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Human health risk impact assessment of some heavy metals in groundwater around abandoned barite mine sites in parts of Benue state, Nigeria

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Abstract

An evaluation of the impacts of various heavy metals in the water on the hazard to human health was undertaken to ascertain whether the water from hand-dug wells close to abandoned barite mines in the research region was safe for human consumption. Analyses of the health risks connected to heavy metal exposure in humans through diet, skin absorption, inhalation, and ingestion are frequently used to assess these concerns. Chromium (Cr), Cadmium (Cd), Barium (Ba), Manganese (Mn), Lead (Pb), Arsenic (As), Nickel (Ni), and Zinc were evaluated for the research area's Chronic Daily Intake (CDI), Hazard Quotients (HQ), and Hazard Index (HI) (Zn). Four (4) water samples from hand-dug wells close to abandoned barite mining sites were tested for heavy metals. The Chronic Daily Intake (CDI), Hazard Quotient (HQ), and Hazard Index (HI) for adults and children were calculated using non-carcinogenic risks. The skin, the lungs, and the lips are the three different entry points for exposure. Calculate the exposure as if it were a chronic daily use. Hazard Index (HI) values for all of the PTEs (Cr, Cd, Ba, Mn, Pb, As, Ni, and Zn) evaluated in this study ranged from 7.78x10-5 to 4.97x10-2 in the water from the hand-dug wells. The findings suggest that a non-carcinogenic adverse health risk threshold of 1 is appropriate. Prolonged exposure to low quantities of heavy metals may result in mortality, deformities, delayed development, and diminished fertility. Organs may be quickly eliminated by acute exposure to large amounts of heavy metals.

Keywords: Health risk; Heavy metals; Abandoned barite mines; Hazard; Mortality rate; Deformities

1. Introduction

One of the main global causes of heavy metal contamination is mining. During substantial mineral extraction, a significant number of hazardous dust particles and volatile components are actually discharged into the environment, significantly harming aquatic and terrestrial ecosystems (Jordán & D'Alessandro, 2004). It is important to note that mining often only impacts a limited area of land (Nriagu and Pacyna, 1988; Salomons, 1995). Due to their chemical makeup, which is primarily associated to a very low amount of organic materials, a poor nutritional content, and a very high concentration of metals, mining deposits provide a hostile environment that prevents plant development (Wong *et al.,* 1998; Boularbah *et al.,* 2006a, 2006b; El Khalil *et al.,* 2008; Probst *et al.,* 2009). As a result of their high susceptibility to wind and water erosion in the absence of vegetation, these materials are a frequent source of pollution in the area. On the land, the air, the water, and the scenery in particular, mining may have a negative impact on the environment. Soil deterioration is one of the mining industry's most obvious side effects. For instance, soils near mining sites are often contaminated with multi-metal pollutants (Cd, Cu, Zn, and Pb), which restricts the usage of the land (Simón *et al*., 1999; Boularbah *et al*., 2006a; El Khalil *et al*., 2008; El Hamiani *et al*., 2010; El Hamiani *et al*., 2015).

In the research region, the health hazards connected to domestic water usage and consumption were evaluated. Despite the fact that certain of these metals may be required for humans, when their levels surpass the allowed limits, they may nevertheless pose a danger to those same individuals (Adamu *et al.,* 2014). Humans may be directly or indirectly

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exposed to such harmful heavy metals (Ayantobo *et al.,* 2014). Indirect exposure is caused through bioaccumulation, while direct exposure is caused by inhalation, cutaneous absorption, or water consumption (USEPA, 2011). Arsenic, mercury, and cadmium are three heavy metals that have recently attracted a lot of media attention. They could harm the environment, the mental system, the digestive system, the liver, and the kidneys. They might be discovered in water sources as well. The major cause for worry is that the only sources of household water for the people living in the research region are hand-dug wells and abandoned mining ponds. The main goals of this research are to measure the amount of heavy metals in groundwater and then investigate the potential health risks to people living in the study location.

1.1. Statement of problem

Because they are dangerous to both human health and the environment, abandoned mines are an issue for people all over the globe. In abandoned or dormant mines, exploration, mining, or production often stop and are not revived. Because toxins and heavy metals may build up in the body over time and harm reproduction or cause death, life in polluted water is very perilous. The health of the community is impacted by mining operations on a variety of different levels. Groundwater heavy metal poisoning is still a significant problem since exposure to these metals may harm both human receptors and many ecosystems. Weathering and man-made activities like mining, both of which result in the release of heavy metals into the environment, are characteristics of the study area in Benue State. In numerous locations, mining has caused significant landscape damage, which is likely a factor in the nearby water pollution. Several metals that are harmful to plants, dangerous to humans, and capable of bioaccumulation are released during this mining process.

1.2. Study location and research area accessibility

The investigation was concentrated on four local government districts in southern Benue State, which includes a number of closed barite mining operations. The sample sites are the only abandoned barite mines that are still in existence in the state of Benue (Fig 1). The mining regions are dispersed throughout the various slopes of four local authorities. The bulk of the locations have been abandoned by 2012. The first mining operations started in 2010. The main route in the region connects Makurdi to Gboko, Lessel, and Konshisha. The road and a system of walkways make the location simple to reach.

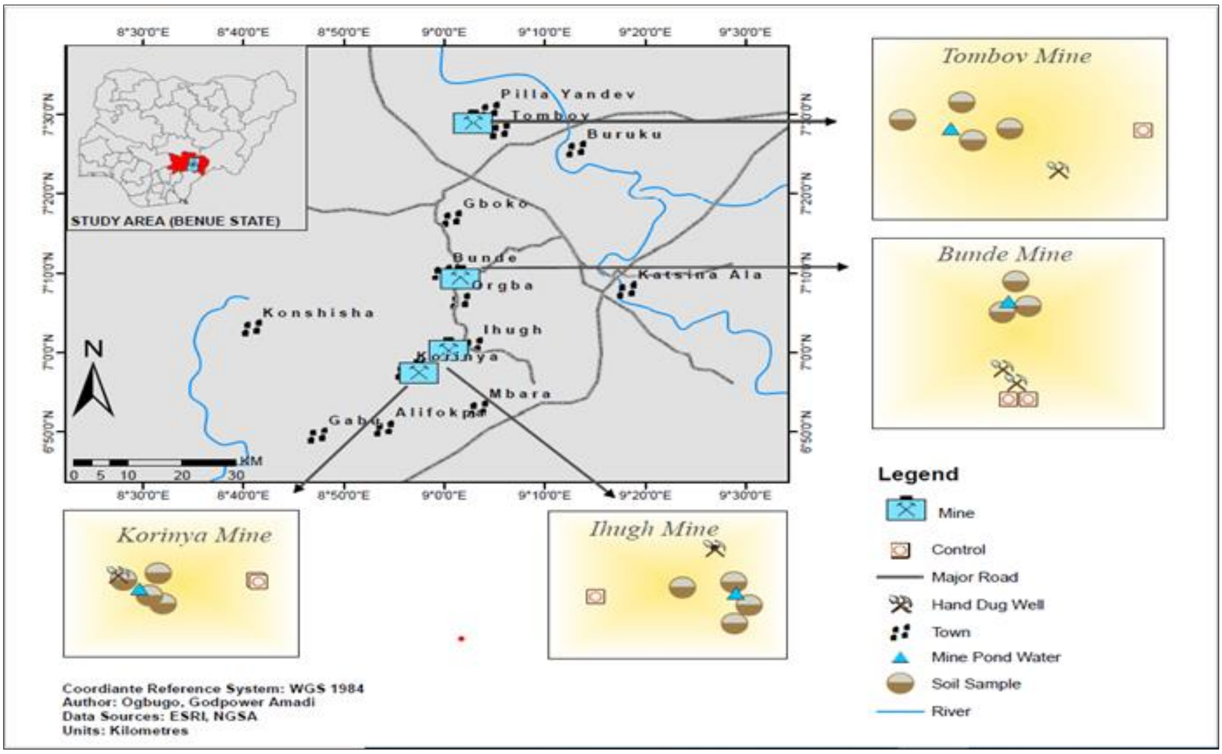

Figure 1 Map of Study Area

2. Material and methods

2.1. In-situ Tests

On the work site, they had employed every portable tool available. Additional than temperature, pH, salinity, and electrical conductivity, water has other properties. While immersed, the device's calibration was read and recorded.

2.2. Gathering and evaluating samples

Water samples for analysis were taken from the hand-dug wells that were close to the defunct barite mining sites. Total dissolved solids (TDS), pH, and temperature were all measured on the spot. All of the samples were gathered in low density polyethylene bottles and processed in the lab using a 0.45 m membrane. The water samples were acidified to a pH of 2 using 0.5ml of pure HNO3acid in order to preserve them for trace element analysis.

2.3. Human Health Risk Assessment

The common use of heavy metal health risk assessments allows for the computation of carcinogenic and non-carcinogenic dangers to humans through dietary exposure and intake. The person's chronic daily intake is calculated using three separate exposure routes: oral ingestion, inhalation, and skin contact.

Risk assessment, according to Adamu *et al.,* (2014) is the process of figuring out how often an event will occur and how severe the negative health impacts will probably be if people are exposed to environmental dangers over a certain time period (2015). Health risk assessments of each potentially hazardous metal are conducted with the goal of establishing the degree of risk and categorizing the material as either likely to cause cancer or not (Lim *et al.,* 2008). For both adults and children, the reference dose (RfD) and the slope factor (SF) are used to calculate the risk of cancer and non-carcinogen, respectively. The toxicity indices of each potentially dangerous component are shown in Table 1. IRIS USEPA 2011 The expected duration, frequency, and level of human exposure to each potentially harmful metal are reported as chronic daily intake and calculated using:

$$\mathrm{CDI}_{\mathrm{ingestion}} = \frac{C_W \ x\ IngR\ x\ EF\ x\ ED}{BW_A\ x\ AT} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Where CDI is the maximum daily exposure (mg/l) to heavy metals for a consumer. Ingestion Rate, Exposure Frequency, Exposure Duration, Body Weight, and ETA are the acronyms for these terms, respectively. Cw (mg/l) is a unit of measurement for the concentration of heavy metals in groundwater.

Table 1 Input parameters used in evaluating CDI values

Factor/parameter	Symbol	Units	Adult	Children
Exposure Duration	ED	Years	24	6
Exposure frequency	EF	years	350	350
Averaging time	AT(ED x 365)	days	8760	2190
Body weight	BW	Kg	70	15
Ingestion rate	Ing R	L/day	2	1

Source: USEPA (2004, 2006)

2.3.1. Hazard Quotient (HQ)

The last stage in analyzing health issues is characterizing hazards. At this point, the analyses of dose response and exposure are integrated to illustrate the likelihood that effects may materialize in individuals under certain exposure settings. The following are some examples of how the hazard quotient depicts the severity of injury:

The Hazard Quotient (HQ) for non-carcinogenic risk was calculated by the USEPA (1999) using the following formula:

$$\text{Hazard quotient (HQ)} = \frac{CDI}{RfD} \quad \ldots\ldots\ldots\ldots(2)$$

Where CDI is the daily dose of heavy metals (mg/l) to which consumers may be exposed, and RfD is the reference dose, which is the daily dosage that enables a person to sustain this amount of exposure for a prolonged period of time without experiencing any adverse effects.

Table 2 The oral toxicity reference dose (RfD) values for the heavy metals

S/n	Metals	Oral RfD (mg/kg/day)	Oral SF (mg/kg/day)
1	As	3.0 × 10−4	1.5
2	Cd	5.0 × 10−4	0.38
3	Cr	3.0 × 10−3	0.5
4	Ba	0.2	n. a
5	Pb	3.5 × 10−3	0.0085
6	Ni	2.0 × 10−2	0.91
7	Zn	0.3	n. d
8	Mn	1.4 × 10−1	n. d

n.a = not available; n.d = not detecteble

2.4. Hazard Index

Since there are several toxicants present, the interactions are taken into consideration. It is believed that the cumulative toxic risks are increased when potentially dangerous substances are present in the same medium. By summing the HQs, the Hazard Index, which indicates the overall hazardous risk, may be computed (Kolluru *et al.*, 1996; Paustenbach, 2002; Zheng *et al.,* 2010).

HQ is calculated using the formula

$$HI = \sum HQ_i = \sum \frac{CDI_i}{RfD_i} \text{ ………….(3)}$$

Where HI is the hazard index for the overall hazardous risk and n is the total number of metals under consideration. It is assumed that the chemical or exposure technique has few non-carcinogenic adverse effects if HI 1.0.

3. Results

3.1. Chronic Daily Intake

The Chronic Daily Intake (CDI) of the assessed heavy metals of in the study area is presented in Table 3. The Chronic Daily Intake values for adult and children respectively recorded for Pb in Tombo was ($9.51x10^{-9}$ and $6.39x10^{-10}$mg/kg/day), Korinya ($1.18x10^{-8}$ and $5.52x10^{-8}$mg/kg/day) and Ihugh ($3.42x10^{-9}$and $1.60x10^{-8}$mg/kg/day) and Bunde ($1.15x10^{-8}$ and $5.34x10^{-8}$mg/kg/day) respectively

The Chronic Daily Intake values of Ba for adult and Children in Tombo was ($7.12x10^{-10}$and$3.32x10^{-8}$ mg/kg/day), Korinya ($1.81x10^{-9}$ and $8.44x10^{-9}$mg/kg/day), Ihugh ($1.92x10^{-10}$ and $8.95x10^{-10}$mg/kg/day) and Bunde ($5.75x10^{-10}$ and $4.35x10^{-7}$mg/kg/day) respectively.

The Chronic Daily Intake values of Cd for adult and children in Tombo ($5.32x10^{-8}$ and $2.60x10^{-7}$ mg/kg/day), Korinya ($9.12x10^{-8}$ and $1.32x10^{-7}$mg/kg/day), Ihugh ($5.15x10^{-8}$ and $1.66x10^{-7}$mg/kg/day) and Bunde ($4.79x10^{-8}$ and $1.26x10^{-7}$mg/kg/day) respectively.

The Chronic Daily Intake values of Cr adult and children in Tombo was ($5.5x10^{-8}$ and $2.71x10^{-8}$ mg/kg/day), Korinya ($2.82x10^{-8}$ and $9.38x10^{-8}$ mg/kg/day), Ihugh ($6.36x10^{-8}$ and $2.94x10^{-7}$ mg/kg/day) and Bunde ($2.71x10^{-8}$ and $2.25x10^{-7}$ mg/kg/day) respectively

The Chronic Daily Intake values of Mn adult and children in Tombo was $3.42x10^{-8}$ and $1.60x10^{-7}$, Korinya $4.40x10^{-8}$ and $2.05x10^{-7}$, Ihugh $5.68x10^{-8}$ and $3.77x10^{-7}$ and Bunde $5.88x10^{-7}$ and $2.75x10^{-7}$ respectively

The Chronic Daily Intake values of As adult and children in Tombo was 1.10x10^{-10} and 2.56x10^{-10} mg/kg/day, Korinya 0.00x10^{+00} and 1.28x10^{-10}mg/kg/day, Ihugh 8.22x10^{-11}and 3.84x10^{-10} mg/kg/day and Bunde 0.00x10^{+00} and 1.28x10^{-10} mg/kg/day respectively

The Chronic Daily Intake values of Ni adult and children in Tombo was 7.40x10^{-10} and 1.28x10^{-10} mg/kg/day, Korinya 3.84x10^{-10} and 1.79x10^{-9} mg/kg/day, Ihugh 9.86x10^{-10} and 4.60x10^{-9}mg/kg/day and Bunde 6.03x10^{-10} and 2.81x10^{-9} mg/kg/day respectively

The Chronic Daily Intake values of Zn adult and children in Tombo was (1.44x10^{-8} and 1.91x10^{-7} mg/kg/day), Korinya (2.53x10^{-8} and 1.18x10^{-7} mg/kg/day), Ihugh (1.09x10^{-8}and 5.10x10^{-8} mg/kg/day) and Bunde (2.99x10^{-8} and 1.39x10^{-7} mg/kg/day) respectively

Table 3 Chronic Daily Intakes (CDI) of the heavy metals at the various locations.

Metals	**Tombo**		**Korinya**		**Ihugh**		**Bunde**	
	Adults	**Children**	**Adults**	**Children**	**Adults**	**Children**	**Adults**	**Children**
Cr	5.5x10^{-8}	2.48x10^{-5}	2.82x10^{-8}	9.38x10^{-8}	6.36x10^{-8}	2.94x10^{-7}	2.71x10^{-8}	2.25x10^{-7}
Cd	5.32x10^{-8}	2.60x10^{-7}	9.12x10^{-8}	1.32x10^{-7}	5.15x10^{-8}	1.66x10^{-7}	4.79x10^{-8}	1.26x10^{-7}
Ba	7.12x10^{-10}	3.32x10^{-8}	1.81x10^{-9}	8.44x10^{-9}	1.92x10^{-10}	8.95x10^{-10}	5.75x10^{-10}	4.35x10^{-7}
Mn	3.42x10^{-8}	1.60x10^{-7}	4.40x10^{-8}	2.05x10^{-7}	5.68x10^{-8}	3.77x10^{-7}	5.88x10^{-7}	2.75x10^{-7}
Pb	9.51x10^{-9}	6.39x10^{-10}	1.18x10^{-8}	5.52x10^{-8}	3.42x10^{-9}	1.60x10^{-8}	1.15x10^{-8}	5.34x10^{-8}
As	1.10x10^{-10}	2.56x10^{-10}	0.00x10^{+00}	1.28x10^{-10}	8.22x10^{-11}	3.84x10^{-10}	0.00x10^{+00}	1.28x10^{-10}
Ni	7.40x10^{-10}	1.28x10^{-10}	3.84x10^{-10}	1.79x10^{-9}	9.86x10^{-10}	4.60x10^{-9}	6.03x10^{-10}	2.81x10^{-9}
Zn	1.44x10^{-8}	1.91x10^{-7}	2.53x10^{-8}	1.18x10^{-7}	1.09x10^{-8}	5.10x10^{-8}	2.99x10^{-8}	1.39x10^{-7}

3.2. Hazard Quotient

The Hazard Quotients (HQ) of the assessed heavy metals are presented in Table 4. The Hazard Quotient values of Pb for adult and children are 2.72x10^{-6} and 1.83x10^{-7} at Tombo, Korinya 3.38x10^{-6} and 1.58x10^{-5} Ihugh 9.78x10^{-7} and 4.57x10^{-6} and Bunde 3.27x10^{-6} and 1.53x10^{-5}.

The Hazard Quotient values of Zn for adult and children are 4.79x10^{-8} and 6.38x10^{-7} respectively at Tombo, 8.42x10^{-8} and 3.93x10^{-7} at Korinya, 3.64x10-8 and 1.70x10-7 at Ihugh and 9.95x10^{-8} and 4.65x10^{-7} at Bunde.

The Hazard Quotient values of Cd for adult and children are 1.77x10^{-5} and 8.65x10^{-5} at Tombo, 3.04x10^{-5} and 4.39x10^{-5} at Korinya, 1.72x10^{-5} and 5.55x10^{-5} at Ihugh and 1.60x10^{-5} and 4.21x10^{-5} at Bunde respectively.

The Hazard Quotient values of Cr for adult and children respectively are 1.11x10^{-4} and 4.96x10^{-2} in Tombo 5.65x10^{-5} and 1.88x10^{-4} in Korinya, 1.27x10^{-4} and 5.88x10^{-4} at Ihugh and 5.42x10^{-5} and 4.49x10^{-4} at Bunde respectively.

The Hazard Quotient values of Ba for adult and children respectively are (3.56x10^{-9} and 1.66x10^{-7})in Tombo, (9.04x10^{-9} and 4.22x10$^{-8)}$ in Korinya, (9.59x10^{-10} and 4.47x10^{-9})at Ihugh and (2.88x10^{-9} and 2.17x10^{-6}) at Bunde respectively.

The Hazard Quotient values of Mn for adult and children respectively are 2.45x10^{-7} and 1.14x10^{-6} in Tombo, 3.14x10^{-7} and 1.47x10^{-6} in Korinya, 4.06x10^{-7}and 2.69x10^{-6} at Ihugh and 4.20x10^{-6} and 1.96x10^{-6} at Bunde respectively.

The Hazard Quotient values of As for adult and children respectively are 3.01x10^{-8} and 1.41x10^{-7} in Tombo, 0.00x10^{+00} and 4.26x10^{-7} in Korinya, 2.74x10^{-7} and 1.28x10^{-6} at Ihugh and 0.00x10^{+00} and 4.26x10^{-7} at Bunde respectively.

The Hazard Quotient values of Ni for adult and children respectively are 3.70x10-8 and 6.39x10-9 in Tombo, 1.92x10^{-8} and 8.95x10^{-8} in Korinya, 4.93x10^{-8} and 2.30x10^{-7} at Ihugh and 3.01x10^{-8}and 1.41x10^{-7}at Bunde respectively.

3.3. Hazard Index

The hazard indices (HI) recorded for adults and children in the four different locations were far less than threshold value (1). Hence, the non-carcinogenic adverse effect is negligible.

Table 4 Hazard Quotient (HQ) and Hazard Index (HI) of heavy metals at the study area

Metals	**Tombo**		**Korinya**		**Ihugh**		**Bunde**	
	Adult	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**
Cr	$1.11x10^{-4}$	$4.96x10^{-2}$	$5.65x10^{-5}$	$1.88x10^{-4}$	$1.27x10^{-4}$	$5.88x10^{-4}$	$5.42x10^{-5}$	$4.49x10^{-4}$
Cd	$1.77x10^{-5}$	$8.65x10^{-5}$	$3.04x10^{-5}$	$4.39x10^{-5}$	$1.72x10^{-5}$	$5.55x10^{-5}$	$1.60x10^{-5}$	$4.21x10^{-5}$
Ba	$3.56x10^{-9}$	$1.66x10^{-7}$	$9.04x10^{-9}$	$4.22x10^{-8}$	$9.59x10^{-10}$	$4.47x10^{-9}$	$2.88x10^{-9}$	$2.17x10^{-6}$
Mn	$2.45x10^{-7}$	$1.14x10^{-6}$	$3.14x10^{-7}$	$1.47x10^{-6}$	$4.06x10^{-7}$	$2.69x10^{-6}$	$4.20x10^{-6}$	$1.96x10^{-6}$
Pb	$2.72x10^{-6}$	$1.83x10^{-7}$	$3.38x10^{-6}$	$1.58x10^{-5}$	$9.78x10^{-7}$	$4.57x10^{-6}$	$3.27x10^{-6}$	$1.53x10^{-5}$
As	$3.65x10^{-7}$	$8.52x10^{-7}$	$0.00x10^{+00}$	$4.26x10^{-7}$	$2.74x10^{-7}$	$1.28x10^{-6}$	$0.00x10^{+00}$	$4.26x10^{-7}$
Ni	$3.70x10^{-8}$	$6.39x10^{-9}$	$1.92x10^{-8}$	$8.95x10^{-8}$	$4.93x10^{-8}$	$2.30x10^{-7}$	$3.01x10^{-8}$	$1.41x10^{-7}$
Zn	$4.79x10^{-8}$	$6.38x10^{-7}$	$8.42x10^{-8}$	$3.93x10^{-7}$	3.64x10-8	1.70x10-7	$9.95x10^{-8}$	$4.65x10^{-7}$
HI	$1.32x10^{-4}$	$4.97x10^{-2}$	$9.07x10^{-5}$	$2.50x10^{-4}$	$1.46x10^{-4}$	$6.53x10^{-4}$	$7.78x10^{-5}$	$5.12x10^{-4}$

4. Discussion

Table 3 displays the findings of the CDI estimates for the levels of Cr, Cd, Ba, Mn, Pb, As, Ni, and Zn in groundwater from hand-dug wells. For each of the four study locations, the lead oral reference dose (RfD) values for both adults and children were lower than the lead CDI values. Low lead CDI levels for Pb, Zn, and As were found in hand-dug wells, but not for Cr, Cd, Ba, Mn, or Ni, which were not examined.

Table 4 displays the assessment of the risks of heavy metals on human health at each of the four study sites. A limit of tolerable non-carcinogenic adverse health risk was reached for each heavy metal studied, including Cr, Cd, Ba, Mn, Pb, As, Ni, and Zn, with Hazard Quotients (HQ) values lower than 1. Abara *et al.* (2019) demonstrated in a second study that the concentrations of Pb, Zn, and As in groundwater from hand-dug wells close to abandoned barite mining sites were bearable and not carcinogenic.

Hazard Index (HI) values for all of the PTEs (Cr, Cd, Ba, Mn, Pb, As, Ni, and Zn) evaluated in this study ranged from 7.78x10-5 to 4.97x10-2 in the water from the hand-dug wells. The findings suggest that a non-carcinogenic adverse health risk threshold of 1 is appropriate. According to Lewis and Clark (1996), prolonged exposure to low quantities of heavy metals may result in mortality, deformities, delayed development, and diminished fertility. Organs may be quickly eliminated by acute exposure to large amounts of heavy metals.

5. Conclusion

In this study, the risks to human health associated with accessing groundwater supplies and the impacts of abandoned barite mines on those sources were also examined. Every abandoned mine was near the residences of a hamlet, often barely a hundred meters away. The WHO's 2007 Nigerian Standard for Drinking Water Quality and the study's heavy metal requirements were both fulfilled (2017). Groundwater from hand-dug wells is an important source of domestic water in the study area. No single heavy metal was found to be especially detrimental according to the health risk assessment, and their combined effects did not reach the hazard index threshold value of 1.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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