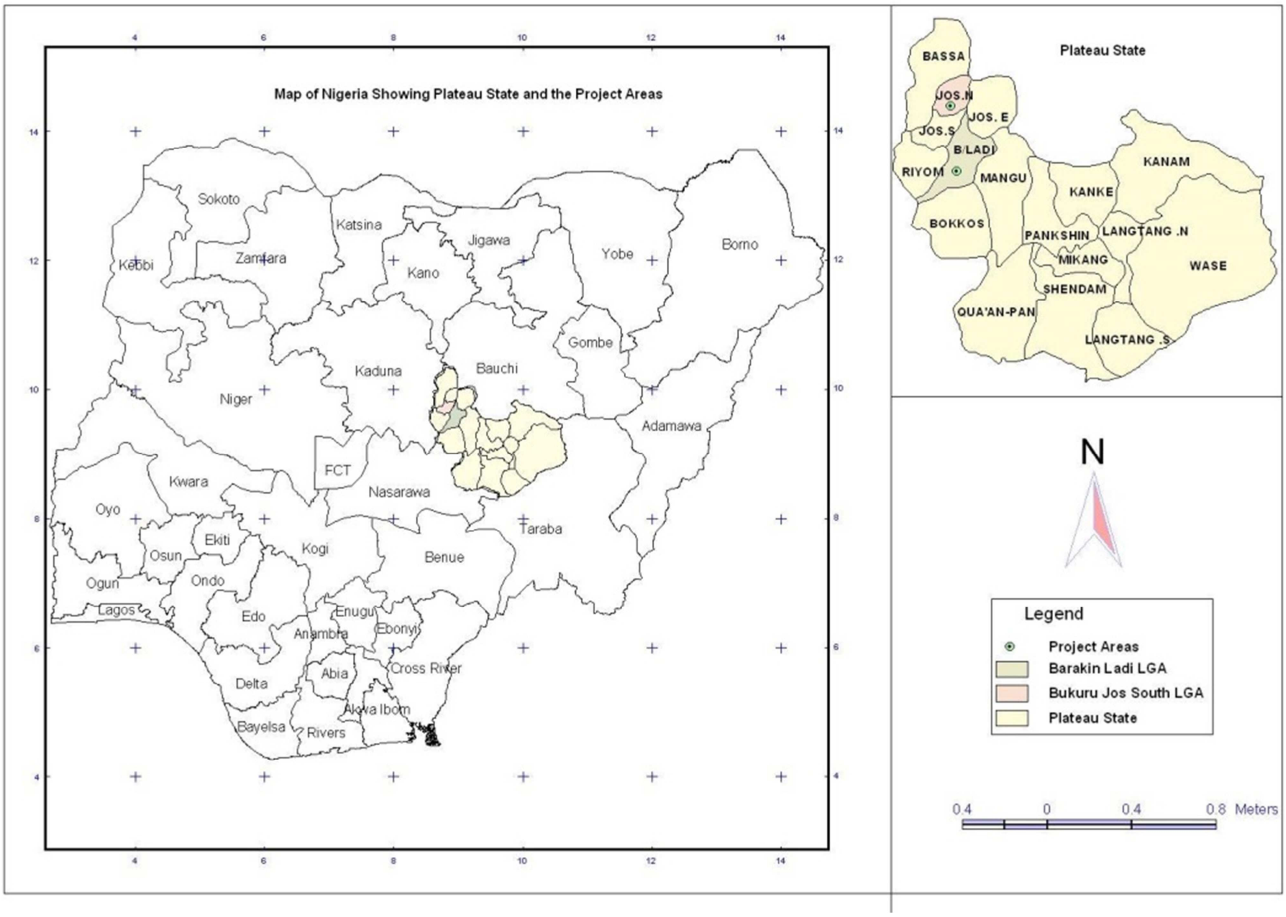


***Figure 4.*** *Administrative map of Nigeria showing Plateau state and the study area.*

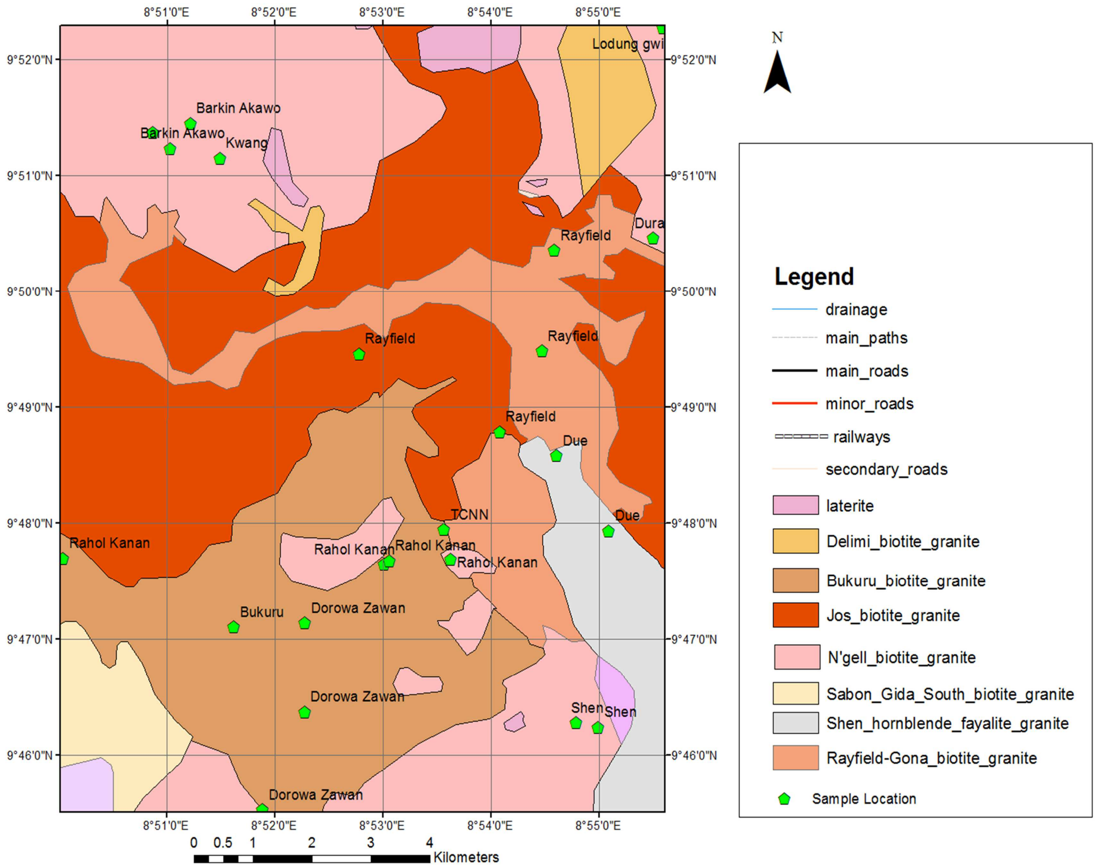


***Figure 5.*** *Geological Map of the study area showing the sample collection Point.*

## 2. Materials and Method

The concentration, the form, the soil or water pH, including the extent of exposure to the elements normally determines the magnitude of hazard by chemical and bacteriological elements. Knowing the level of concentration of these elements requires carrying out a detailed sampling and analysis of samples from the study area. The methodology adopted for this research therefore, involves a Systematic sampling and collection of mine pond water and ground water in the study area including GPS reading of every spot where samples are collected, and the depth of collection (where possible). All vessels used for the collection of water samples were previously soaked in dilute acid and rinsed several times with distilled water.

The heavy metal analysis of the water samples was done using the inductively coupled plasma optical emission spectroscopy (ICP-OES), Microsoft excel and Arc Geographic Information System (Arc GIS) are used in the production of the plots and maps for interpretation of the results while the pollution index of the samples was determined using the contamination factor (CF).

## 3. Results

A total of twenty one samples were analyzed for heavy metals (Pb, Zn, Cu, Fe, and Mn), the statistical summaries of the results are presented in Tables 1 alongside the World Health Organization [13] and [6].

***Table 1.*** *Statistical Summary of the geochemical Parameter.*

| **Mine Pond (MP) Samples** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | **Water Standards** | | |
| **Parameter** | **Mean** | **Median** | **Standard Deviation** | **Range** | **WHO 2004** | | **NSDWQ 2007** |
| | | | | | **RL** | **MPL** | **MP** |
| Fe (mg/l) | 1.25 | 0.29 | 3.35 | 0.13-1.22 | - | 0.3 | 0.3 |
| Mn (mg/l) | 0.05 | 0.04 | 0.06 | ND-0.27 | 0.05 | 0.3 | 0.2 |
| Pb (µg/l) | - | ND | - | ND | - | - | 0.01 |
| Zn (µg/l) | 248.6 | 88 | 510.7 | 42-2150 | - | 3 | 3 |
| Cu (µg/l) | 3.94 | 4.0 | 4.6 | ND-15 | - | 1 | 1 |

WHO = WORLD HEALTH ORGANIZATION, NSDWQ = NIGERIA STANDARD FOR DRINKING WATER QUALITY, RL = RECOMMENDED LEVEL, MPL = MAXIMUM PERMISSIBLE LEVEL, MP = MAXIMUM PERMITTED

***Table 2.*** *Statistical Summary of the geochemical Parameter.*

| Groundwater (GW) Samples | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | Mean | Median | Standard Deviation | Range | Water Standards WHO 2004 RL | WHO 2004 MPL | NSDWQ 2007 MP |
| Fe (mg/l) | 0.35 | 0.13 | 0.49 | 0.05-1.09 | - | 0.3 | 0.3 |
| Mn | 0.03 | - | 0.02 | 0.01 – 0.06 | 0.05 | 0.3 | 0.2 |
| Pb (µg/l) | 23.3 | 10 | 11.5 | ND-30 | - | - | 0.01 |
| Zn (µg/l) | 992.8 | 454 | 1581.2 | 80-3350 | - | 3 | 3 |
| Cu (µg/l) | 14.5 | 14 | 14.4 | 5-35 | - | 1 | 1 |

WHO = WORLD HEALTH ORGANIZATION, NSDWQ = NIGERIA STANDARD FOR DRINKING WATER QUALITY, RL = RECOMMENDED LEVEL, MPL = MAXIMUM PERMISSIBLE LEVEL, MP = MAXIMUM PERMITTED

The level of contamination of the mine ponds and ground water by heavy metals was determined using the formular; CF=Cm/Cb

Where CF= Contamination factor

Cm= Heavy metals concentration of samples from chemical analysis

Cb= WHO Maximum recommended intake level.

The value obtained is then used to determine the level of contamination as either Low, Moderate, or Considerable or Very high, as can be seen on table 2.

***Table 3.*** *Classification of contamination factor.*

| Contamination factor (CF) | Classification |
|---|---|
| <1 | Low contamination |
| 1-3 | Moderate contamination |
| 3-6 | Considerable contamination |
| >6 | Very high contamination |

After [4]

***Table 4.*** *Contamination Factor (Cf) of the Samples.*

| Sample | Fe mg/l | Contamination | Pb mg/l | Contamination | Zn | Contamination | Cu mg/l | Contamination | Mn | contamination |
|---|---|---|---|---|---|---|---|---|---|---|
| MP 1 | 0.53 | Low | 0.8 | Low | 0.02 | Low | 0.002 | Low | 0.13 | Low |
| MP 2 | 0.13 | Low | 0.8 | Low | 0.03 | Low | 0.001 | Low | 0.03 | Low |
| MP 3 | 0.23 | Low | 4 | Considerable | 0.06 | Low | 0.008 | Low | 0.1 | Low |
| MP 4 | 0.14 | Low | 0.8 | Low | 0.05 | Low | 0.0009 | Low | 0.00002 | Low |
| MP 5 | 0.21 | Low | 0.8 | Low | 0.02 | Low | 0.002 | Low | 0.1 | Low |
| MP 6 | 0.27 | Low | 0.8 | Low | 0.72 | Low | 0.008 | Low | 0.08 | Low |
| MP 7 | 0.26 | Low | 0.8 | Low | 0.03 | Low | 0.0009 | Low | 0.13 | Low |
| MP 8 | 0.56 | Low | 0.8 | Low | 0.22 | Low | 0.003 | Low | 0.08 | Low |
| MP 9 | 0.29 | Low | 0.8 | Low | 0.02 | Low | 0.001 | Low | 0.13 | Low |
| MP 10 | 0.26 | Low | 0.8 | Low | 0.03 | Low | 0.0009 | Low | 0.1 | Low |
| MP 12 | 0.45 | Low | 0.8 | Low | 0.03 | Low | 0.0009 | Low | 0.15 | Low |
| GW 13 | 1.09 | moderate | 0.8 | Low | 0.15 | Low | 0.01 | Low | 0.08 | Low |
| GW 14 | 0.13 | Low | 1 | Moderate | 0.03 | Low | 0.003 | Low | 0.05 | Low |
| GW 15 | 0.11 | Low | 3 | Considerable | 1.12 | Moderate | 0.02 | Low | 0.03 | Low |
| MP 16 | 0.51 | Low | 0.8 | Low | 0.02 | Low | 0.003 | Low | 0.08 | Low |
| MP 17 | 0.15 | Low | 0.8 | Low | 0.03 | Low | 0.002 | Low | 0.05 | Low |
| MP 18 | 0.47 | Low | 0.8 | Low | 0.01 | Low | 0.0009 | Low | 0.05 | Low |
| MP 19 | 0.35 | Low | 0.8 | Low | 0.03 | Low | 0.001 | Low | 0.15 | Low |
| MP 20 | 0.33 | Low | 0.8 | Low | 0.04 | Low | 0.002 | Low | 0.15 | Low |
| MP 21 | 1.22 | moderate | 0.8 | Low | 0.05 | Low | 0.003 | Low | 0.68 | Low |
| GW 55 | 0.06 | Low | 3.0 | Moderate | 0.03 | Low | 0.002 | Low | 0.03 | Low |

The results obtained are further illustrated using graphs to highlight the concentration of the heavy metals in the study area, while the spatial maps are used to show the occurrence of the heavy metals over the different rock types and also to confirm if they influence the results.

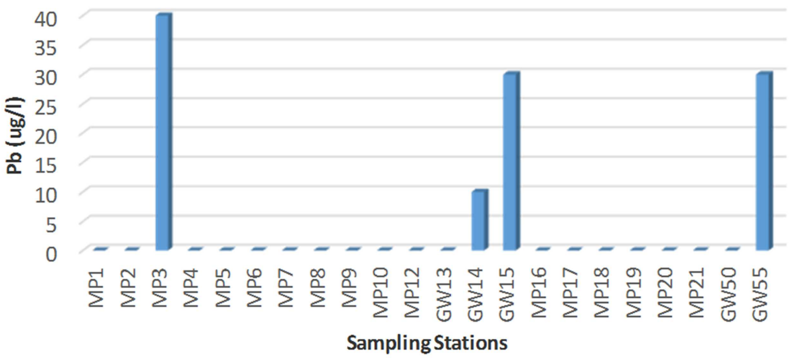


***Figure 6.*** *Lead (Pb) Concentration in the Water Samples.*

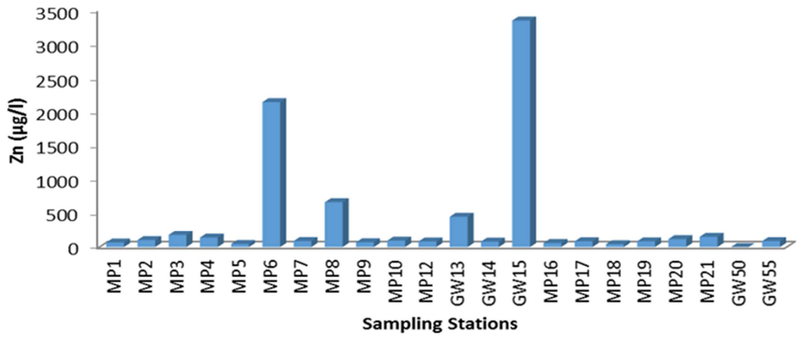


***Figure 7.*** *Zinc (Zn) Concentration in the Water Samples.*

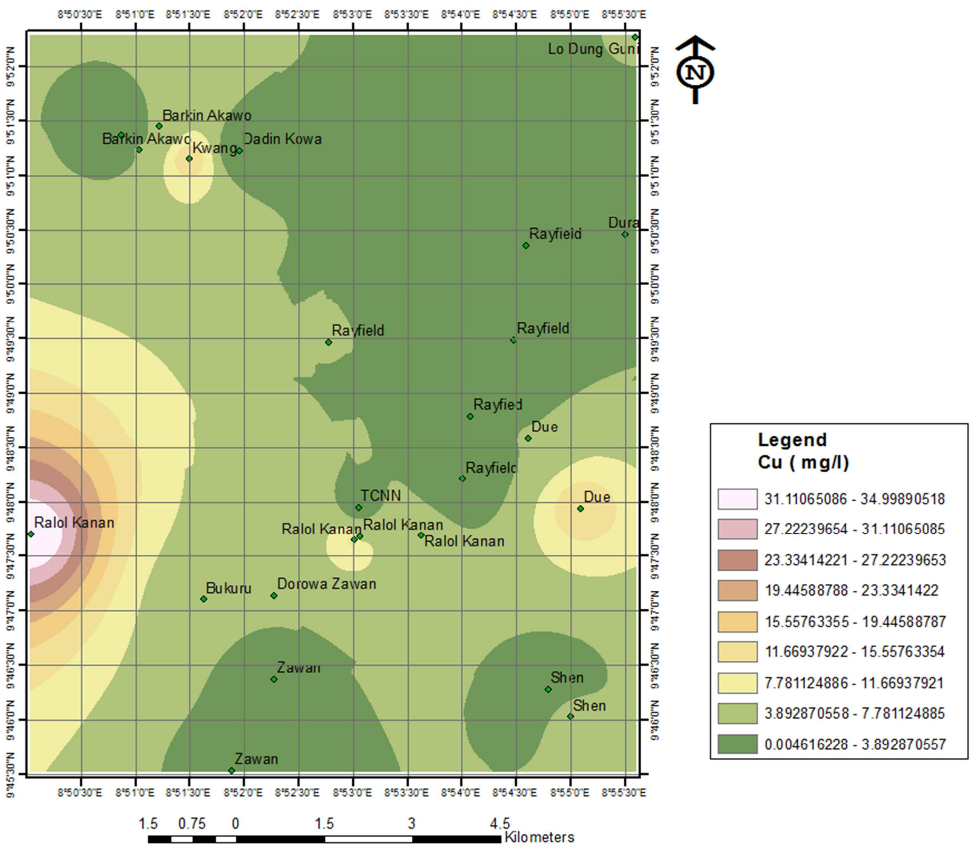


***Figure 8.*** *Spatial Map Showing Distribution of Cu In the Study Area.*

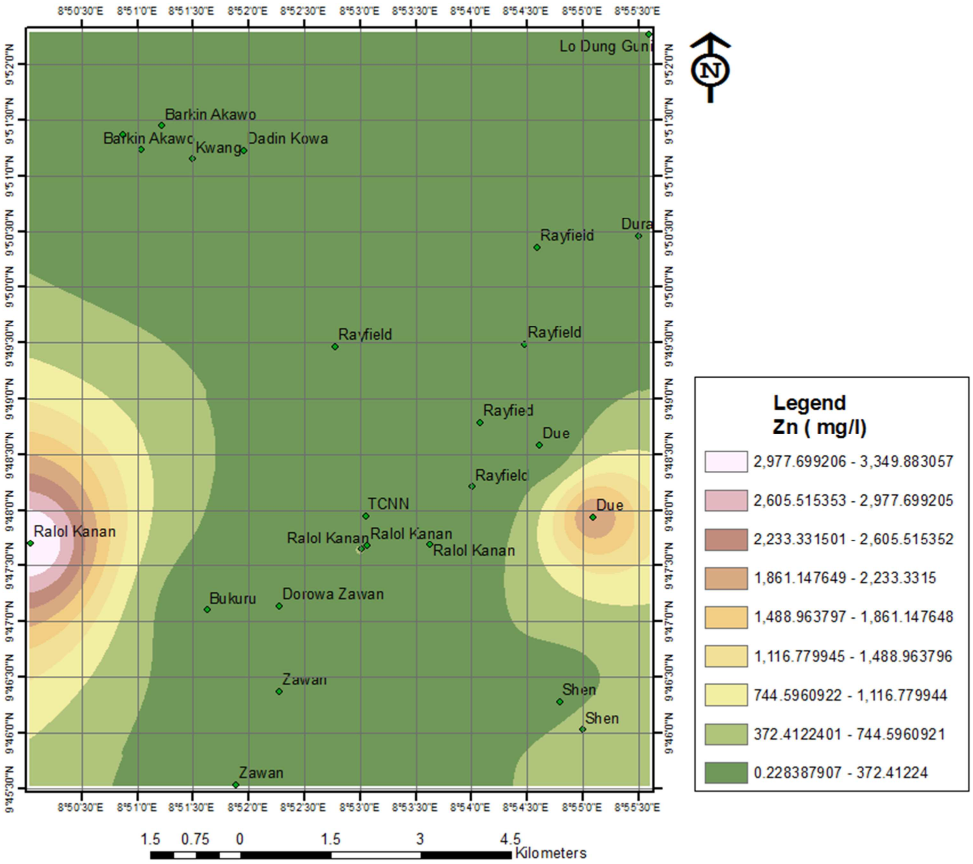


***Figure 9.*** *Spatial Map Showing Distribution of Zn.*

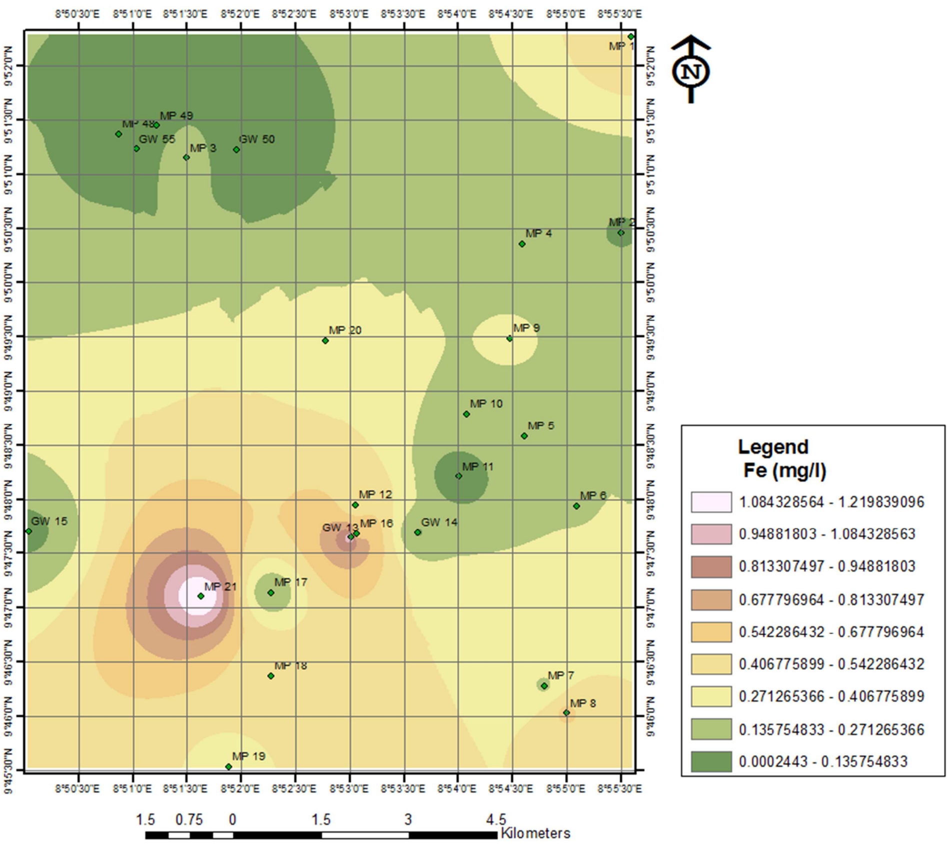


***Figure 10.*** *Spatial Map showing Distribution of Fe in the study area.*

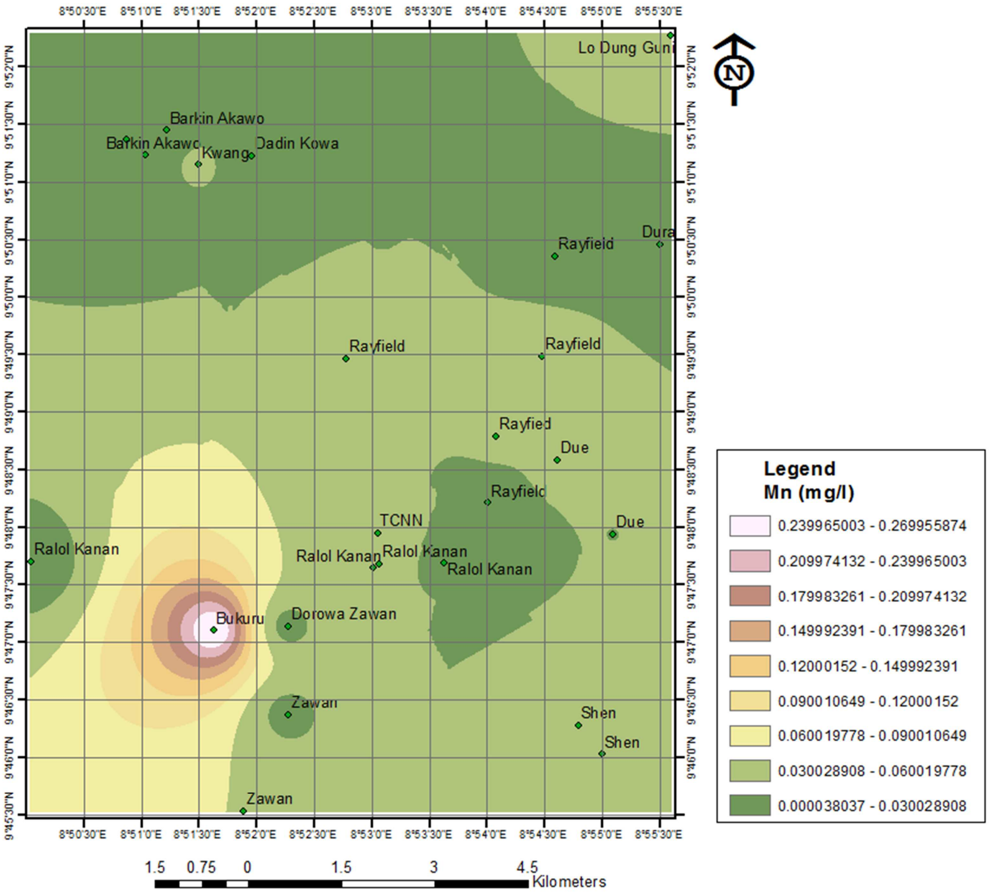


***Figure 11.*** *Spatial Map Showing Distribution of Manganese in the study area.*

# 4. Discussion

For both the mine pond and groundwater, the Iron (Fe) concentration are higher than the WHO and Nigeria recommended and maximum permissible level (0.3mg/l). Fe has a range of 0.13 to 1.22 mg/l (mine pond) and 0.05 to 1.09 mg/l (groundwater) with mean values of 1.25 mg/l and 0.35 mg/l respectively Fig. The Fe values of 0.45, 0.47, 0.51, 0.53 and 0.56 mg/l observed in mine pond samples and value of 1.09 mg/l observed in groundwater are those above the highest desirable and maximum permissible level [13] and [NSDWQ] of 0.3 mg/l, other concentrations are below this level. The high Fe value may have been enhanced by terrigenous activities of weathering and erosion of iron bearing minerals in the host rocks of the study area (Fig. 1) or by anthropogenic sources. Fe in small quantities is an essential element for all living organisms, its presence in water however may cause staining of laundry and scaling in pipes as well as undesirable taste. Colour is strongly influenced by the presence of iron either as natural impurities or as corrosion products. On exposure to the atmosphere, the ferrous iron can oxidizes to ferric iron, giving an objectionable reddish-brown colour to the groundwater. High iron content can as well promote the growth of “iron bacteria” which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on piping and water retaining vessels.

Lead (Pb) was detected in one mine pond sample (MP 3) located at Kwang Dilimi with a concentration of 40 µg/l, while groundwater samples had concentration ranging from Not Detected (ND) to 30 µg/l with a mean value of 23.3 µg/l (Table 1 and 2). Figure 6 shows Pb concentration in the waters of the study area. Pb was detected in samples MP3, GW 14, GW 15 and GW 55. The presence of Pb indicates poor water quality, unsafe for drinking. Water containing Pb can be hazardous to health if used for drinking and other domestic purposes as it is known to be carcinogenic and also interferes with Vitamin D metabolism. It also affects mental development in infants, and is toxic to the central and peripheral nervous systems. In Zamfara (Sunke and Abere villages), North Eastern Nigeria, in the year 2015 it was reported [9] that over one hundred people died, of lead poisoning most of whom were children, while many women who were engaged in crushing the rocks containing gold using mortar and pestle had miscarriages as a result of inhaling the poisonous dust. Similarly, it was reported that 11 people died from drinking contaminated water in Mutai Village, Gubja local government area of Yobe state, North Eastern Nigeria after heavy rain downpour washed herbicides from farmlands into the only source of water in the village. The Pb recorded in the samples of the study area could have also originated from terrigenous and anthropogenic sources. This could be so because the rocks of the area were known to be rich in tin and columbite, while the mining process carried out to exploit the minerals could also cause dispersion of the associated mineral element.

The results show that Zinc (Zn) concentration in the mine pond has a range of 42 µg/l to 2150 µg/l with a mean value of 248.6 µg/l while the concentration in groundwater Zinc (Zn) has a range of 80 µg/l to 3350 µg/l with a mean value of 992.8 µg/l (tables 1&2). These values are higher than the WHO and Nigeria permissible level (3 µg/l) with the highest value of 3350 µg/l obtained from groundwater (GW 15), a shallow well located on coordinate N009$^0$ 47.697' and E008$^0$ 50.044'at Rahol Kanan and serves as a source of domestic water supply. The water well is situated very close to a mine pond and is possibly being recharged by it. However, the Zn content in the pond water is less than that of the well water. This could indicate possible leaching of the Zinc metal from the rock types of the environment and also from other anthropogenic sources such as waste disposal. The zinc minerals associated with the biotite granite rocks of the study area which were the primary host of tin mineralization may have been exposed in the cause of tin mining and subsequently leached into the water bodies. Figure 7 shows the Zinc concentration in the water samples. Zinc is an essential element to man, but if ingested in gross amounts can be toxic. The principal significance of excessive amounts of Zinc in water is its emetic effect.

The Copper (Cu) concentration observed in the samples ranges from Not Detected (ND) to 15 µg/l, with a mean value of 3.94 µg/l in respect of the mine ponds, while for the groundwater, Cu concentration ranges from 4 to 35 µg/l with a mean value of 14.5 µg/l (Table 1 and 2). These values are higher than the 1µg/l permissible level of WHO and Nigeria drinking water standards. The highest Cu value of 35 µg/l value was obtained from groundwater (GW 15) located at Rahol Kanan. This makes the water unsafe for drinking purposes and other domestic purposes. Figure 8 shows the distribution of Cu concentration over the rock types of the area while table 1 and 2 shows the concentration values obtained. Excess Cu in drinking water can lead to gastrointestinal disorder and other related health impact.

The concentration of Manganese recorded from the samples ranges from Not Detected (ND) to 0.27 mg/l and 0.01 to 0.06 mg/l, with mean values of 0.05 mg/l (mine pond) and 0.03 mg/l (groundwater). These values are within the 0.3 mg/l maximum permissible level of WHO and 0.2 mg/l maximum permitted level of Nigeria drinking water standards. This makes the water possibly suitable for drinking purpose. As with iron, manganese is found widely in soils and is a constituent of many ground waters. It, too, may be brought into solution in reducing conditions and the excess metal will be later deposited as the water is reaerated. Manganese has a staining effect which is more severe than that of iron, this may have accounted for the stringent limits applied to it. Again the source of manganese is most likely from terrigenous sources due to weathering and erosion of the rocks in the study area. The distribution of manganese over the rock types is as presented on Fig. 11.

# 5. Conclusion

The results of the analysis showed varying levels of concentration of trace metals, most of which are low and fall within the acceptable limits of the world health organization and the Nigeria standard for drinking water quality. The level of contamination as determined by the contamination factor showed that the contamination in the area is generally low (CF<1) for 93.33% of the study area, moderate (1≤CF<3) with respect to Fe, Pb and Zn for 4.76% of the study area, and considerable (3≤CF<6), for 1.9% of the study area with respect to Pb.

This result shows that the mine pond and ground water of the study area are suitable for domestic and other municipal uses, they may however require monitoring as time goes on considering the continuous increase in human population and informal mining activities presently ongoing in the area to guard against the possibility of water pollution.

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