Assessment of Water Quality Using Heavy Metal Evaluation Index: A case study of Riruwai Mining Area, Kano State, Nigeria

Badamasi H.*, Hassan U.F., Adamu H.M., Baba N.M.

1Department of Chemistry, Federal University Dutse, Jigawa State, Nigeria
2Department of Chemistry, Abubakar Tafawa Balewa University, Bauchi State, Nigeria
3Department of Chemistry, Federal University of Lafia, Nasarawa State, Nigeria

Email: hamza.badamasi@fud.edu.ng

Abstract
Water quality status of drinking water with respect to seven heavy metals (As, Cd, Cr, Hg, Mn, Pb, and Zn) in the mining area of Riruwai, Kano State, Nigeria was investigated using the heavy metal evaluation index (HEI). A total of thirty-one (31) water samples were collected from five (5) sampling sites (underground mining site water, tap water, mining pond water, borehole, and the well water) in February 2020 (dry season) and August 2020 (rainy season). Heavy metal concentrations were determined using Atomic Absorption Spectrometer (AAS), and the measured concentrations were used to compute the HEI. The findings of the study revealed that the mean concentrations of heavy metals in the dry and rainy seasons decreased in the order of Zn > Mn > As > Cr > Cd > Pb > Hg with higher concentrations recorded in the rainy season. The concentrations of heavy metals exceeded the WHO (2011) and NSDWQ (2007) threshold limits in 90% of the samples analyzed. The HEI values in the sampling locations ranged from less than 10.00 (low-level pollution) to greater than 20.00 (high-level pollution) with 29 % of the samples recorded in the high-level pollution zone, 14 % in the medium pollution zone, and 57 % in the low-level pollution zone. This indicates that more than one-quarter of the samples are highly polluted by heavy metals. Therefore, it is recommended that water resources of the Riruwai mining area should not be used for human consumption, particularly the water from underground and mining pond samples, and measures to reduce heavy metals concentration levels should be implemented.

Keywords: Atomic Absorption Spectrometer, Heavy metal evaluation index, Riruwai, Water quality

*Author for Correspondence
Badamasi. H., Hassan U.F., Adamu H.M., Baba N.M., DUJOPAS 7 (2b): 33-41, 2021
INTRODUCTION

Water plays an important role in human health and well-being (Varol and Sekerci, 2018). Water resource contamination remains a major concern in several regions of developing countries, particularly in sub-Saharan regions where contaminated water poses significant risks to human health and the environment (Nienie et al., 2017). Rapid population growth, industrial development, agricultural practices, and mining activities has contributed to the water resources overutilization for many years, placing unprecedented pressure on global water supplies (Arulbalaji et al., 2019). In Nigeria, poorly regulated population growth, urbanization and inappropriate management of water resources have adversely impacted both its quality and quantity (Oyebande and Balogun, 1992).

Mining has made a significant contribution to Nigeria’s socioeconomic development. However, the accompanying environmental damage caused by mining activities is of serious concern (Adriano, 2001). Previous studies had demonstrated that the extensive mining activities have deleterious effects on the water resources due to the release of toxic heavy metals from various environmental components such as soils, sediments, surface water and groundwater (Tiwari et al., 2016). Heavy metal contamination of water bodies is a major concern due to their potential toxicity and accumulation in aquatic ecosystems (Tscheikner-Gratl et al., 2019).

Heavy metal evaluation index (HEI) have been widely used for the study of metal pollution in the surface water and groundwater (Tiwari et al., 2016). The HEI method uses the World Health Organization’s maximum admissible concentrations for drinking water to monitor the values of heavy metals (Prasanna et al., 2012), and it provides information on the overall quality and pollution status of surface water and groundwater (Mahato et al., 2014). HEI is a preferred method for heavy metal pollution assessment over indices such as the heavy metal pollution index (HPI) and contamination degree (Cd) because it produces better results than Cd and HPI (Kwaya et al., 2019). Because water pollution has direct repercussions for aquatic life and human health, monitoring and evaluation of water quality is extremely crucial (Maria-Alexandra et al., 2013). To the best of our knowledge, no scientific studies have been conducted to assess the water quality status of Riruwai water resources using HEI. Therefore, the present study is aimed to use HEI to investigate the groundwater quality status in relation to heavy metal pollution in the mining area of Riruwai, Kano State.

MATERIALS AND METHODS

Study Area
Riruwai town is located in Doguwa Local Government Area of Kano State, Northern Nigeria. It is situated between latitude of 10°43’97”N - 10°45’01”N and longitude of 8°43’3”E - 8°47’39” E, and covers an area of 129 km² (Figure 1). Riruwai has an estimated population of 150,645 people based on the 2006 census report (NPC, 2006). Riruwai is among the younger granite complexes in Nigeria. It is surrounded by a collection of metamorphic and calc-alkaline meta-igneous rocks that transitioned from Precambrian to Cambrian ages (Olasehinde et al., 2012). Riruwai is primarily a mining community. Large scale mining began in 1979, with nearly 900 tons of Zn-Sn ore production per day. After five years of operation, the mining activities were closed down. However, artisanal and small-scale mining activities are still taking place in the area (Abdullahi, 2017). Study of the minerology of area confirmed the presence large quantities of columbite, cassiterite, sphalerite, Wolframite, Zn, Sn, U, Th, Nb, Ta, Quartz and feldspar (Abdullahi, 2017).
Assessment of Water Quality Using Heavy Metal Evaluation Index: A case study of Riruwai Mining Area, Kano State, Nigeria

Badamasi H., Hassan U.F., Adamu H.M., Baba, N.M., DUJOPAS 7 (2b): 33-41, 2021

Figure 1: Map showing the study Area

Collection of Water Samples
A total of 31 samples were collected from 5 sampling stations during dry season (February, 2020) and rainy season (August, 2020). The sampling stations include: underground mining site water (RGW1), tap water (RGW2), mining pond water (RGW3), borehole (RGW4), and the well water (RGW5). The GPS of the sampling locations are presented in Table 1. The samples were collected in 1000 cm$^3$ polyethylene bottles (which were pre-washed in 20.00 % HNO$_3$) as recommended by the standard procedures (APHA, 1998) except for the determination of Hg where borosilicate glass bottles were used to minimize Hg$^{2+}$ lost and contamination as reported by Bravo et al. (2018). The collected samples were filtered, acidified with 65.00 % of HNO$_3$ to prevent the precipitation of metals, placed in an ice-box and transported to the laboratory for further analysis (APHA, 2005).

Table 1: GPS Coordinates of the Sampling Locations

<table>
<thead>
<tr>
<th>S/N</th>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RGW1</td>
<td>10°43'50.16''S</td>
<td>8°44'16.476''E</td>
</tr>
<tr>
<td>2</td>
<td>RGW2</td>
<td>10°43'50.16''S</td>
<td>8°44'16.476''E</td>
</tr>
<tr>
<td>3</td>
<td>RGW3</td>
<td>10°44'4.56''S</td>
<td>8°44'8.736''E</td>
</tr>
<tr>
<td>4</td>
<td>RGW4</td>
<td>10°44'13.2''S</td>
<td>8°44'6.468''E</td>
</tr>
<tr>
<td>5</td>
<td>RGW5</td>
<td>10°44'9.6''S</td>
<td>8°44'34.836''E</td>
</tr>
</tbody>
</table>

RGW1 = Underground water, RGW2 = Tap water, RGW3 = Mining pond, RGW4 = Borehole, RGW5 = Well water

Concentration and Digestion of Water Samples
About 500.00 cm$^3$ of the filtered water sample (in a 1000 cm$^3$ beaker) was placed on a hot plate and evaporated to 50.00 cm$^3$. The remaining solution was allowed to cool and transferred into a 250 cm$^3$ beaker. 10.00 cm$^3$ of concentrated HNO$_3$ was added and the resulting solution was heated slowly at 80 °C until a clear solution was obtained (APHA, 1998). The digested sample was allowed to cool, filtered and then transferred into a 100 cm$^3$ volumetric flask and made up to mark with more deionized water.
Determination of Heavy Metals in the Water Samples
The levels of As, Cd, Cr, Hg, Mn, Pb and Zn were determined in the digested samples using Angstrom Atomic Absorption Spectrometer (Model AAS-320) by selecting appropriate wavelength for each element.

Computation of Heavy Metal Evaluation Index (HEI)
HEI provides an overall quality of the water with respect to heavy metals (Edet and Offiong, 2002) and is expressed using the relation:

$$HEI = \sum_{i=1}^{n} \frac{H_c}{H_{mac}}$$

(1)

Where: $H_c$ is the measured concentrations of heavy metals, and $H_{mac}$ is maximum admissible concentration (MAC) of the $i$th parameter provided by World Health Organization (WHO, 2011).

Quality Control and Statistical Analysis
All samples were analyzed in triplicate, the standard solution of all metals were prepared by successive dilution of certified standards (1000 mg/dm$^3$) procured from Sigma Aldrich and calibration curve of each metal was constructed. Blank determinations were carried out to correct any background contamination from reagents, filter papers or other systemic sources of error. Statistical analyses were carried out using SPSS 23.0 (SPSS Inc., Chicago, USA). Graphs were plotted using OriginPro 2016 (Originlab Corporation, USA) software.

RESULTS AND DISCUSSION

Heavy Metal Concentration in the Water Samples
The mean concentrations of arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), manganese (Mn), lead (Pb) and zinc (Zn) in water samples from five different sampling sites: underground mining site water (RGW1), tap water (RGW2), mining pond water (RGW3), borehole (RGW5), and the well water (RGW5) during the dry and rainy seasons are depicted in Tables 2 and 3.

Table 2: Levels of Heavy Metal in Water Samples from Riruwai, during Dry Season

<table>
<thead>
<tr>
<th>Heavy Metals (mg/dm$^3$)</th>
<th>Sampling Locations</th>
<th>WHO (2011)</th>
<th>NSDWQ (2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RGW1</td>
<td>RGW2</td>
<td>RGW3</td>
</tr>
<tr>
<td>As</td>
<td>0.15 ± 0.02</td>
<td>0.02 ± 0.00</td>
<td>0.21 ± 0.02</td>
</tr>
<tr>
<td>Cd</td>
<td>0.11 ± 0.00</td>
<td>BDL</td>
<td>0.08 ± 0.01</td>
</tr>
<tr>
<td>Cr</td>
<td>0.13 ± 0.01</td>
<td>0.04 ± 0.01</td>
<td>0.25 ± 0.03</td>
</tr>
<tr>
<td>Hg</td>
<td>0.09 ± 0.03</td>
<td>BDL</td>
<td>0.07 ± 0.01</td>
</tr>
<tr>
<td>Mn</td>
<td>0.66 ± 0.02</td>
<td>0.14 ± 0.03</td>
<td>0.50 ± 0.01</td>
</tr>
<tr>
<td>Pb</td>
<td>0.06 ± 0.01</td>
<td>0.007 ± 0.00</td>
<td>0.08 ± 0.02</td>
</tr>
<tr>
<td>Zn</td>
<td>11.73 ± 2.61</td>
<td>5.26 ± 0.03</td>
<td>17.43 ± 0.07</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation (n = 3), BDL = Beyond detection limit, RGW1 = Underground mining area water samples, RGW2 = Tap water samples, RGW3 = Mining pond water samples, RGW4 = Borehole water samples, RGW5 = Well water samples, WHO = World health Organization, NSDWQ = Nigerian Standards for Drinking Water Quality.

Badamasi H., Hassan U.F., Adamu H.M., Baba, N.M., DUJOPAS 7 (2b): 33-41, 2021 36
The concentrations of As, Cd, Cr, Hg, Mn, Pb and Zn in the five sampling stations ranged as follows: As (BDL - 0.21), Cd (BDL - 0.11), Cr (BDL - 0.25), Hg (BDL - 0.09), Mn (0.12 - 0.66), Pb (0.003 - 0.08) and Zn (2.29 - 17.43) during the dry season. During the rainy season, the concentrations ranged as follows: As (0.005 - 0.35), Cd (0.001 - 0.15), Cr (0.001 - 0.32), Hg (BDL - 0.14), Mn (0.16 - 0.92), Pb (0.007 - 0.10) and Zn (2.85 - 20.03). The mean concentrations of heavy metals decreased in the order of Zn > Mn > As > Cr > Cd > Pb > Hg with higher concentrations of heavy metals recorded in the rainy season. This was in good agreement with results reported by Prasad et al. (2014) and Singh et al. (2018). In 90% of the samples analyzed for both seasons, the concentrations of all heavy metals exceeded the national and international standards for drinking water quality. Okegye and Gajere (2015) reported that most groundwater resources in the mining areas are usually contaminated by heavy metals. In another study, Biswas et al. 2017 studied the heavy metals pollution indices in irrigation and drinking water systems of Barapukuria coal mine area, Bangladesh, their findings indicate that most of the groundwater samples showed high concentrations of heavy metals.

**Heavy Metal Evaluation Index (HEI)**

The results of HEI for underground mining site water (RGW1), tap water (RGW2), mining pond water (RGW3), borehole (RGW5), and the well water (RGW5) during the dry and rainy seasons are shown in Figures 2-6.

<table>
<thead>
<tr>
<th>Heavy Metals (mg/dm³)</th>
<th>Sampling Locations</th>
<th>WHO (2011)</th>
<th>NSDWQ (2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RGW1</td>
<td>RGW2</td>
<td>RGW3</td>
</tr>
<tr>
<td>As</td>
<td>0.20 ± 0.03</td>
<td>0.03 ± 0.01</td>
<td>0.35 ± 0.04</td>
</tr>
<tr>
<td>Cd</td>
<td>0.15 ± 0.01</td>
<td>0.009 ± 0.00</td>
<td>0.11 ± 0.01</td>
</tr>
<tr>
<td>Cr</td>
<td>0.17 ± 0.03</td>
<td>0.06 ± 0.01</td>
<td>0.32 ± 0.05</td>
</tr>
<tr>
<td>Hg</td>
<td>0.14 ± 0.03</td>
<td>BDL</td>
<td>0.09 ± 0.00</td>
</tr>
<tr>
<td>Mn</td>
<td>0.92 ± 0.05</td>
<td>0.17 ± 0.01</td>
<td>0.73 ± 0.03</td>
</tr>
<tr>
<td>Pb</td>
<td>0.09 ± 0.03</td>
<td>0.03 ± 0.02</td>
<td>0.10 ± 0.04</td>
</tr>
<tr>
<td>Zn</td>
<td>14.05 ± 0.08</td>
<td>7.01 ± 0.03</td>
<td>20.03 ± 0.06</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation (n = 3), BDL = Beyond detection limit, RGW1 = Underground mining area water samples, RGW2 = Tap water samples, RGW3 = Mining pond water samples, RGW4 = Borehole water samples, RGW5 = Well water samples, WHO = World health Organization, NSDWQ = Nigerian Standards for Drinking Water Quality.

![Figure 2: Heavy Metal Evaluation Index of Riruwai Underground Water](image-url)
Assessment of Water Quality Using Heavy Metal Evaluation Index: A case study of Riruwai Mining Area, Kano State, Nigeria

Badamasi H., Hassan U.F., Adamu H.M., Baba, N.M., DUJOPAS 7 (2b): 33-41, 2021

Figure 3: Heavy Metal Evaluation Index of Riruwai Tap Water

Figure 4: Heavy Metal Evaluation Index of Riruwai Mining Pond Water

Figure 5: Heavy Metal Evaluation Index of Riruwai Borehole Water
The HEI values of arsenic ranged from 0.00 to 21.00, with the highest value recorded in RGW3 and lowest value obtained in RGW5 during the dry season. During the rainy season, the HEI values of arsenic spread from 0.50 to 35.00, with highest value obtained in RGW3 and the lowest value observed at RGW5. The HEI values of cadmium ranged from 0.00 (RGW2) to 2.20 (RGW1) during the dry season. During the rainy season, the values of cadmium ranged from 0.02 (RGW5) to 5.00 (RGW4). The HEI values of chromium were ranged from 0.00 to 83.33, with highest HEI value recorded in RGW3 and lowest obtained in RGW4. During the rainy season, the HEI values of chromium were ranged from 0.30 to 106.67, with the highest value observed in RGW3 and the lowest obtained in RGW5. The HEI values of mercury ranged from 0.00 to 15.00, with highest value recorded in RGW3 and the lowest obtained in RGW5 during the dry season. During the rainy season, the HEI values of mercury ranged from 0.00 to 23.35, with highest value recorded in RGW1 and the lowest value (0.00) obtained in RGW2 and RGW5. The HEI values of manganese ranged from 0.60 (RGW5) to 2.50 (RGW3) and 0.80 (RGW5) to 4.60 (RGW1) during the dry and rainy seasons respectively. The HEI values of lead ranged from 0.30 to 8.00 and 5.00 to 11.00 during the dry and rainy seasons respectively. The HEI values of zinc ranged from 7.63 to 58.10, with the highest value recorded in RGW3 and the lowest observed at RGW5 during the dry season. During the rainy season, the HEI values of zinc were ranged from 9.50 (RGW5) to 66.78 (RGW3). This findings was consistent with those of Prasad et al. (2014) and Boateng et al. (2015). Ghaderpoori et al. (2018) proposed HEI pollution level classification of surface and groundwater. According to their classification, HEI of less than 10.00 indicates low-level pollution. HEI values between 10.00 and 20.00 indicate medium-level pollution, while HEI values greater than 20.00 indicate high-level pollution. In this study, the HEI of heavy metals in the five sampling locations ranged from low-level to high-level of pollution, with higher values recorded in the rainy season. Twenty-nine (29) percent of samples are recorded in high-level pollution zone, fourteen (14) percent in the medium pollution zone, and fifty seven (57) percent are in the low-level pollution zone. This indicates that more than one-quarter of the samples analyzed are highly polluted by heavy metals, which is deeply worrisome. Kwaya et al. 2019 report a similar trend when they investigated the heavy metals pollution indices of the groundwater of Maru town, Zamfara state, Northwestern Nigeria.

CONCLUSION
The findings of the study revealed that the mean concentrations of the heavy metals in the dry and rainy seasons decreased in the order of Zn > Mn > As > Cr > Cd > Pb > Hg, with
higher concentrations of heavy metals recorded in the rainy season. In 90% of the samples analyzed, the concentrations of all heavy metals exceeded the WHO and NSDWQ threshold limits for both seasons. HEI values in the sampling locations ranged from low to high levels, with higher values observed during the rainy season. More than one-quarter of the samples analyzed are highly polluted by heavy metals, which is highly concerning. Thus, water resources from the Riruwai mining area, particularly water from underground and mining pond samples, should not be used for human consumption, and measures should be taken to reduce heavy metals concentration levels.

REFERENCES


Assessment of Water Quality Using Heavy Metal Evaluation Index: A case study of Riruwai Mining Area, Kano State, Nigeria


