



An Evaluative Study on Metallic Concentration in Different Ground and Industrial Water Sources in Jos South Local Government Area of Plateau State, Nigeria

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Authors' contributions

This work was conceptualized by authors YD and OA. Authors YD and OA designed and carried out the geological mapping of the study area and also wrote the protocol and first draft of the manuscript. Authors IG and SWK performed the statistical analysis. Author IG and SWK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The present study investigated the concentrations and human health risk of certain metallic elements like cadmium (Cd), chromium (Cr) and Lead (Pb), Zinc (Zn), magnesium (Mg), calcium (Ca) and copper (Cu) in ground water, wells, mining ponds and industrial effluent in Jos South Local Government Area of Plateau state, Nigeria.

Study Design: The work is descriptive.

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Methodology: Water samples were obtained from our study areas and carefully filtered using Whatman filter paper into a 250ml conical flask to obtain a clear filtrate. The p^H of the filtrate was determined using p^H meter 3510. Heavy metal determination was done by atomic absorption spectrophotometry (AAS) after digestion of water samples with 5% nitric acid (HNO_3).

Results: Results obtained indicated that mining ponds, ground water, industrial effluents as well as factory-based sachet water, all contained Pb(1.320 to 1.440 mg/l),Cr(-0.0046 to 0.318 mg/l), Cd(1.320 to 1.440 mg/l), Zn(-0.0106 to 0.5327 mg/l), Cu(0.4359 to 0.7838 mg/l), Mg(5.789 to 22.830 mg/l), Ca(15.241 to 19.706 mg/l) at a concentration that is significantly ($P= 0.05$) higher compared to the WHO allowable concentrations for drinking water which could be attributed to inadequate scientific method used in the processing of water and also chemical materials used for bagging and bottling the water for market supply.

Conclusion: Metallic contaminants are inevitable components of water from our study area and packaging materials for supply of bottle water are themselves a major risk factor and alternative source of metallic contaminant leaching into factory based sachet water.

Keywords: Heavy metals; industrial effluent; factory-based water.

1. INTRODUCTION

In agricultural, municipal and urban runoff, toxic metals are typically present, which can be hazardous to human beings and biotic life. Increased urbanization and industrialization in our waterways are responsible for an increased level of trace metals, especially heavy metals. There are more than 50 elements that can be labelled as heavy metals, 17 of which are known to be very toxic and relatively available [1]. Heavy metals are indestructible and have a detrimental impact on marine life, animals and humans in most instances. [2]. When released into the atmosphere, many harmful chemical elements accumulate in the soil and sediments of water bodies [3]. Heavy metals have a major impact on aquatic flora & fauna, which reaches the food chain by biomagnification and eventually affects human beings as well [4]. The essential trace elements are heavy metals such as copper, but toxicity is shown if there are excess concentrations in drinking water. Also, at low concentrations, cadmium is highly toxic and can bio-accumulate in animals and habitats and has a biological half-life of 10 to 33 years in the human body. Long-term cadmium exposures often cause renal damage. In most countries and international organisations, cadmium is considered to be one of the priority pollutants for monitoring. Water toxicity is directly linked to the degradation of water. The consistency of land and surface water supplies should be continually evaluated [5]. In drinking water, the known lethal effects of heavy metal toxicity include diminished or decreased mental and central nervous capacity and lower energy levels. They also cause blood composition abnormalities, seriously affecting vital organs such as the kidneys and

liver [6]. Long term exposure to these metals results in physical, muscular, neurological degenerative processes that cause Alzheimer's disease (brain disorder), Parkinson's disease (brain degenerative disease), muscular dystrophy (progressive weakening of the skeletal muscle), multiple sclerosis (a nervous system disease that affects brain and spinal cord). Lead is also one of the most common heavy metals found in drinking water, displaying general metabolic poison and enzyme inhibitor if it exceeds its permissible limit [7]. Lead has the potential to replace bone calcium to form long-term replacement sites. The critical trace elements are heavy metals like copper, but they exhibit excess toxicity. If they remain more or less from their original limits in drinking water, toxicity may result from any of the heavy metals. Using industrial and anthropogenic practices of urban settlement around the drainage basin of rivers, hazardous chemicals and heavy metals join rivers [8,9]. The types of contaminants introduced into the aquatic environment have been reported to be primarily affected by the different anthropogenic activities taking place in the surrounding farmlands. Mining and smelting operations, the dumping of untreated and partially processed waste, metal chelates from various factories and the indiscriminate use of heavy metal-containing fertilizers and pesticides in agricultural fields are the major anthropogenic causes of heavy metal pollution. Heavy metals contaminate surface and ground water, causing the quality of drinking water and irrigation water to deteriorate and can enter the human food chain, posing a risk to human health [10]. Heavy metal soil contamination is caused by various metals, especially Cu, Ni, Cd, Zn, Cr and Pb [11]. Some heavy metals have been reported to be

bio-important to humans (such as Fe, Zn, Ca and Mg), and their daily medicinal and nutritional allocations have been recommended. However, it has been noted that some others (such as As, Cd, Pb, and methylated forms of Hg) have no known bio-importance in human biochemistry and physiology and ingestion can be toxic even at very low concentrations [12]. The metal plant uptake from soils at high concentrations may result in a great health risk considering food-chain implications. Uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to human health [13]. The purpose of this work is to investigate the presence of certain heavy metals in different drinking water sources from four (4) different locations in Jos Metropolis.

1.1 Geology of Study Area

The geology of the study area which is 8600 km² and bounded by 300-600m escarpments around much of its circumference, falls within the Jos - Bukuru Complex which is predominantly of biotite- granite type as exhaustively studied by [14], The geology of the Jos Plateau is made-up of the Precambrian Basement migmatite-gneiss-quartzite complex which underlies about half of the entire State and in some places has been intruded by Precambrian to the late Paleozoic Pan-African granite (Older Granite), diorite, charnockite etc. Intrusive into these Basement Complex rocks are the Jurassic anorogenic alkali Younger Granites [15]. In association with the Younger Granites are volcanic rocks such as basalts and rhyolites that overlie or cross-cut this formation as well as the Basement rocks. These volcanic rocks are believed to have been formed during the early Cenozoic (Tertiary) Older Basalts and Quaternary Newer Basalts [16]. Most of the sediments were formed from denuded younger granitic rocks which brought about the rich detrital deposits in economic minerals like; Cassiterite (tin ore), Columbite (niobite-tantalite) etc.

2. MATERIALS AND METHODS

All chemicals and reagents were of the analytical grade and were obtained from BDH Chemicals

Ltd, UK.5% trioxonitrate (V) acid was used for the digestion of the samples.

2.1 Sample Collection and Location

Ground water samples, industrial effluent, water from mining ponds as well as factory based water were randomly obtained from the same study area using a clean sterile 250ml conical flask. Samples were taken to the laboratory and carefully allowed to settle.

2.2 P^H Determination

The water samples were stirred vigorously by using a clean glass stirring rod and 35ml was poured into a glass beaker using the watch glass for a cover. The samples were allowed to stand for at least one hour to give room for stability in the temperature. The temperature of the sample was measured and the temperature controller of the P^H meter was adjusted to that of the sample temperature. The P^H meter was then standardized by means of standard solution. The electrode of the P^H meter was immersed into the water samples with the beaker slanted to obtain a good contact between the sample and the electrode. The P^H of the samples were then read and recorded.

2.3 Sample Digestion

To ensure the removal of organic impurities from the samples and thus prevent interference in analysis, the samples were digested with 5% concentrated nitric acid, HNO₃. 5ml of nitric acid was added to 250ml of water in a 250ml conical flask. The mixture was evaporated to half its volume in a water-bath after which it was allowed to cool and then filtered using a Whatman Filter Paper. The digested water samples were analyzed for the presence of Lead, Cadmium, Chromium, Zinc, Calcium, Magnesium and Copper using the Buck Scientific 210 VGP Atomic Absorption Spectrophotometer. The calibration plot method was used for the analysis with their respective wave length (Cd (228.8 nm) Pb (283.3 nm), Cr (357.9 nm), Cu (324.8 nm), Zn (213.9 nm), Mg (285.2 nm), Ca(422.7 nm).

Table 1.Co-ordinates of the sample sites

Locations of Sample Collections	Latitude	Longitude
Location for Sample A	9°51'15.0"N	8°56'16.0"E
Location for Sample B	9°51'14.0"N	8°56'23.0"E
Location for Sample C	9°52'24.0"N	8°52'27.0"E
Location for Sample D	9°53'28.0"N	8°52'05.0"E

Table 2. Concentration of different metals in samples

Samples	Cd	Pb	Cr	Cu	Zn	Mg	Ca
A	1.331±0.0116	1.331±0.0116	0.2401±0.000115	0.4359±0.000768	0.00080±0.000115	22.830±0.0577	19.706±0.000115
B	1.370±0.0087 ^b	1.370±0.0087 ^b	0.1681±0.000768 ^a	0.5583±0.000352 ^b	-0.0106±0.000115 ^a	22.599±0.0577 ^a	17.681±0.000115 ^a
C	1.320±0.0088 ^a	1.320±0.0088 ^a	-0.0465±0.00127 ^a	0.5753±0.00583 ^b	0.0003±0.000115 ^a	5.789±0.0577 ^a	15.241±0.000115 ^a
D	1.440±0.0144 ^b	1.440±0.0144 ^b	0.3187±0.000569 ^b	0.7838±0.00165 ^b	0.5327±0.000115 ^a	19.840±0.0577 ^a	17.713±0.000115 ^a
P-values	0.0002	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values are expressed as mean ± SEM, n = 3. If p value is less than 0.05, there is significant difference in mean values. ^aValues are significantly low when compared with control (P= 0.05) ^bValues are significantly high when compared with control (P= 0.05)

Table 3. P^H values of samples collected

Location of sample collection	P ^H values	Scientific control
Factory based water	6.92 ± 0.42	0 – 6.00: Acidic
Mining Pond	6.49 ± 0.26	7.00: Neutral
Industrial effluent	4.87 ± 2.4	7.10 – 14.00: Basic
Domestic Natural aquifer	5.78 ± 0.8	

Table 4. World health organization (WHO) standard for heavy metals

S/N	Metal	Highest desirable mg/l	Maximum desirable mg/l
1	Ca	1.0	2.5
2	Mg	0.2	0.4
3	Zn	1.0	3.0
4	Cu	0.5	2.0
5	Cd	0.003	0.03
6	Pb	0.4	0.4
7	Cr	0.05	0.05



Fig.1. Location of sampled points on the map of the study area

The digested samples were analyzed in duplicates with the average concentration of the metal present being displayed in mg/L by the instrument after extrapolation from the standard curve.

2.4 Statistical Analysis

Data collected were analysed using one way analysis of variance (ANOVA) to compare different groups and values were considered

significant at $p = 0.05$. Results were presented as the mean \pm SEM.

3. RESULTS AND DISCUSSION

The purpose of this research work is to examine the concentration of heavy metals in some soil and run-off water in three villages of Jos South Local Government Area of Plateau State, Nigeria. The toxicity of heavy metals in water is a major environmental issue due to the direct effect of drinking water or the ingestion of infected marine species on human health.

From the results of our investigation, the mean concentration of Cadmium in location A, B, C and D were found to be 1.331 ± 0.01 , 1.37 ± 0.01 , 1.32 ± 0.01 , 1.44 ± 0.01 mg/L respectively which is significantly higher than the WHO maximum permissible limits for drinking water of 0.003 mg/L. This investigation agrees with the findings of [17]. Cadmium is a highly toxic and non-essential metal with harmful effects on living organisms [18]. In marine settings, cadmium is a chief contaminant because it can dissolve quickly in water [19,20] Cadmium has been reported to have both carcinogenic characteristics and a long biological half-life. As a result of accumulation in the liver and renal cortex, this could cause chronic effects [21]. It can also cause kidney damage as well as produce acute health effects resulting from over exposure to high concentrations [22]. The higher concentrations of Cadmium reported in all four locations may be due to the nature of the geological formation of the soil and run-off from agriculture activities where phosphate fertilizers have been applied (Cadmium is a common impurity in phosphate fertilizers) or as a result of anthropogenic activities around the sources of water [23].

The mean concentration of Lead analysed in samples A, B, C and D were found to be 1.33 ± 0.01 , 1.37 ± 0.01 , 1.33 ± 0.01 and 1.44 ± 0.01 mg/l respectively. These values are significantly higher than the WHO standard for maximum permissible level for drinking water which is 0.01 mg/L. [23]. Lead is described as potentially harmful to most life forms, even at low concentrations it is known to be toxic and relatively accessible to aquatic organisms [24]. Lead is harmful to humans and can lead to behavioural changes and reduced IQ test results [25]. Lead particulate from the combustion of leaded fuel, degradation of lead-containing materials and burning of building and electronic waste with residue washed into rivers may be

attributed to potential sources of lead in the rivers [26]. Haemoglobin production, the cardiovascular system and acute and chronic damage to the central nervous system (CNS) and the peripheral nervous system are also inhibited by lead poisoning (PNS). Anaemia, fatigue, stomach disorders and anoxia are among other chronic symptoms. Lead can cause pregnancy complications, high blood pressure, muscle and joint pains, etc. [27].

Our investigation shows that the mean concentration of chromium in samples A, B, C and D were found to be 0.24 ± 0.0 , 0.17 ± 0.01 , 0.047 ± 0.00 and 0.319 ± 0.00 mg/L respectively. At positions A, B and D, these values are substantially higher. These values are greater than the WHO value of 0.03 mg/l for the overall allowable drinking water standard. In this water sample, chromium sources may be attributable to waste consisting of lead-chromium batteries, coloured polythene bags, recycled plastic products, and empty containers of paint. Natural chromium compounds are normally in a trivalent state (Cr (III)); they act as human micronutrients and play a vital role in lipid and sugar metabolism [28]. Nonetheless, anthropogenic activities can release the hexavalent type of concentrations of chromium into bodies of water that are considered carcinogenic to human health by various regulatory and non-regulatory agencies. [29].

The highest acceptable concentration of copper is (0.1 mg/L) [30]. For good health, low copper is necessary and too much can be harmful. Nervous system, liver and kidney failure can cause death by ingesting large amounts of copper compounds. Our investigation shows that copper in samples A, B, C and D respectively are 0.44 ± 0.00 , 0.59 ± 0.00 , 0.58 ± 0.01 and 0.78 ± 0.00 mg/L. All of these are significantly higher than the WHO accepted value for drinking water. Chronic anaemia can result from the contamination of drinking water with high levels of copper. Research has shown that copper ingestion has also been associated with coronary heart disease and high blood pressure, while coronary heart disease has also been associated with copper deficiency [30]. High levels of copper can cause vomiting, stomach pain, nausea, diarrhoea due to leaching from copper pipes into drinking water [31]. Our investigation does not agree with the findings of [32].

Zinc is an important necessity for a healthy body, it can be damaging and also cause toxicity in excess [33]. Studies have shown that one of the

main anthropogenic sources of trace metals like zinc is the improper use of phosphate and urea fertilizers. Although the input of this metal into agricultural soil with each fertilizer application may be minimal, residue deposition in water bodies may result in soil leaching during precipitation [34]. Our investigation shows water samples from locations A, B, C and D have 0.0008 ± 0.00 , 0.0106 ± 0.00 , 0.0003 ± 0.00 and 0.538 ± 0.00 mg/L of Zinc respectively. Zinc, especially if taken orally, is considered to be relatively non-toxic. Excess quantities, however, can cause system dysfunction that leads to growth and reproduction impairment. Vomiting, diarrhoea, bloody urine, icterus (yellow mucus membrane), liver failure, kidney failure and anaemia have been identified as clinical symptoms of zinc toxicities [35].

Magnesium concentration from our investigation in locations A, B, C, and D were found to be 22.83 ± 0.06 , 22.59 ± 0.06 , 5.78 ± 0.06 and 19.84 ± 0.06 mg/l respectively. The result of our investigation has higher concentration of magnesium in all the four locations when compared to the ones obtained by [36]. Magnesium is a cofactor for some 350 cellular enzymes, many of which are involved in energy metabolism. It is also involved in protein and nucleic acid synthesis and is needed for normal vascular tone and insulin sensitivity [37]. Magnesium in drinking water may have a laxative effect, particularly with magnesium sulphate concentrations above 700 mg/L. However, the human body tends to adapt to this laxative effect with time [38].

Inadequate intake of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures. Another value of calcium in groundwater, for example, is its ability to inhibit the absorption of heavy metals in the body and is believed to increase bone mass and avoid some cancer forms [39]. Our investigation shows that calcium concentration in locations A, B, C and D are 19.706 ± 0.00 , 17.681 ± 0.00 , 15.241 ± 0.00 , and 17.713 ± 0.00 mg/l respectively. This shows that the calcium concentration in location A has the highest occurrence. Dissolved calcium concentration which is probably essential for human health is ranging from 10 to 100 mg/L [40] Calcium concentration in all our study areas agree with this range, signifying that its concentration in all locations is safe for

consumption as high calcium ions intake by humans may cause human heart to stop in systole, which eventually may cause respiratory and cardiac failure [41]. Water treatment processes can decrease the minerals content in treated drinking water [42].

4. CONCLUSION

On the basis of the outcome of this investigation, the authors observed that samples from the various sources of water were highly contaminated with heavy metals beyond the accepted and permissible level that the human body can tolerate. Factory-based sachet water has also been reported as polluted with the same heavy metals. This could be as a result of the packaging and bottling materials used during production. Sources of water located close to mining ponds and industrial areas should be discouraged from being consumed as they could serve as a source of contaminant in drinking water. Natural aquifers within our study area which are a major source of drinking water were also found to contain high concentrations of heavy metals. From a hydrogeological point of view, we know that groundwater migrates within the sedimentary formations and also through interconnected fractures in basement rocks prevalent in our study area. These could be a point of transport of heavy metals leached from auto-mechanic workshop, paint factories, heavy metals leached from Cassiterite rich younger granite complex, petroleum products spilled and leached into the groundwater. We therefore advice that water sources from our study area should be specially treated by substantial scientific processes before consumption and concerned government agencies should also discourage the storage of factory based water in polyvinyl chloride materials, tanks and other sources of sachet material as these packaging vessels are also sources of contaminant which could be detrimental to the human health. Furthermore, extensive scientific investigations should be carried out on plants and other consumable aquatic life obtained from the study area to ascertain the level of these heavy metal concentrations that could possibly passed unto humans through the food chain.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not

intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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