*Archives of Current Research International*
*7(1): 1-7, 2017; Article no.ACRI.32323*
*ISSN: 2454-7077*

**SCIENCEDOMAIN** *international*
www.sciencedomain.org

# Quality Assessment of Water Bodies in Selected Mining Communities of Plateau State, Nigeria

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***Authors' Contributions***

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/ACRI/2017/32323
Editor(s):
(1) Sivakumar Manickam, Department of Chemical and Environmental Engineering, The University of Nottingham Malaysia Campus, Malaysia.
Reviewers:
(1) Antipas T. S. Massawe, University of Dar es Salaam, Tanzania.
(2) Arnaldo Sarti, Institute of Chemistry (UNESP - Universidade Estadual Paulista, Campus Araraquara), São Paulo, Brazil.
(3) Saima Fazal, South China University of Technology, China.
Complete Peer review History: http://www.sciencedomain.org/review-history/18269

***Original Research Article***

***Received 20th February 2017***
***Accepted 8th March 2017***
***Published 20th March 2017***

## ABSTRACT

**Aims:** The study assessed the portability as well as the suitability for use in irrigation of water samples from mine ponds, streams, wells and boreholes of selected cassiterite mine sites in Plateau State of Nigeria.
**Study Design:** Experimental design was used in the sampling and analyses of water samples from different water sources in the study area.
**Methodology:** These samples were analysed using the Atomic Absorption Spectrophotometric (AAS) model AA 6800 in accordance with the provision of ASTMD 856-10 at the Geochemistry Laboratory of the Nigerian Geological Survey Agency (NGSA), Kaduna, Nigeria.
**Results:** The mean pH values of water samples collected from mine ponds, streams, wells and boreholes were 5.6, 6.5, 6.3 and 6.3 respectively. While those of As were 0.027 ppm, 0.013 ppm, 0.013 ppm and 0.013 ppm and those of Cd were. 0.013 ppm, 0.0098 ppm, 0.007 ppm and 0.0079 ppm. The mean concentrations of Cr in water samples collected from mine ponds, streams, wells and boreholes were 0.06 ppm, 0.03 ppm, 0.03 ppm and 0.03 ppm respectively. While those of Pb were 0.06 ppm, 0.02 ppm, 0.02 ppm and 0.03 ppm and the average % Na in the water samples collected from mine ponds, streams, wells and boreholes were 87, 73, 69 and 60 respectively.
**Conclusion:** The water samples collected from the different sources in the study area were acidic

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and had unenviable amount of toxic contaminants (Cd, Pb and As) in concentrations higher than the maximum allowable limits set by WHO (2011). The consumption of water with high concentrations of Pb for example can lead to mental retardation in children as well as nervous, skeletal, circulatory, enzymatic, endocrine, and immune systems damages while Cd may make the consumers prone to lung cancer, bone fractures, kidney dysfunction, and hypertension. The water samples were also not suitable for irrigation purposes because of the high % Na.

*Keywords: Cassiterite mine sites; mine ponds; toxic contaminants; environmental niche.*

## 1. INTRODUCTION

Mineral resources represent the key material foundation for socio-economic development of any Nation. This makes the exploitation and utilization of mineral resources essential for modernization. Nonetheless, despite the importance of mineral resources, mineral extraction has inflicted serious environmental and health damages, especially in the realm of heavy metal pollution. A number of research endeavours had therefore been undertaken to create a public awareness of the risks of prolonged human exposure to heavy metals [1]. Heavy metals such as lead (Pb), zinc (Zn), cadmium (Cd), mercury (Hg) and chromium (Cr) generally refer to metals and metalloids having densities greater than 5 g/cm$^3$. Metalloids such as arsenic (As) often fall into the heavy metal category due to similarities in chemical properties and environmental behavior. Heavy metal pollution is covert, persistent and irreversible. This kind of pollution not only degrades the quality of the atmosphere, water bodies, and food crops, but also threatens the health and well-being of animals and human beings by way of the food chain. For example, Pb is a non-essential element to the human body, and excessive intake of the metal can damage the nervous, skeletal, circulatory, enzymatic, endocrine, and immune systems of those exposed to it. Moreover, chronic exposure to Cd can have adverse effects such as lung cancer, pulmonary adenocarcinomas, prostatic proliferative lesions, bone fractures, kidney dysfunction, and hypertension, while the chronic effects of As consist of dermal lesions, peripheral neuropathy, skin cancer, and peripheral vascular disease.

[2] classified elements according to toxicity. Most of the very toxic and relatively accessible elements such as Cd and Cr are associated with the minerals mined in the study area. Heavy metals in stream sediments soils and water bodies occur as a result of the constituents of the ore and leachates from waste dumpsites among other sources. Heavy metals such as As, Cd, Pb exhibit extreme toxicity even at trace levels. Mine wastes (overburden and tailings) in the study area were used for building construction, as foundry sand for steel casting, road fill for road maintenance, for frying groundnuts and as recreational facilities in Jos wild life park for sand bathing by children [3]. Occasionally, the heaps of mine tailings are exposed to weathering and leaching. They thereby constitute a source of pollution to the nearby water bodies. Rain water could also wash off heavy metals in mine tailings, which as surface run off could pollute the water [4].

Water that accumulated in mine ponds was being used for various for domestic and industrial uses such as dry season irrigation farming, drinking, cooking and in the manufacture of soft and alcoholic drinks as well as recreational facilities such as sailing club and for agricultural purposes such as rock water fish farm [3]. It had therefore become necessary to determine the suitability of the water sources for these purposes.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Area

The study area is located within Jos South and Barkin Ladi Local Government Areas of Plateau State. It lies between latitude 9°32'N to 9°54'N and longitude 8°50'E to 8°55'E on Naraguta topographical sheets. It covers an area of about 356.4km$^2$. It lies in the North central geopolitical region of Nigeria. It is situated almost at the geographical centre of Nigeria, and about 179 km from Abuja, the nation's capital. Jos is linked by road, rail and air to the rest of the country [5].

The study area played host to a lot of mining activities by foreign companies which rendered the area derelict with numerous waste dumps and ponds. The impact of the past mining activities on the landscape became very devastating as several mined-out pits ranging from 10 m to about 40 m in depth were left with various hazardous effects. These mined-out pits which are filled with water are generally referred to as mine ponds. Abandoned mine ponds pose serious threat to human and animal lives [6,7]. The abandoned mine ponds and the numerous mounds of mine dumps and mill tailings resulting from mining activities that were carried out without consideration to the environment has led to soil, water and air pollution and loss of biodiversity. Today, hand methods by a single person or a group of people are used for mining near-surface, high grade deposit in the study area. The area was therefore described as a "disaster area" by the state government because of its devastated landscape as a result of indiscriminate mining activities over the years [8].

## 2.2 Water Sampling and Analyses

Water samples were collected in accordance with the provision of [9,10]. Heavy metals concentrations of samples were determined using the atomic absorption spectrophotometric (AAS) model AA 6800 in accordance with the provision of [11] at the Geochemistry Laboratory of the Nigerian Geological Survey Agency (NGSA), Kaduna. The results were compared with the international guidelines for drinking water quality presented by [12]. The suitability of the water samples for irrigation was determined by comparing the Electrical Conductivity (EC), Percentage Sodium (% Na) and Sodium Absorption Ratio (SAR) with Table 1.

**Table 1. Suitability of water for irrigation based on EC and % Na [13], SAR [14]**

| Quality parameter | Range of values | Description |
|---|---|---|
| EC | <250 | Excellent |
| | 250 – 750 | Good |
| | 750 – 2000 | Permissible |
| | 2000 – 3000 | Doubtful |
| | > 3000 | Unsuitable |
| SAR | < 10 | Excellent |
| | 10 – 18 | Good |
| | 18 – 26 | Doubtful |
| | > 26 | Unsuitable |
| %Na | < 20 | Excellent |
| | 20 – 40 | Good |
| | 40 – 60 | Permissible |
| | 60 – 80 | Doubtful |
| | > 80 | Unsuitable |

# 3. RESULTS AND DISCUSSION

## 3.1 pH and Heavy Metal Concentrations in Water Samples

Figs. 1-5 show the boxplots of the pH values as well as As, Cd, Cr and Pb concentrations respectively in water samples collected from the study area.

### 3.1.1 pH of Water Samples

The mean pH values of water samples collected from mine ponds, streams, wells and boreholes were 5.6, 6.5, 6.3 and 6.3 respectively (Fig. 1).

These values were lower than the mean pH values of the control samples as well as the recommended and maximum permissible limits of 6.8 and 7.0 set by WHO (2011) for pH of portable water. There were no significant differences between pH values of water samples collected from the study area and the mean control values, recommended limit of 7.0 and maximum permissible limit of 6.8 except for water samples collected from mine ponds.

### 3.1.2 Arsenic concentrations in water samples

The mean concentrations of arsenic of water samples collected from mine ponds, streams, wells and boreholes were 0.027 ppm, 0.013 ppm, 0.013 ppm and 0.013 ppm respectively (Fig. 2).

These values were higher than the mean arsenic concentrations of the control samples as well as the maximum permissible limits of 0.01 ppm set by WHO (2011) for portable water. There were however no significant difference between the arsenic concentrations water samples collected from the study area and the mean control value as well as the maximum permissible limit of 0.01 ppm except for water samples collected from the mine ponds.

### 3.1.3 Cadmium concentrations in water samples

The mean concentrations of cadmium in water samples collected from mine ponds, streams, wells and boreholes were 0.013 ppm, 0.0098 ppm, 0.007 ppm and 0.0079 respectively (Fig. 3).

These values were higher than the mean cadmium concentrations of the control samples as well as the maximum permissible limits of 0.003 ppm set by WHO (2011) for portable water. There were no significant differences between the cadmium concentrations water samples collected from the study area and the mean control value as well as the maximum permissible limit of 0.003 ppm except for water samples collected from the mine ponds.

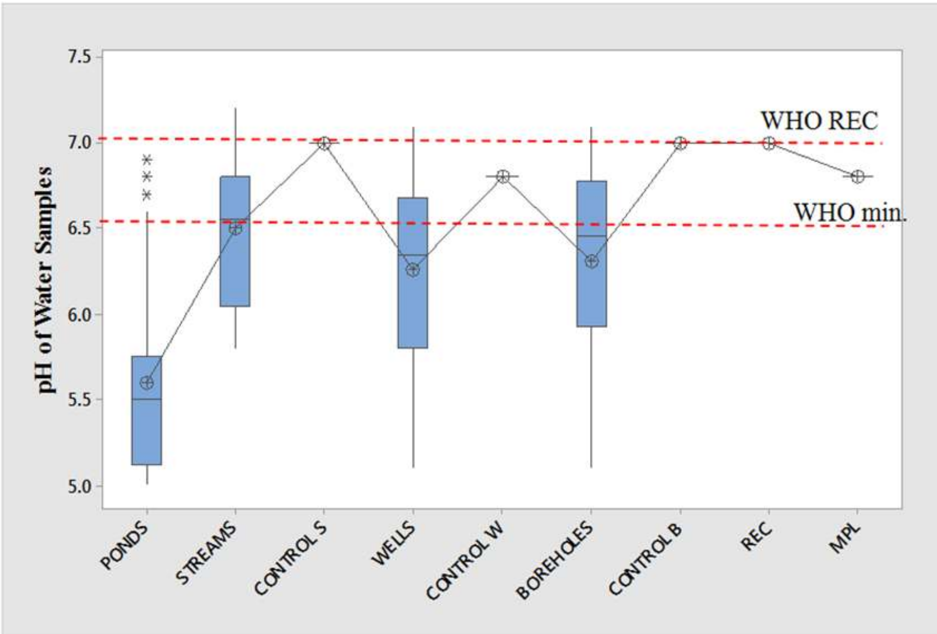


**Fig. 1. pH of water samples collected from the study area**

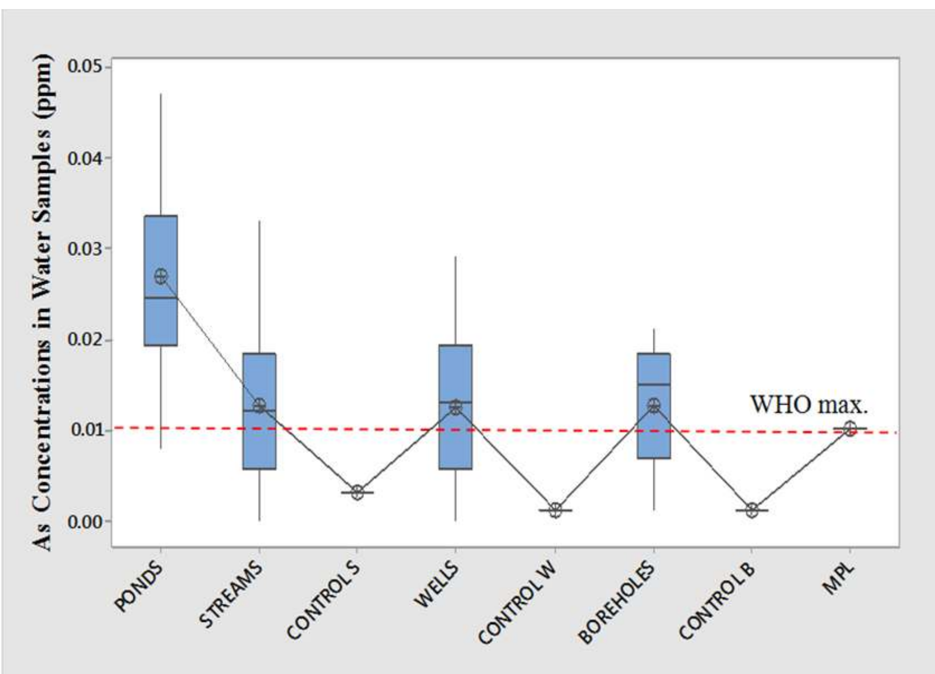


**Fig. 2. Arsenic concentrations in water samples collected from the study area**

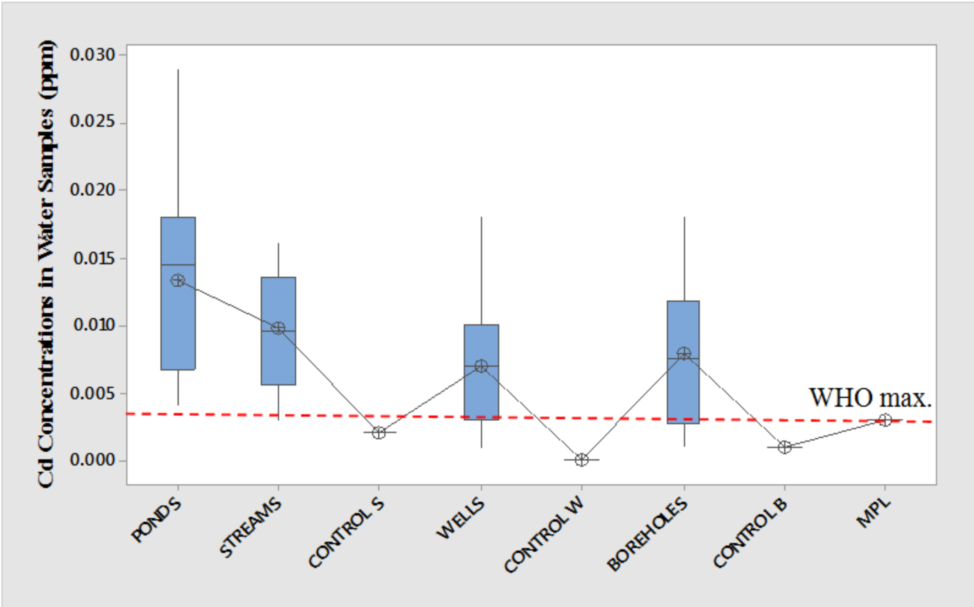


**Fig. 3. Cadmium concentrations in water samples collected from the study area**

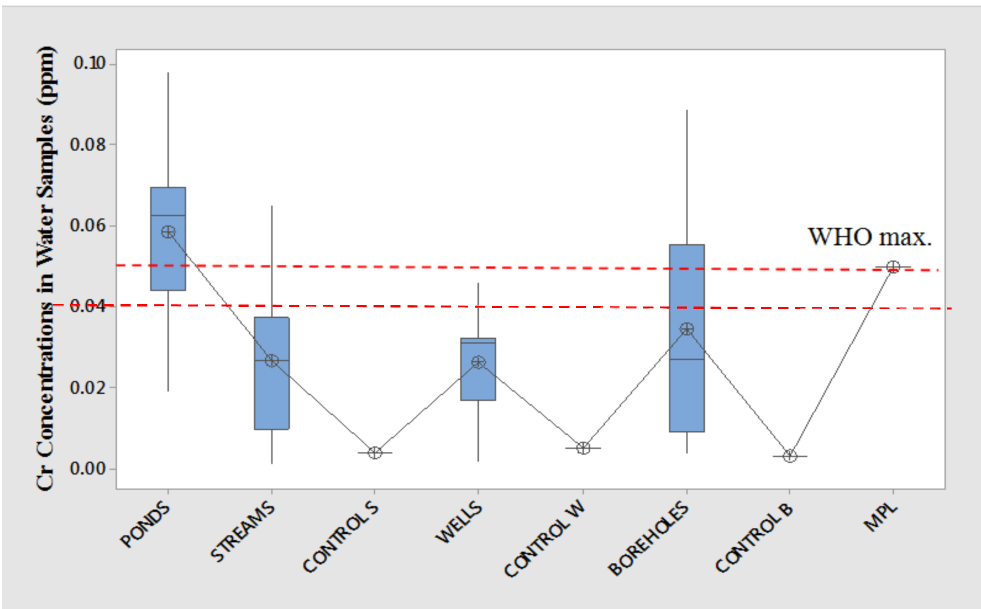


**Fig. 4. Chromium concentrations in water samples collected from the study area**

### 3.1.4 Chromium concentrations in water samples

The mean concentrations of chromium in water samples collected from mine ponds, streams, wells and boreholes were 0.06 ppm, 0.03 ppm, 0.03 ppm and 0.03 ppm respectively (Fig. 4 above). These values were within the maximum permissible limits of 0.05 ppm set by WHO (2011) for portable water except for water samples collected from mine ponds. There were no significant differences between the chromium concentrations water samples collected from the study area and the mean control value as well as the maximum permissible limit of 0.05 ppm.

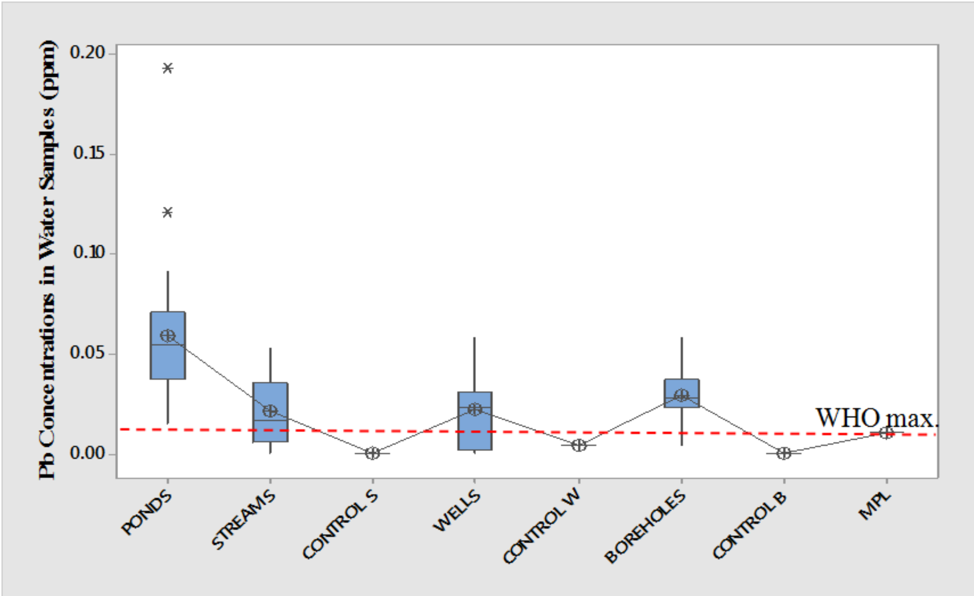


**Fig. 5. Lead concentrations in water samples collected from the study area**

**Table 2. Physicochemical parameters of water samples from the study area**

| | EC | K | Na | Ca | Mg | % Na | SAR |
|---|---|---|---|---|---|---|---|
| Mine ponds | 73.8 | 6.4 | 6.6 | 1.8 | 0.1 | 87 | 6.8 |
| Streams | 53.8 | 7.8 | 5.2 | 3.8 | 0.9 | 73 | 3.4 |
| Wells | 52.9 | 6.5 | 4.8 | 4.2 | 0.8 | 69 | 3 |
| Boreholes | 46.8 | 3.9 | 4.4 | 4.6 | 0.9 | 60 | 2.7 |
| Control Stream | 31.3 | 3.8 | 2.8 | 4.6 | 0.3 | 57 | 1.8 |
| Control Well | 29.9 | 2.1 | 1.5 | 4 | 0.1 | 46 | 1 |
| Control Borehole | 28.9 | 0.7 | 0.8 | 2.2 | 0.9 | 32 | 0.6 |

#### 3.1.5 Lead concentrations in water samples

The mean concentrations of lead in water samples collected from mine ponds, streams, wells and boreholes were 0.06 ppm, 0.02 ppm, 0.02 ppm and 0.03 ppm respectively (Fig. 5 above).

These values were higher than the mean lead concentrations of the control samples as well as the maximum permissible limits of 0.01 ppm set by WHO (2011) for portable water. There are no significant differences between the cadmium concentrations water samples collected from the study area and the mean control value as well as the maximum permissible limit of 0.01 ppm.

### 3.2 EC, % Na and SAR of Water Samples

The results of the Electrical Conductivity, Percentage Sodium (%Na) and Sodium Absorption Ratio (SAR) of water samples from the study area are presented in Table 2 above.

Electrical Conductivity (EC) ranged from 47–74 µS/cm. These water samples can therefore be used for farm irrigation. The % Na ranged between 60 and 87. This made the samples doubtful and unsuitable for farm irrigation. The sodium absorption ratio (SAR) ranged between 2.7-6.8. The samples were therefore classified as excellent in their use for farm irrigation.

## 4. CONCLUSION

It was discovered that the water bodies in the study area have unenviable concentration of examined heavy metals above the maximum allowable limits set by WHO (2011) except chromium that had an average concentration of 0.03 ppm in streams, wells and boreholes of the study area as a most of the water sources have been affected by the mining activities. This could have serious health implications on the consumers. This does not only pose threat to humans in that area but to the basic links in the ecosystem food web as well as the environmental niches and the ecosystem they comprise. The high % Na of 87, 73, 69 and 60 respectively in the water samples collected from mine ponds, streams, wells and boreholes also rendered the water samples unsuitable for irrigation purposes.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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