ABUAD Journal of Engineering and Applied Sciences (AJEAS)
ISSN: 2992-5584
Volume 2, Issue 1, 36-42

Effect of Lithium Mining on Quality of Water using Atomic Absorption Spectrometer (A Case Study of Toto Lithium Mine)

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Date Submitted: 29/02/2024
Date Accepted: 29/03/2024
Date Published: 30/06/2024

Abstract: *The study focused on the evaluation of effect of lithium mining in water in Toto community. Lithium has a substantial negative impact on both human and the environment particularly on the contamination of water and water depletion. Lithium processing requires hazardous chemicals. Therefore, communities, ecosystems and agricultural production may suffer as a result of the release of such chemicals through leaching, spills, or air emissions. Water samples were obtained from Lithium site and taken for Atomic Absorption Spectrometer (AAS) analysis. The possible effect of heavy metals present in the water were evaluated and analyzed to offer solutions. Random Sampling method was used to obtain five (5) water samples from the mine site. The study revealed that out of the thirteen (13) elements considered, the concentrations of four of them were varied from a very high concentration to low concentration. The elements are Li, Mg, Fe and Ca with an average of 62.4173 micrograms per litre (µg/L), 29.3130 µg/L, 2.6518 µg/L and 0.9773 µg/L respectively. That of lithium which is 62.4173 µg/L is far above the allowable and acceptable standard limit given by the World Health Organization (WHO) and is therefore considered inimical for human consumption.*

Keywords: Lithium, AAS, elements, WHO, water sample.

1. INTRODUCTION

The process of mining involves the extraction of useful materials (e.g. lithium, coal, gold and iron) from the earth which is dated back to prehistoric times. The substances or materials obtained through mining processes are from various types of mining. These types of mining are placer mining, open-pit mining and underground mining [1].

Mining activities are important not only because of its financial benefits to the global economy but because mined materials are used to construct good instruments that make human environment better and presentable. Mining is a tedious activity and sometimes can be hazardous and therefore safety measures and precautions are taken to prevent the loss of lives and properties [1].

Lithium-ion battery technology has continued to advance, and the usage of lithium is anticipated to increase in the coming years. With an atomic number of 3, an atomic weight of 6.94, lithium is a soft, silvery-white alkaline metal. It is a least dense metal and element under standard condition. Australia is the major producer of lithium from hard rock while Chile supplies the majorly of the lithium extracted from brine. The Salar de Atacama in Chile contains the highest concentration of brine and accounts for about 30% of the world's unknown lithium deposits. According to [2], this region account for 65% of the world lithium market in 2009. Despite its virtual acceptance as the gold standard in treating bipolar disorder, prescription rate for lithium has been decreasing recently. One major observation of lithium is its side effect and toxicity both on man and the environment (which include soil, plants and animals). According to the clean water act, it takes a dangerous level of pollution in the environment for many emerging pollutants to be detected, after which remediation and clean-up cost will increase largely and many changes are irreversible [3].

Some notable effects of lithium mining on the environment are ground destabilization, loss of biodiversity, water loss, increase in river salinity, soil pollution and toxic waste release. Lithium extraction harms the soil and streams and causes air contamination [3]. Due to its numerous usages in things like nuclear fusion, light aircraft alloys, and rechargeable batteries, the demand for lithium has been steadily rising. By 2025, the demand for lithium is anticipated to quadruple, driven by battery applications, particularly electric cars [4].

The batteries serve as source of power for all electronic drive vehicles (EDV). Currently, lithium is the element of choice for high energy-density rechargeable batteries. The Laser-induced breakdown spectroscopies (LIBs) have the highest charge-to-weight ratio when compared to other battery technologies. However, this is a suitable quality for transportation application batteries. There is a rapid demand for LIBs due to their emergence as key technologies for developing low-carbon transportation networks since their 1991 commercial debut [5-7]. Albeit, the socio-economic effects of lithium can be assessed across different aspects using various indicators for different stakeholders [8, 9].

Consequent to this, pollutions from technological development cannot be prevented by a reactive approach but by a proactive approach. The screening level of drinking water as proposed by the US Geological Survey is 10 microgram/litre (mg/l) or parts per billion (p/b). [4] agreed that inorganic water pollutants have caused millions of deaths annually. They also affirmed that Portable X-Ray Florescence Spectrometry is the cheapest method of analysing water sample though it is not the most efficient.

The Atomic Absorption Spectrometer (AAS) is an analytical chemistry technique that is used in establishing the concentration of specific metal element in a sample. The AAS is capable of determining over 62 distinct metal concentrations in a solution. The technique typically atomizes the sample using a flame that employs alternative atomizers, like a graphite furnace [10]. By measuring the absorbed radiation of the chemical element, AAS is used for determining the amounts of chemical elements present in environmental samples and it is often carried out by analyzing the spectra formed when the sample is radiation excited [11]. After the absorption of ultraviolet and visible light, atoms move to higher energy levels. Therefore, the atomic absorption technique is used to measure the quantity of energy absorbed by the sample as photons of light.

The initial wavelength and the light wavelength that have passed through the sample are measured by a detector and then compared with one another. Variations in absorbed wavelength subsequently integrated by a signal processor are the major causes of readout's peaks in energy absorption at distinct wavelengths. For an electron to leave an atom, there is a unique ionization energy to every chemical element. Eash atoms emit it owns specific spectral line and a photon with energy E is released when an electron in the atom transitions from one energy level to another. According [12], there is a unique pattern of wavelength at which energy is absorbed by atoms due to their distinct element arrangements in each atom's outer shell. However, since there is a unique set of energy levels for each element which results in an extremely narrow absorption, the selectivity in AAS is imperative.

According to Beers' Law, it is important to choose the right monochromator to obtain a linear calibration curve because doing it with a regular monochromator is often difficult due to the absorbing species bandwidth that must be wider that the light source. Monochromators are essential component of the AAS used in separating thousands of lines produced by elements present in a sample [12]. According to the Beer-Lambert law, absorbance is directly proportional to the concentration of analyte absorbed for a current set of conditions.

A calibration curve is used to determine the concentration and it is obtained using the standards of a known concentration. Consequent to this, a direct application of Beer-Lambert law in AAS is challenging because of the variations in atomization efficiency from the sample [13]. The chemical reactions and interactions of matter are basic determinants of the chemical processes employed. Quality experimental skills are required in most cases because the techniques are largely empirical for a long time. In most cases, there are three methods mainly used to accurately measure metals.

The three most popular ways for matching patterns are the internal standard method, standard addition methods and calibration curves produced by pattern successions. It is important to take interference and backdrop into account while analysing the data. The approach that is employed in this research is the usage of calibration curves from a collection of patterns. It entails assessing the target sample within a set of samples with known concentrations that were all produced under the same circumstances.

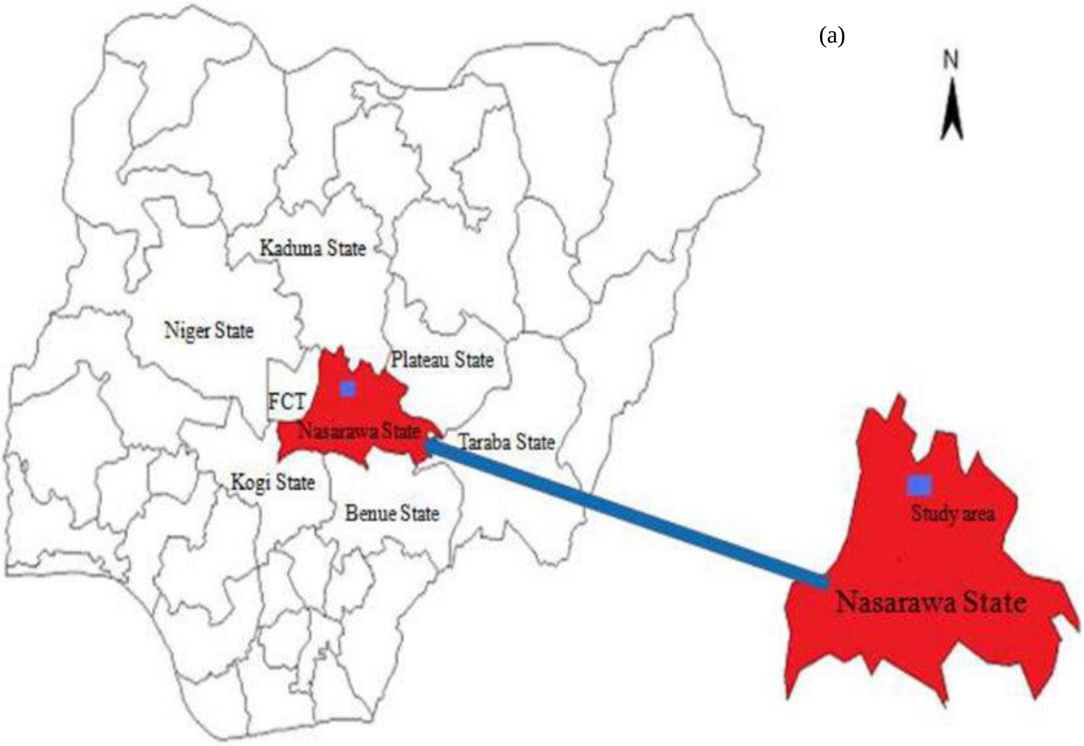
Using known quantities of a given element to create a calibration curve, one must first build a foundation for comparison before attempting to quantify how much of that element is present in a sample. The detector is configured to exclusively monitor energy transmitted at a chosen wavelength in order to produce this curve. When the concentration of the target atom in the sample rises, the absorption will also climb in line with it.

The measured absorption is then plotted for each concentration such that a line can be created connecting the dots. The concentration of the chemical under examination can be inferred from this line using the substance's absorbance as a guide. A multi-element mixture's individual constituents can be quantitatively determined by using specialized light sources and choosing particular wavelengths [14].

As a result of rush for lithium, many miners (skilled and unskilled) currently venture into the business of lithium mining not minding the impacts on the health of the local inhabitants of the environment, and the effects of heavy metals on soil pH as it relates to crops and farming activity within the area. If proactive measures are not considered, Lithium might be the nest global pollutant with emerging concern, hence, the motivation for this research to evaluate the effects of heavy metals associated with the rising of lithium mining activities in the study area.

1.1 Location of the Study Area

The study area is at Toto Local Government Area of Nasarawa State, Nigeria. The study area has geographical coordinates between the North of **N** 08°22'44" and East of **E** 07°05'04". The geology of the area forms part of the upper Proterozoic low-grade (green schist facies) schist belts of Central Nigeria, and consists of schists, banded iron, quartzite, and marble. Figures 1 (a) and (b) show the map of the study area.



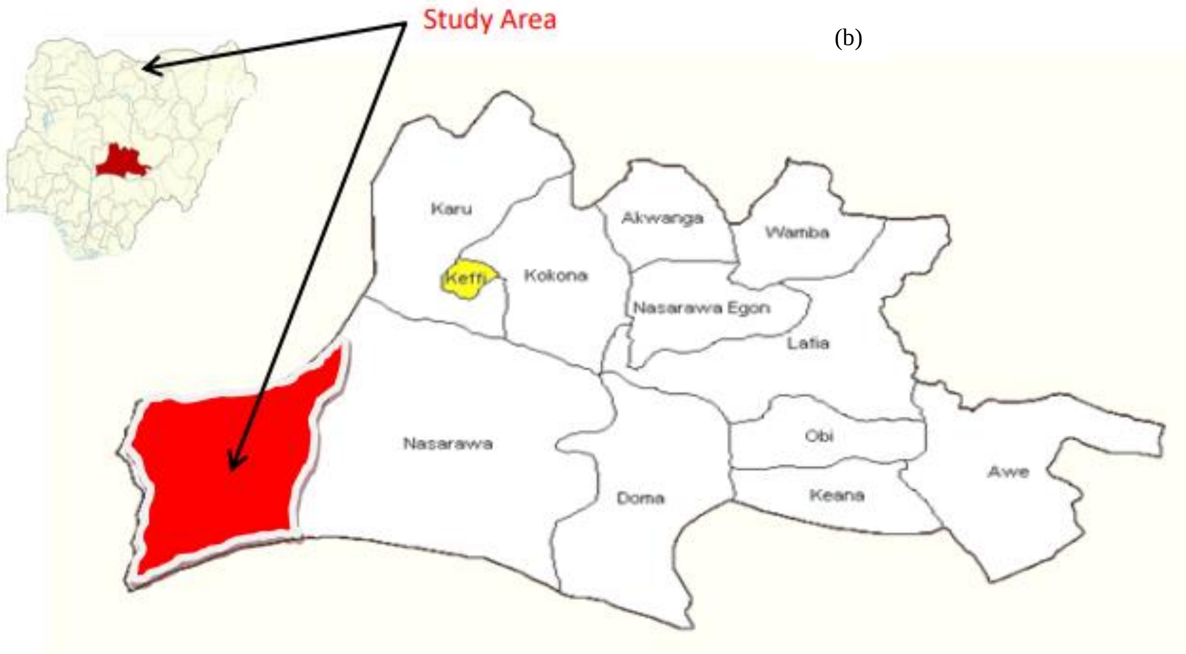


Figure 1: Map of the study area [15]

2. MATERIALS AND METHOD

The purpose of this study was to evaluate the effects of lithium concentration in water as a result of mining activities in the study area using Atomic Absorption Spectrometer (AAS) and to analyse if, there are presence of other heavy metals concentrations which could be harmful to the environment.

2.1 Sources of Lithium

Lithium mainly comes from two sources.

a) Spodumene, a hard silicate mineral found in pegmatites (13% of reserves) and
b) Lithium chloride in brine lake deposits (87% of reserves). The third possible source, seawater, is currently deemed infeasible [16].

2.2 AAS Instrument

This analytical tool, which works on the basis of AAS, is highly helpful in determining the amount of metal ions present in samples of drinking water. The sample element transforms into that element's atomic vapor when sample solution is inhaled into a flame. While most atoms remain in their ground states, others are activated thermally by flame. The wavelength radiation emitted by a specific source such as the hollow cathode lamp made of the metal is absorbed by the ground state atoms. According to [17], the wavelength of radiation emitted by the lamp's source is now comparable to that absorbed by the atoms in the flame.

The AAS method follows the Beers's Law which stipulated that absorbance is directly proportionate to concentration. Atomic absorption spectrophotometer has a light source which include monochromator, lamp sample cell, detector and output device [18]. Figure 3 shows the pictorial view of the AAS. Other materials used for the research are shown in Table 1.

Table 1: Materials and equipment used for field studies

S/N	Material/Equipment	Purpose
1	Sample Container	For obtaining water samples and ensuring well labelled samples
2	Global Positioning System (GPS)	For determining the coordinates of the study location
3	Marker and pen	For sample labeling and note taking
4	Field notes book	For recording observation and measurements
5	Measuring tape	For length measurements

Random sampling method was adopted to obtain a minimum of five water samples from the Toto mine site. Before the laboratory analysis, samples were digested, which means elements of the samples were exposed so that AAS can analyse them. The digestion was done using 2 ml of nitric acid of HNO_3. An interview was also conducted with the local miners to know the type of mining approach they use. The laboratory experiment and analysis were carried out in the Geology Laboratory of the University of Jos using the AAS machine.

3. RESULTS AND DISCUSSION

Quality and safe drinking water is the basis for good human health [19]. When water is polluted then, it can be a source of unwanted substances, harmful to human health and causes diseases. The results of the metal analysis in water samples of the research area are shown in Table 2. Table 2 reveals the concentration of 4 hazardous heavy metals namely Li, Mg, Fe and Ca.

Table 2: Summary of elements present in the five samples

S/N	Element	Sample 1 (μg/L)	Sample 2 (μg/L)	Sample 3 (μg/L)	Sample 4 (μg/L)	Sample 5 (μg/L)	Average of samples (μg/L)	WHO Standard (μg/L)	Variation (μg/L)
1	**Au**	0.0876	0.1245	0.1044	0.0640	0.0775	0.0916	0.0101	0.0815
2	**Cu**	0.1848	0.1334	0.1473	0.1873	0.1231	0.1552	1.0020	-0.8468
3	**Mn**	0.0353	0.1875	0.0250	0.1027	0.0625	0.0826	0.0500	0.0326
4	**Cr**	0.0321	0.0082	ND	0.0300	0.0104	0.0202	0.0501	-0.0299
5	**Ni**	0.0039	0.0072	ND	0.0034	0.0076	0.0055	0.1010	-0.0955
6	**Co**	0.0122	0.0116	0.0134	0.0120	0.0128	0.0124	0.0130	-0.0006
7	**Pb**	0.0036	0.0134	ND	0.0054	0.0142	0.0092	0.0500	-0.0408
8	**Cd**	0.0008	0.0017	0.0021	0.0009	0.0010	0.0013	0.0051	-0.0038
9	**Zn**	0.0040	ND	0.0020	0.0028	0.0032	0.0030	5.0002	-4.9972
10	**Ca**	1.2385	1.4342	0.2593	1.2461	0.7085	0.9773	0.7500	0.2273
11	**Mg**	32.2113	31.5589	24.1689	26.9669	31.6591	29.3130	0.5002	28.8128
12	**Fe**	2.6493	2.6450	2.6611	2.5799	2.7237	2.6518	0.1001	2.5517
13	**Li**	64.1256	61.5627	61.5637	63.0663	61.7683	62.4173	0.7020	61.7153

Note: ND denotes 'Not Detected'

Figures 2 and 3 show the graph and bar charts of the composition elements of heavy metals present in water at Toto area as compared with the permissible limits of WHO standard respectively.

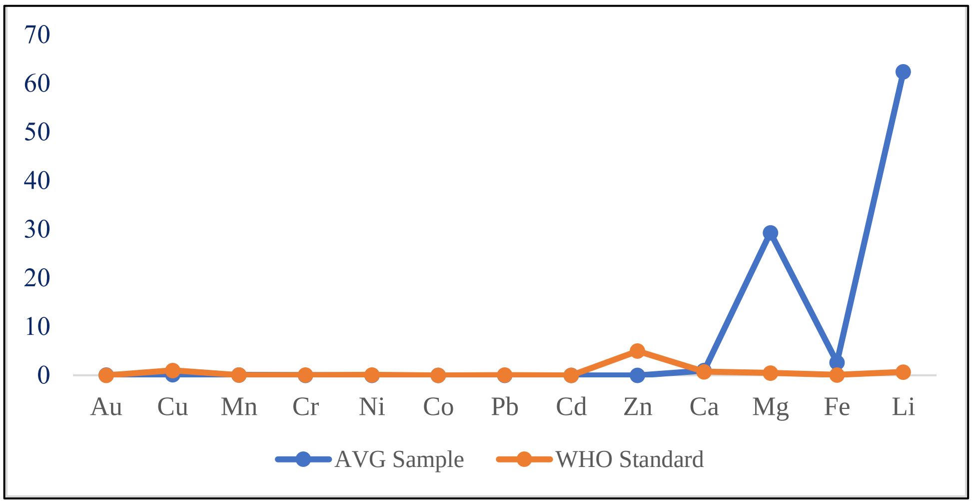


Figure 2: Graph of the composition elements in samples collected and the permissible limits by WHO

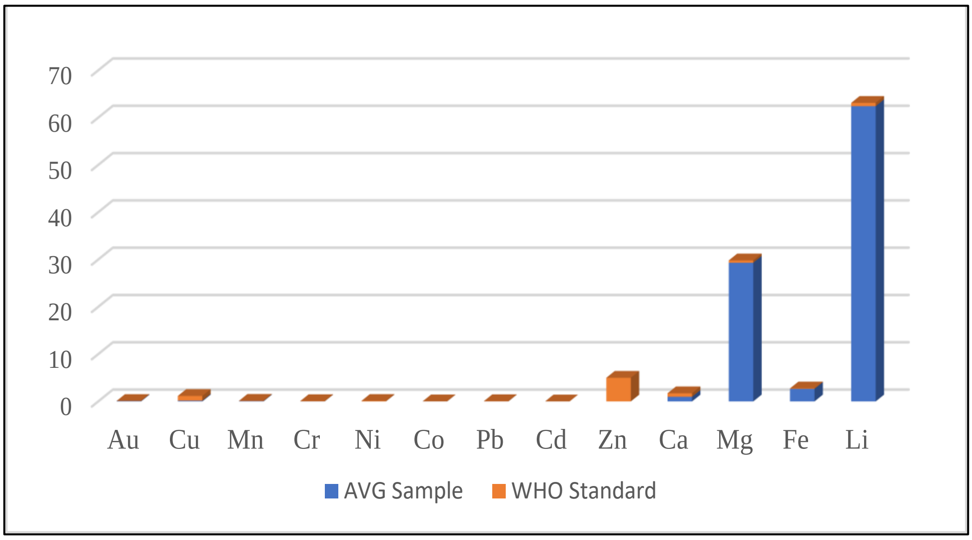


Figure 2. Graph of a bar chart showing the elements in samples collected as compared with the WHO standard

Some heavy metals are essential for health but in limited concentrations. High concentrations of heavy metals in drinking water create harmful effects for health [20].

From the results in Table 2, the maximum and minimum concentrations of Gold (Au) are found as 0.1245 µg/L and 0.0640 µg/L in samples 2 and 4 respectively with an average concentration of 0.0916 µg/L, which is considered permissible compared to the World Health Organization (WHO) standard. It has a variation of 0.0815 µg/L.

For Copper (Cu) element, the maximum and minimum concentrations are 0.1873 µg/L and 0.1231 µg/L in samples 4 and 5 respectively with an average concentration of 0.1552 µg/L, which is also considered permissible when compared with the average standard of WHO. It has a variation of 0.8468 µg/L.

The result for Manganese (Mn) element shows the maximum and minimum concentrations of 0.1875 µg/L and 0.0250 µg/Lin samples 2 and 3 respectively with an average concentration of 0.0826 µg/L, which is equally considered permissible to the average standard of WHO. The variation is 0.0326 µg/L.

The result for Chromium (Cr) element shows that the maximum and minimum concentrations are 0.0321 µg/L and 0.0082 µg/L in samples 1 and 2 respectively with an average concentration of 0.0202 µg/L, which is also considered lower than the average standard of WHO with a difference of 0.0299 µg/L. It can be observed that there was no result detected in sample 3 by the AAS.

For Nickel (Ni) element, the maximum and minimum concentrations are 0.0076 µg/L and 0.0034 µg/L in samples 5 and 4 respectively with an average concentration of 0.0055 µg/L, which is also considered lower than the average standard of WHO with a difference of 0.0955 µg/L. It can also be observed that there was no result detected in sample 3 by the AAS.

For Cobalt (Co) element, the maximum and minimum concentrations are 0.0134 µg/L and 0.0116 µg/L in samples 3 and 2 respectively. The average concentration of 0.0124 µg/L is permissible and considered lower than the WHO standard with a variation 0.0006 µg/L.

The result of Lead (Pb) shows that the maximum and minimum concentrations are 0.0142 µg/L and 0.0036 µg/L in samples 5 and 1 respectively with an average concentration of 0.0092 µg/L, which is still considered lower compared to the average WHO standard with a difference of 0.0408 µg/L. It can also be observed that there was no result detected in sample 3 by the AAS.

From the result of Cadmium (Cd), the maximum and minimum concentrations are 0.0021 µg/L and 0.0008 µg/L in samples 3 and 1 respectively with an average concentration of 0.0013 µg/L. It is also considered permissible when compared with the average standard of WHO. It has variation of 0.0038 µg/L.

For Zinc (Zn) element, the maximum and minimum concentrations are 0.0040 µg/L and 0.0020 µg/L in samples 1 and 3 respectively with an average concentration of 0.0030 µg/L, which is also considered very low to the average standard of WHO with a difference of 4.9972 µg/L. It can also be observed that there was no result detected in sample 2 by the AAS.

From the result of Calcium (Ca), the maximum and minimum concentrations are 1.4342 µg/L and 0.2593 µg/L in samples 2 and 3 respectively with a mean concentration of 0.9773 µg/L. The average concentration observed is higher than the average permissible limit of WHO standard with a variation of 0.2273 µg/L.

The result of Magnesium (Mg) element shows that the maximum and minimum concentrations are 32.2113 µg/L and 24.1689 µg/L in samples 1 and 3 respectively with an average concentration of 29.3130 µg/L. This is considered very high compared to the average permissible limit of WHO standard with a difference of 28.8128 µg/L.

For the result of Iron (Fe), the maximum and minimum concentrations are 2.7237 µg/L and 2.5799 µg/L in samples 5 and 4 respectively with an average concentration of 2.6518 µg/L. This is also considered high compared to the average permissible limit of WHO standard with a difference of 2.5517 µg/L.

Lithium (Li) result shows that the concentration of Li is extremely very high with a maximum average concentration of 64.1256 µg/L and a minimum average concentration of 61.5627 µg/L in the samples 1 and 2 respectively. The variation between the result and that of the permissible limit of WHO standard is 61.7153 µg/L.

From the findings, it is clearly observed that the concentration of elements presents in each sample in the Table 2 above are predominantly minimal, except for Li, Mg, Fe and Ca in ascending order of increment in variations to the World Health Organization standard. These four elements are very harmful to human health. This was also corroborated by [9] and [19-21]. Though the effect might not show immediately but gradually over the years, it will manifest.

However, the concentration of each element found in the water differs due to different activities done in each pit. Therefore, as a result of the effects of rainfall in some pits, there is an observable low concentration of elements in water samples collected compared to the WHO standard. In some samples, other elements that were not dictated or found by the AAS were attributed to nefarious or illegal mining effects carried out in such pits.

4. CONCLUSION

There is no question on whether the world will need more sustainable energy in the future or not. Humans and society depend on mobility, so perhaps cities will need to reconsider urban planning or at the very least, centralize it in order to provide the essential infrastructures. Therefore, the infrastructure and economic incentives for lithium and cobalt mining extractions need to be redesigned, or perhaps, appropriate legislation need to be put in place globally to allow for more sustainable mining operations. Societies traditionally tend to eventually converge on the correct route when it comes to efficiency and survival. Addressing the environmental and human effects of vital commodities like cobalt and lithium is more crucial now than ever before. The findings from the research have shown that, the water from the mine site contains some harmful heavy metals such as Li. Lithium has the highest average concentration of 62.4173 mg/l in the water compared to that of WHO standard which is just 0.018 mg/l. This is followed by Magnesium (Mg) with an average concentration of 29.3130 mg/l in the water as compared to the WHO standard of 0.1002 mg/l. Iron (Fe) and Calcium (Ca) follow the trend with average concentrations of 2.6518 mg/l and 0.9773 mg/l respectively as compared to the normal standard of WHO concentrations of 0.3001 mg/l and 0.51 mg/l respectively. These higher concentration elements of heavy metals in the water samples from the pits are inimical, and thereby suggest that the water from the environment is not suitable for drinking due to the mining activities unless it is hygienically treated.

ACKNOWLEDGMENT

The authors acknowledge and appreciate the people of Toto community in Nasarawa State, Nigeria for granting us access to the study area despite the security situation of the country. The authors are also grateful to the University of Jos, Nigeria and University of Ilorin, Nigeria for the use of their laboratories.

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