Assessment of Physico-chemical Parameters and Heavy Metal Concentrations in Well Water of Logo 2 Area of Makurdi, Nigeria

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Specialty Section:
This article was submitted to Physics, a section of NAPAS.

***Accepted:** 3 March, 2022*
***Published:** 1May 2022*

Citation:
Tsor JO, Biam JT, Terver D, Shimlumun AP, Jombo GTA. (2022). Assessment of Physico-chemical Parameters and Heavy Metal Concentrations in Well Water of Logo-2 Area of Makurdi, Nigeria. Nig Annals of Pure & Appl Sci. 5(1):137-148. DOI: 10.5281/zenodo.6905019.

Publisher:
cPrint, Nig. Ltd
***E-mail**:*
Cprintpublisher@gmail.com

Access Code

http://napas.org.ng

ABSTRACT

In this study, the concentration of six heavy metals (HMs) in well water: Cadmium (Cd), Copper (Cu), Lead (Pb), Manganese (Mn), Nickel (Ni) and Zinc (Zn) were determined from ten hand dug wells in Logo 2 area of Makurdi, Nigeria for samples labelled A to J using the flame Atomic Absorption Spectrophotometer (AAS) model PG 990. Sample dissolution was carried out using open acid digestion method. The results obtained showed that *HM* concentrations in the wells in this area were in the following ranges Cd 0.0072 – 0.0149 mg/L; Mn 0.0413 – 0.6117 mg/L; Ni 0.0013 – 0.0157 mg/L and Zn 0.0758 – 0.4975 mg/L; while Cu and Pb were undetectable for all wells. The concentrations of *HMs* in the wells studied were arranged in descending order as Mn>Zn>Cd>Ni. Cd showed 100% contamination above World Health Organization (WHO) and National Industrial Standards (NIS) Maximum Permissible Guidelines (MPGs) for all the wells assessed, Ni and Zn had all their values 100% below the Maximum Permissible Guidelines set by WHO and NIS while Mn concentrations of 4 samples of the wells (40%) fell above the MPGs and 6 samples of the wells (60%) fell below the MPGs for Mn set by WHO and NIS. The physico-chemical parameters: pH, temperature, Dissolved Oxygen (DO), Total Suspended Solids (TSS) and turbidity assessed in this study all fell below the permissible levels for drinking water guidelines of WHO and NIS. The study shows that well water in this area is safe for drinking with respect to the physico-chemical parameters, Ni and Zn but not safe for Mn and Cd while Cu and Pb were not detected. The authors strongly recommend proper health education and sensitization against the domestic usage of water from hand dug wells in this densely populated area to prevent residents of the area from health risks associated with heavy metal contamination of well water presently patronized by majority of them since *HMs* are non-biodegradable and bio-accumulate. Also, laws governing Environmental Impact Assessments and wastes management in cities and towns should be strengthened, and strictly implemented to curb the web of utilization of waters from such wells

Keywords: Bio-accumulation, non-biodegradable, well water, Heavy Metals, Makurdi, Nigeria

INTRODUCTION

It is no longer news that water is a natural and irreparable resource that is needed for the sustenance of both plant and animal life on earth. Water has two sources which are surface water derived from ponds, streams, lakes, rivers, seas and oceans, and groundwater derived from wells and boreholes. It can be contaminated by physical, biological and chemical contaminants thereby leading to various ailments to both plants and animals. It has been established that even though 71% of the earth surface is covered by water, only 2.5% of it is fresh and available for human consumption (Sholehhudin *et al*., 2021).

Groundwater is a prime source of drinking water in the world, since it is generally of good quality and available all year round. Evaluation of groundwater quality is an essential aspect in understanding the role of rock-water interaction and/or impacts of anthropogenic influences on the groundwater system. About 75% of the world's total population faces tremendous water scarcity, while 660 million people lack access to safe potable water (Rao & Chaudhary, 2019).

The near zero presence of public potable water in Makurdi the Benue State capital of the North Central part of Nigeria has forced most of its inhabitants to depend on ground water particularly hand dug well water for drinking and other domestic usages all year round. Water from this hand dug wells is not subjected to strict environmental guidelines set by the World Health Organization (WHO) and the Nigerian Industrial Standards (NIS) before drinking by the inhabitants of the area.

Water from contaminated wells is caused by both natural and man-made sources but the man-made sources seem to contribute more contaminants than the natural ones (Momodu & Anyakora, 2010). These contaminants which include heavy metals can cause a variety of illnesses including gastrointestinal, liver, kidney, lung, intestinal, neurological and reproductive illnesses. The effects are more dangerous on the infants, the aged and the pregnant women (WHO, 2007).

Heavy metals contamination of ground and surface waters has attracted researchers from various areas of chemical, biological, physical, medical and biomedical sciences in recent times. A heavy Metal (HM) as defined in literatures is any naturally occurring element with high atomic weight and high density that is at least five times that of the density of water (Tsor & Jombo, 2022; Saleh & Aglan, 2018; Salomons *et al*., 1995). Pollutants are so numerous in nature but HMs attract the attention of medical, environmental, pure and applied scientists such as medical doctors, chemists, physicists, and biologists as a result of their toxic nature. HMs are naturally ubiquitous in trace amounts in natural waters but can be very toxic even in very small concentrations (Momodu & Anyakora, 2010). Their concentrations in water are increasing on a daily basis due to increased human activities as a result of urbanization, industrialization, transportation, electricity generation, and agricultural activities among others which are soaring as human population continues to witness astronomical rise.

Metals such as arsenic (As), lead (Pb), cadmium (Cd), nickel (Ni), mercury (Hg), chromium (Cr), cobalt (Co), zinc (Zn), and selenium (Se) are highly toxic even in very small concentrations in water (Saleh & Aglan, 2018; Salomons *et al.,* 1995). Increasing concentrations of heavy metals in our water resources is currently an area of great concern, especially since a large number of industries are discharging their metal containing effluents into fresh water without any adequate treatment. Our surface and ground waters are not spared from contamination by heavy metals. This contamination can be by air and water erosion, leaching into the soil of heavy metals down to the water aquifers thereby causing well water contamination and the concentrations continue to rise since HMs bio-accumulate and are non-biodegradable.

Heavy metals are considered harmful to humans, other animals and plants because they are highly non-biodegradable, have long biological half-lives which refer to the natural cleansing periods of HMs by such body organs like kidney, liver, lung, intestines, etc. and possess the potential to bio-accumulate in different parts of the bodies of both plants and animals (Suruchi & Pankaj, 2011). Adults absorb 35% to 50% of lead through drinking water, while children consume more than 50% of lead through drinking water (WHOa, 2011).

In the European Communities, thirteen HMs namely: As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sn and Tn are of highest concern. Some of them (Co, Cu, Cr, Ni) are actually necessary for humans in minute amounts while others like Hg, Pb and As are carcinogenic or toxic affecting the central nervous system, Hg, Pb, Cd and Cu affect the kidney or liver, while Ni, Cd, Cu, and Cr affect skin, bones, or teeth (WHOb, 2011). The contamination of water by HMs actually affects all organisms. Humans who drink the water ingest it and other organisms feed on them directly or it enters the food chain and causes diverse health effects to more organisms (Iyoti, 2020).

Some anthropogenic sources of HMs contamination of the environment are: automobile exhausts which release Pb; smelting which releases As, Cu and Zn; insecticides which release As; burning of fossil fuels which releases Ni, Va, Hg, Se and Sn. Heavy metals are transported as runoffs from industries, municipalities, urban areas, agricultural farms, automobile and metal work workshops (Iyoti, 2020). These can reach ground water (wells and boreholes) through leaching into the ground and pouring into open wells due to flooding as run-offs when the wells do not have proper covers, or when the height of the well doors are too low and become submerged during floods or by both.

For water quality to meet drinking standards as far as the six heavy metals of this study are concerned, it must meet the Maximum Permissible Guidelines set by the WHO (Tsaridou & Karabellas, 2021) and NIS (NIS, 2015) as seen on Table 1.

Table 1. Heavy Metals' Maximum Permissible Guidelines for Drinking Water by WHO (Tsaridou & Karabellas, 2021) and NIS (2015)

Heavy Metal	WHO Guideline value (mg/L)	NIS Guideline Value (mg/L
Cadmium (Cd)	0.003	0.003
Copper (Cu)	2.00	1.00
Lead (Pb)	0.01	0.01
Manganese (Mn)	0.20	0.20
Nickel (Ni)	0.07	0.02
Zinc (Zn)	3.00	3.00

The Maximum Permissible Guidelines for drinking water set by the WHO (WHO, 2017) and the NIS (NIS, 2015) for physico-chemical parameters analysed for this study are as in Table 2.

Table 2. Physico-Chemical Guidelines for Drinking Water set by WHO (Aturamu, 2012) and NIS (NIS, 2015)

Physico-Chemical *Water parameter*	*WHO Guideline value*	*NIS Guideline Value*
pH	8.2 – 8.8	6.5 – 8.5
Temperature (°C)	28.0 – 30.0	Ambient
Total Suspended Solids (mg/L)	90 – 860	1500
Dissolved Oxygen (mg/L)	4.9 - 10.3	-
Turbidity (NTU)	5.0	-

In Logo 2 area of Makurdi, the use of well water for most purposes has become inevitable since the governments at all levels have failed to provide potable drinking water for the inhabitants of the area. As a result, there is every need to embark on the assessment of the concentrations of heavy metals in well water which is the major source of water for the inhabitants in this place. Logo 2 is a settlement opposite the Benue State University, Makurdi, Nigeria. Due to inadequate accommodation to the students of this university, more than half of the student population reside off campus of which most reside in this area because of its proximity to the university. These future leaders live in this high-density populated area without potable water supply. As a result, these students and the rest of the other occupants of this area result to the use of hand dug well waters for drinking and other domestic usages. It has also been observed that the water from these wells is not subjected to any form of treatment before use by both the students and the other residents of the area. This area is subjected to annual floods which carry along with them contaminants of various forms from different sources that enter the wells some of which do not have covers or are poorly covered, or have well covers that are of inadequate height above ground levels. Also, Logo 2 is a high- density populated area because most of the plots are far less than the minimum plots of 30.48 m by 30.48m which contain buildings that occupy most of the plots with very small rooms which usually do accommodate at least 2 occupants. Many other people beside students that reside here do carry out commercial activities in the university for their living. The WHO and NIS have provided maximum Contaminant Levels for the presence of heavy metals.

This study assessed five physico-chemical parameters and the concentrations of six HMs in the area using samples collected from 10 different hand dug well waters of the study area and their health hazards on the inhabitants of this area were determined, and the residents were adequately advised on the health implications of their continued use of their only source of drinking water. The results were also compared with the Maximum Permissible Guidelines for heavy metals and physico-chemical properties stipulated by the WHO and NIS as seen in Tables 1 and 2 respectively for drinking water and conclusions were drawn.

MATERIALS AND METHODS

Study Area

This study was carried out in Logo 2 area of

Makurdi in the Sub-Saharan Africa. Makurdi is the state capital of Benue state in Nigeria. It doubles as the headquarters of Makurdi Local Government Area. Makurdi is located on the Geographical coordinates 7.73^{0}N and 8.53^{0}E with an altitude of 113 m above sea level. Makurdi and its environs had an estimated population of 365,000 persons in 2016. Makurdi is located in a deep valley. The city is divided into two areas by the river Benue which is the second largest river in Nigeria. Makurdi has two bridges and each of them is one meter long. Makurdi is affected by flood annually, thereby transporting along with the water run-offs heavy metals which contaminate the soil, surface and ground water in the area (Daniel *et al.,* 2021; Encyclopedia Britanica; Benue State Ministry of Lands and Survey, 2011).

Logo 2 is located within the Makurdi metropolis and is marked with the red outline as seen in Figure 1. A significant population of Makurdi is located in Logo 2 because it is located opposite the Benue State University along the Makurdi - Gboko road and most of the students of this university reside off campus in this area because of its proximity to the university. Due to the absence of potable water supply in the area, most of the inhabitants result to the use of ground water sourced mostly from wells since boreholes are even very few in the area.

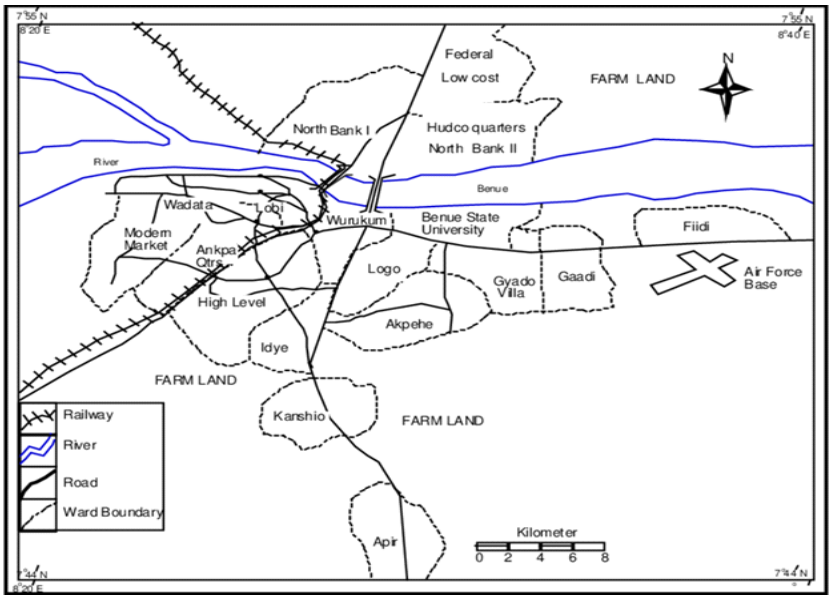

Figure 1 . Map of Makurdi Metropolis showing the study site. Source: (Daniel *et al*., 2021)

Sample collection

Ten wells labelled A, B, C, D, E, F, G, H, I and J were selected in the study area. Ten plastic bottles of one-liter capacities were used to collect water samples from each of the wells as labelled above. The plastic bottles were previously washed in non-ionic detergent and rinsed with tap water after which it was soaked in 10% JHD nitric acid HNO_3(Analar Grade) for 24 hours and finally rinsed in deionized water ready for use (Ubwa *et al*., 2013; Oluyemi *et al*., 2010). Before commencement of sampling, each bottle was rinsed three times with water from the well to be fetched and the samples were accordingly labelled, transported to the laboratory and stored in a refrigerator at the temperature of $4^{O}C$ ready for analysis. The sampling was done in March 2022, one of the dry season months during which water scarcity is on the high side in the study area and there was no rainfall for harvesting of rainfall water from roofs of buildings.

The pH and temperature values were determined using the Jenway pH meter model 3510 at the various sites. The Dissolved Oxygen (DO) values were also determined and recorded at the various sites using the Hanna DO meter with model HI 9146. The two physico-chemical parameters determined in the laboratory were the Total Suspended Solids (TSS) which was determined gravimetrically using the ADAM PW184 Analytical balance, and turbidity which was determined using HACH 2100P turbidity meter.

Sample Preparation and Analysis

250 ml of each of the ten water samples was transferred into a beaker and 5 ml of concentrated HNO_3 added. Each beaker was then covered with a watch glass and returned to the hot plate. For more heating with the addition of few drops of concentrated HNO_3 until the solution appeared light coloured and clear. The walls of the beaker and the watch glass were washed down with distilled water and the sample filtered with Whatman paper 0.45μm to remove insoluble materials that could clog the atomizer. The volumes of the filtrates were made up to the 250 ml with distilled water (Ubwa *et al.*, 2013). A blank sample was similarly treated so as to give room for blank correction. This was done by transferring 250 ml of distilled water into a beaker and digested as described above. Calibration standards were prepared from stock solutions by dilution and were matrix matched with the acid concentration of the digested samples. The digested samples were then analysed for heavy metals using Atomic Absorption Spectrophotometer (AAS) Model PG 990 at the Department of Chemistry, Benue State University Makurdi, Nigeria. The calibration plot method was adopted for the analysis. Air-acetylene flame was used and the cathode lamp of the corresponding elements was the resonance line source, the wavelengths for the determination of the various elements (Cd, Cu, Pb, Mn, Ni and Zn) were determined and recorded (Momodu & Anyakora, 2010).

RESULTS

Calibration Curve and Wavelength Values of Heavy Metals

This study obtained the various calibration curves using a series of varying concentrations of the standard metal solutions for the six metals studied. The analytical quality control of determinations of the study was carried out by calibrating the AAS instrument used with standard metal solutions (Oluyemi & Olabanji, 2011). The results of the wavelengths and calibration curves of the heavy metals used were tested with respect to sensitivity, precision and accuracy as in (Oluyemi & Olabanji, 2011) and the results are presented in Table 3.

Table 3: Wavelengths and calibration curves of the heavy metals used for this study

Heavy Metal	Wavelength (nm)	Calibration curve
Cadmium (Cd)	228.8	1.000
Copper (Cu)	324.7	1.000
Lead (Pb)	217.0	0.999
Manganese (Mn)	279.5	0.992
Nickel (Ni)	232.0	0.997
Zinc (Zn)	213.9	0.994

It is clear from Table 3 that the calibration curves obtained have shown high linearity level with the coefficient of determination r^2 values that ranged between 0.992 and 1.000.

Physico-Chemical Parameters of Well Water Samples used

The results of the five physico-chemical parameters determined in this study were TSS, DO, pH, temperature and turbidity with the results presented in Table 4.

Table 4. Physico-chemical parameters of water from the Ten Wells in Logo 2 Area of Makurdi in March 2022.

Name of well	Well ID	TSS (mg/L)	DO (ppm)	pH	Temp (°C)	Turbidity (NTU)
Asongo	A	0.002	4.27	6.1	30.0	1.98
Adole	B	0.012	5.87	6.2	30.0	2.04
Okanu	C	0.199	4.61	6.2	29.9	1.72
Kwembe	D	0.137	4.69	6.2	29.9	1.49
Amem	E	0.305	4.40	6.3	29.8	1.08
Tsor	F	0.011	4.70	6.1	30.0	1.39
Tija	G	0.081	4.53	6.3	30.0	0.94
Aernyam	H	0.008	4.88	6.2	30.0	1.48
Pakson	I	0.079	4.37	6.0	30.0	1.90
Wasika	J	0.118	4.72	6.1	30.0	1.83

The ranges of the five physico-chemical parameters for the ten wells of this study from Table 4 are as follows: TSS (0.002–0.305) mg/L; DO (4.27-5.87) mg/l; pH (6.0-6.3); Temperature (29.8-30.0) °C and turbidity (0.94-2.04) NTU. All TSS values are below the WHO and NIS values of 20 mg/L. Similarly, the pH, temperature, DO and turbidity all have their values which all fell below the guidelines set by both the WHO and NIS for drinking water as could be seen from Tables 1 and 4.

Concentrations of Heavy Metals in Wells of the Study Area

The water samples of the study area were subjected to AAS laboratory analyses to determine the concentrations of the six HMs which included Cd, Cu, Pb, Mn, Ni and Zn. The results obtained are presented in Table 5.

Table 5. Concentration of Heavy Metals in Ten Wells in Logo 2 Area of Makurdi in March 2022.

Name of well	Well ID	Cd(mg/L)	Cu(mg/L)	Pb(mg/L)	Mn(mg/L)	Ni(mg/L)	Zn(mg/L)
Asongo	A	0.0125	-	-	0.0982	0.0102	0.0797
Adole	B	0.0149	-	-	0.2516	0.0110	0.0786
Okanu	C	0.0112	-	-	0.0631	0.0013	0.0758
Kwembe	D	0.0117	-	-	0.0724	0.0116	0.1267
Amem	E	0.0127	-	-	0.0413	0.0117	0.1062
Tsor	F	0.0123	-	-	0.6117	0.0125	0.4975
Tija	G	0.0107	-	-	0.2512	0.0132	0.1198
Aernyam	H	0.0084	-	-	0.0447	0.0111	0.1764
Pakson	I	0.0072	-	-	0.3194	0.0086	0.0954
Wasika	J	0.0095	-	-	0.1067	0.0157	0.0906

The results of the concentrations of the HMs in the various wells as seen in Table 5 were arranged in descending order of abundance as Mn>Zn>Cd>Ni. Pb and Cu were undetectable in all the wells of this study. The ranges of the four heavy metals detected and analyzed in mg/L were: Mn (0.0413-0.6117); Zn (0.0758- 0.4975); Cd (0.0072- 0.0149); Ni (0.0013-0.0157) mg/L. The results show that Pb and Cu were undetectable using the above method. This does not mean that these heavy metals were not present in the water samples. Their presence could be detected by other methods which is beyond the scope of this study.

The results of all the water samples tested for Cd had their concentrations 100% above the Maximum Permissible Contamination Level Guidelines of 0.003 mg/L specified by both WHO and NIS for drinking water. Wells B and E ranked highest and second with concentration values of 0.149 and 0.127 mg/L respectively while wells I and H had the least and second least concentrations of Cd with values of 0.0072 and 0.0084 mg/L respectively.

All the ten well-water samples tested for Ni had their concentrations 100% below the Maximum Permissible Contamination Level Guidelines of 0.07 and 0.002 mg/L specified by both WHO and NIS respectively for drinking water. Well J ranked highest and well C ranked least with concentration values of 0.0157 and 0.0013 mg/L respectively. In a similar way, all the ten well samples of well water collected and analysed for Zn had their concentrations 100% below the Maximum Permissible Contamination Level Guidelines of 3.00 mg/L specified by both WHO and NIS for drinking water. Well F ranked highest with a value of 0.4975 mg/L, while well C had the least value of 0.0758 mg/L.

For samples of well water tested for Mn, four samples namely: B, F, G and I had concentrations above 0.20 mg/L of drinking water guidelines set by both WHO and NIS, with sample F having the highest concentration of 0.6117 mg/L, followed by I, B and G respectively. This implies 40% of the samples had their concentrations above the guidelines while the number of samples of well water tested for Mn which had their concentrations below the prescribed maximum concentration by WHO and NIS stood at 6 amounting to 60%. The samples include: A; C; D; E; H and K.

DISCUSSION

Physico-Chemical Parameters

All the five values of the physico-chemical parameters: pH; temperature; turbidity; DO and TSS were below the guidelines set by both the WHO and NIS for drinking water. The pH values give the level of toxicity in water. The lower the pH value, the higher the toxicity of the water. In all samples, the pH values were within the ranges of 8.2 to 8.8 and 6.5 – 8.5 recommended by WHO and NIS (WHO, 2017; Aturamu, 2012). The temperatures of all the water samples were within the temperature range of 28-30°C set by WHO, which also complies with the NIS guidelines that has set acceptable temperature for drinking water within the ambient range. The implication is that all the five physico-chemical parameters have no adverse effects on well water in the study area.

Heavy Metals Concentration

The level of abundance of Cd was exceptionally high in all the water samples analysed. This results are very close to a study carried out on heavy metal contamination of groundwater in Surulere, Lagos, Nigeria where 84.21% of the water samples tested for cadmium had their concentration values above the Maximum Permissible level set by the WHO and NIS (Momodu & Anyakora, 2010). The probable sources of Cd in the area could be from leaching of heavy metals into the aquifers of the wells from dumpsites with a lot of electronic gadgets and rechargeable lanterns which contain Cd, urban water run-offs during the annual floods in the area, dumping of agricultural wastes, gravimetric deposition of entrained Cd infested dust particles in open wells etc.

Cadmium is carcinogenic in nature (Idrees *et al.,* 2018). It is highly toxic and is responsible for nephrotoxic effects at high concentration levels and long- term exposure, it can cause lung, kidney and bone damages (Oluyemi & Olabanji, 2011; Oluyemi *et al.,* 2010; WHO, 2007). As far as Cd is concerned, all well water in the area is not to be drank unless it is treated.

Manganese presence in the water samples analysed recorded 40% concentrations above the standards set by WHO and NIS for drinking water while that of 60% of the samples were above the standards set by same bodies for Mn. The high concentration values of Mn showed similarities with results of a study carried out on HMs concentrations in well water in east Java province of Indonesia (Sholehhudin *et al.*, 2021). The 4 wells whose water needs to be treated before drinking because of Mn in the descending order of concentration are F, I, B and G.

Those who patronize these wells should undergo regular medical checks for such diseases like neurological diseases, low intelligent quotient (IQ) in children and liver dysfunctions. Sources of Mn in well water in this area could be natural from bedrock of deep wells and anthropogenic from agricultural practices, domestic waste water and sewage sludge (Sholehhudin *et al.,* 2021). Even those using the six wells with values of Mn concentrations below the minimum values for Mn should also carry out such routine medical checks since bioaccumulation of low values for a long period will lead to same adverse effects on the consumers.

Ni and Zn heavy metal concentrations all fell below standards set by both WHO and NIS for drinking water for all the wells. This agrees with the findings of (Sholehhudin *et al.,* 2021) that the natural presence of Zn in groundwater is always less than that of other heavy metals. Zn is one of the minerals needed in trace amounts by the body for the growth of cells and tissues, however excess of its presence in drinking water when ingested by man damages organs like prostate, bone, muscle, liver, and the gastrointestinal system (Sholehhudin *et al.*, 2021). Hence the need to continually check its concentration in well water in this area to see that its bioaccumulation over the years does not lead to the effects mentioned above.

Ni like Cd is carcinogenic when ingested in water even in very small amounts leading to lung and nasal cancers. Other diseases associated with Ni are allergy, cardiovascular and kidney diseases, contact dermatitis and lung fibrosis. Sources of Ni are liquid and solid fuels, municipal and urban wastes, batteries, electronic components, etc. Its low concentrations in all the wells in this area should not be taken for granted.

Cu and Pb in this study were undetected. Their presence should not be taken for granted too since their accumulation over the years also lead to adverse health effects. All preventive measures should be taken as stated in (Idrees *et al.,* 2018; Oluyemi & Olabanji, 2011; Oluyemi *et al.,* 2010; Momodu & Anyakora, 2010;) to avoid their effects on human health.

CONCLUSION

This study has shown that water from the ten wells all fell within the tolerable levels of guidelines for drinking water set by both the WHO and NIS as far as the five physico-chemical parameters pH, temperature, turbidity, DO and TSS are concerned. The study also shows that there exist HM contamination of well water in Logo 2 area of Makurdi, Nigeria. Even though most of the wells fell below the drinking water guidelines set by WHO and NIS, bio-accumulation of these metals which are non-biodegradable in water, soils, air, humans and food chain can cause health hazards like cardiovascular diseases, kidney, liver, lung, intestinal, cardiovascular, retarded growth and carcinogenic diseases among others which can lead to increases in morbidity and mortality rates in the area. Increasing human activities by residents of the area like indiscriminate disposal of wastes, use of wells with covers less than 70 cm above ground level, absence of well covers, proliferation of metal, electronic and mechanical workshops in the area, carrying out of infrastructural developments in the area both by governments and individuals without proper adherence to Environmental Impact Assessment and annual flooding in the area which carry along with the flood water biological, chemical and physical contaminants have significantly contributed to groundwater pollution by heavy metals in the area.

Recommendation

The researchers recommend that more awareness and health education campaigns of residents in the study area should be carried out by environmental scientists, environmental lawyers, individuals, governments and non-governmental organizations on the dangers of indiscriminate and improper wastes disposal, raising the heights of well covers at least 2 feet above the ground level, provision of proper well doors (proper well capping), creation of barriers for HM containment of well water, and regular tests of water qualities in the area to ensure the health risks associated with ingestion of well water contaminated with HMs by the inhabitants of the area is reduced to the barest minimum even if not totally eliminated. In addition, reverse osmosis treatment of well water in the area should be carried out by residents of the area who can afford it to reduce the health impacts of HMs from well water. Biological tests on well water in the area should also be intensified and appropriate measures be suggested to avert contamination from organisms that pollute well water in the area. More vigorous campaigns concerning Environmental Impact Assessment (EIA), Environmental Management and Monitoring on activities that lead to HM emissions and other contaminants to the environment (air, soil, water and biota) which will eventually end up into ground water particularly wells should be strictly enforced all over the country. The study further recommends that future researchers should collect more samples from more wells in logo 2 area and also extend the coverage to a larger geographical coverage for more scientific and representative conclusion of the research findings. Finally, future researches in the area should include depths of wells from which samples were analysed and also carry out soil sample analyses of the study area to find out whether the depths of wells and types of soil in the area contribute to heavy metal contamination of hand dug well water in this area.

Limitations

The study was limited by the fact that only few samples were analysed and so the findings of the research should be accepted in that light. The study never the less brought out the bases for regular analyses of heavy metals in the hand dug well waters in the locality and probably by extension the Makurdi metropolis.

Conflict of Interest

The authors declare no conflicts of interest.

Acknowledgement

The authors hereby acknowledge the immense support and cooperation of the Head of Department of Chemistry of Benue State University Makurdi, Dr Benjamin Asen Anhwange for allowing this experiment to be carried out in the Chemistry Laboratory. We also extend same to the Laboratory Technologist, Mr. Pius Utange who helped in the laboratory analysis of physico-chemical parameters and heavy metals concentrations carried out by this study. The authors hereby state that no funding was received by them for this study.

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