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Arsenic in groundwater of Obi-Uosu Brine fields, North Central, Nigeria

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Abstract

Arsenic occurs naturally in the Earth's crust and may enter groundwater through geochemical processes. Chronic exposure through drinking water can pose substantial health risks. This study assessed arsenic concentrations in shallow groundwater from the Obi-Uosu brine fields and considered potential sources and implications for local water use. Twenty-three samples were collected from shallow hand-dug wells and analysed for arsenic by inductively coupled plasma mass spectrometry (ICP-MS). Measured concentrations were compared with the World Health Organization (WHO) drinking-water guideline using a student's t-test, as reported by the study. Arsenic concentrations ranged from 0.095 to 0.389 mg/L, with a mean of 0.171 mg/L. The mean concentration was significantly higher than the WHO guideline used for comparison. These results indicate that the sampled shallow groundwater is unsuitable for drinking without effective arsenic removal. Because the minimum reported concentration also exceeded the guideline applied in the study, the results warrant prompt confirmation through repeat sampling and laboratory quality-control review. Dissolution of arsenic-bearing minerals and oxidation of sulphides associated with regional lead–zinc mineralization is proposed as possible sources. However, arsenic speciation, mineralogical evidence and source-tracing analyses were not reported; the proposed mechanisms therefore remain unverified. These results characterize sampled wells but cannot establish conditions in untested sources or prove a specific contamination pathway. Communities should use alternative supplies only after testing confirms low arsenic concentrations, and should receive clear guidance on exposure risks. Further work should verify spatial and seasonal variability, assess analytical quality assurance, determine arsenic species and investigate groundwater geochemistry and mineral sources.

Keywords

Arsenic,
Wells,
Obi-Uosu,
Brine Fields,
Groundwater,
Sulphides,
Lead-Zinc.

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INTRODUCTION

Arsenic is an element that is found in nature (soil, rocks and water) and in man made products, such as pesticides and herbicides. It is introduced into water through the dissolution of rocks, minerals and ores from industrial effluents, including mining waste; and via atmospheric deposition (WHO, 2011). Also, water travels through rock sand soils as part of the hydrological cycle and in the process leached elements in solution (Lar, 2009). It is the 20th most abundant element in the continental crust. It occurs mainly in two oxidation states namely, trivalent arsenite (As (III) or pentavalent arsenate as(V). In well oxygenated surface waters, arsenic (V) is the most common arsenic specie that is present, while under reducing conditions such as those often found in deep lake sediments or deep groundwater, the predominant form is arsenic (III). The +III oxidation state is more toxic than the (V) oxidation state. The mobility and toxicity of arsenic are determined by its oxidation state. Acute As poisoning occurs due to drinking of contaminated water. The greatest threat to public health from arsenic originates from contaminated groundwater. People are exposed to elevated levels of inorganic arsenic by drinking contaminated water, using contaminated water in food preparation, irrigation of food crops, industrial processes and natural geochemical processes and natural geochemical processes (Nordstrom, 2002). Acute poisoning involves dryness of the mouth throat, vomiting, diarrhea and nausea (Usman and Lar, 2013). Also, low birth weight, foetal loss and retarded infant growth could occur in children that were given arsenic contaminated water.

Arsenic concentrations in surface water and groundwater can vary by more than four orders of magnitude depending on the amount of available arsenic in the source rocks and the local geological environment (Smedley and Kinniburgh, 2002). The concentration of arsenic in unpolluted fresh water typically ranges from 1 – 10 µg/L, rising to 100 - 500µg/L in areas of sulphide mineralization and mining (Khan, 2011).

Ground waters are generally more vulnerable to as contamination than surface waters because of the interaction of groundwater with aquifer minerals and the increased potential in aquifers for the generation of the physicochemical conditions favourable for As release. Most of the worlds recognized As related health issues are linked with long term use of groundwater for drinking (Smedley, 2002).

Arsenic is classified as a Group A carcinogen (human carcinogen) and severe health effects have been observed in populations drinking arsenic rich water over long periods of time. Research has shown that at least 100 million people in twenty countries are exposed to chronic arsenic poisoning (Ravenscroft et al., 2009). There are reports on groundwater as problems from a magnitude of countries ranging from Argentina, Bangladesh, Chile, China, Hungary, India to Mexico, Romania, Taiwan and several parts of USA (Panagiotaras et al., 2012).

Groundwaters (borehole and hand dug wells) is a major source of water that is used for drinking and domestic purposes in Nigeria because of its purity. However, in rural areas both groundwater and surface waters (rivers, streams and ponds) are being consumed without undergoing any form of treatment before they are used for drinking and domestic purposes. The objective of this paper was to assess the concentration of arsenic in shallow groundwaters of Obi-Uosu and environs.

MATERIALS AND METHODS

Study Area

Obi-Uosu lies within the Middle Benue Trough of Nigeria. It is bounded by latitudes 8◦ 5'N and 8◦ 20' N and longitudes 8◦ 45' E and 8◦ 50'E (Fig 1). The area is flat and certain areas were interrupted by ridges (Osaji, 2019).

In terms of the geological characteristics, several investigators have discussed various aspects concerning the geology of Obi-Uosu (Sallau, 2015,

Nwajide, 2013 and Sallau, 2017). Five major units of Aptians – Santonian rocks exist from oldest to the youngest. These units are Asu River Formation which is composed of shale and siltsone, Awe Formation includes shale and sandstone, Keana Formation consists of sandstone, siltsone and shale. Ezeaku Formation is made up of shale, sandstone and mudrock. Awgu Formation consists of clayey shales and limestone.

Groundwater supplies in the area depend on aquifers within the various geological units. The Awe Formation which consists of flaggy sandstones with interbedded shale is aquiferous, but it yields salt water (Nwajide, 2013).

Sample collection and analyses

A total of twenty-three water samples were collected from shallow hand dug wells in the area Fig 1. Each water sample was filtered through 0.45 μm membrane filter in 250 ml polyethylene bottles and the bottles were repeatedly rinsed with distilled water before collection. The samples were acidified with two drops of nitric acid to fix the arsenic in the groundwater, and then preserved in ice-chested coolers at a temperature of 4◦C. The groundwater samples were analysed at the Central Analytical Facilities, University of Stellenbosch, South Africa. Arsenic was determined by Inductive coupled plasma mass spectrometer (ICP-MS). The detection limit of the analytical tool was 0.01 mg/l.

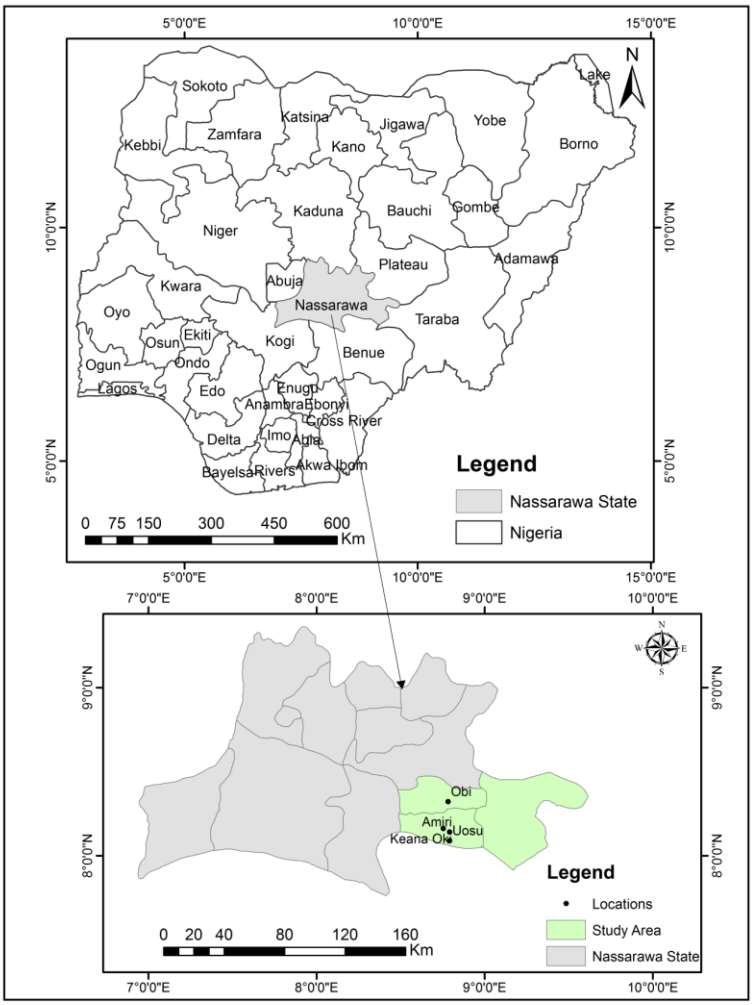

Fig 1 Map of the study area

Statistical analyses

The data were analyzed using Statistical Package for Social Sciences (SPSS) version 16.0. The significance of the difference between arsenic concentration in shallow groundwater and WHO recommended value was determined using a paired student's t- test.

RESULTS AND DISCUSSION

Concentrations of Arsenic in shallow groundwater as well as the WHO maximum allowable limits for drinking water are presented in Table 1. The concentrations of arsenic in the groundwater ranged from 0.095 – 0.389 mg/l. It has a mean value of 0.171 mg/l. The students t-tests conducted on the data yielded a value of t = 0.03 ($p < 0.05$ and degree of freedom). There was a significant difference between mean concentration value of arsenic in the groundwater and WHO (2017) Guidelines for Drinking Water Quality.

TABLE 1: ARSENIC CONCENTRATION IN SHALLOW GROUND WATERS

Sample (id	Location	Description	As(mg)l
Loc 1	Uosu Village	Clear water	0.199
Loc 2	Uosu Dispenary	Clear water	0.141
Loc 3	Uosu Primary School	Clear water	0.131
Loc 4	Uosu Chief House	Clear water	0.143
Loc 5	Uosu Worship Center	Clear water	0.161
Loc 6	Tacha Clan Head	Brownish	0.128
Loc 7	Tacha 1	Brownish water	0.257
Loc 8	Gidan Yusuf Tacha	Clear water	0.182
Loc 9	Gidan Joe Tacha	Light brown water	0.093
Loc 10	Obi Market Square	Clear water	0.095
Loc 11	Maraba Obi Stall	Clear water	0.150
Loc 12	Maraba Obi Clan Head	Light brown	0.160
Loc 13	Obi Dispensary	Clear water	0.184
Loc 14	Obi Medicine Store	Clear water	0.184
Loc 15	Obi Primary School	Light brown water	0.015
Loc 16	Gidan Ibrahim Obi	Clear water	0.192
Loc 17	Pastor Residences Obi	Clear water	0.121
Loc 18	Tacha 2	Clear water	0.389
Loc 19	Obi Clan Head	Clear water	0.209
Loc 20	Akiniwa Clan Head	Clear water	0.189
Loc 21	Akiniwa Market Entrances	Clear water	0.163
Loc 22	Gidan Sule	Clear water	0.158
Loc 23	Marba Akiniwa	Clear water	0.166
WHO (2017)			0.01?

The highest concentration of arsenic detected in the shallow groundwater was 0.389 mg/L. Seventy-six percent of the total sample crossed the WHO (2017) guideline of arsenic concentration in drinking water. Previous studies have reported occurrence of arsenic in ground water of Biu volcanic province, Nigeria (Lar, 2009, Usman and Lar, 2013). Khan (2011) showed that 71 % of sampled exceeded WHO (2017) guidelines of arsenic in drinking water. The maximum concentration of arsenic recorded according to this study was 0.389 mg/L which almost agrees with the result of Emerman et al., 2020.

This study showed the mean arsenic content to be 0.171 mg/l which is similar to the work of Sallau (2015).

Mean arsenic concentration according to Gwacha et al., (2020), was 0.26 Mg/L, whereas according to Shrestha et al., (2013) was 0.14 Mg/L

The allowable limit of arsenic in drinking water is 0.01 Mg/L according to WHO (2017) and the available arsenic concentration in most of the hand dug wells were in excess of this limit.

The mean value of arsenic in this study was 0.17 Mg/L which was lower than a study by Anawar el al., (2011) who reported a mean value of 11.4 Mg/L arsenic concentration in groundwater of Bangladesh.

In Canada, levels of arsenic exceeding 10 Mg/L were observed in 33-93% of wells in seven communities; the total measured levels ranged from 1.5 to 738 mg/L. Boyle and Turner (2005) also report occurrences of elevated arsenic content in bedrock groundwater used for individuals Municipal. water supplies in the mainland coast of British Columbia, Canada. These differences could be due to variation in the Geochemistry of the underlying rocks.

CONCLUSION

This study revealed high arsenic in shall groundwater. Mean value was higher that WHO guideline of arsenic for drinking water. This implies that the shallow groundwater is not suitable for drinking purposes in terms of arsenic concentration.

We recommend that long term monitoring of groundwater parameters is required to understand the dynamics of groundwater contaminants.

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