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Arsenic Contamination of Domestic Water from Northern Nigeria

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ABSTRACT

One hundred and twenty samples of drinking water sourced from wells and boreholes from eight local governments that comprise Kaduna north senatorial district of Kaduna state were randomly collected and subjected to Arsenic elucidation using standard laboratory method. The wells have the following results; 0.28, 0.25, 0.25, 0.40, 0.20, 0.30, 0.25 and 0.34 mg/L while the results obtained from the boreholes are 0.04, 0.03, 0.13, 0.14, 0.08, 0.12, 0.09 and 0.12 mg/L both from Ikara, Kubau, Kudan, Lere, Makarfi, Sabongari, Soba and Zaria local governments respectively. Both results were found to be above the Maximum Contamination Level (MCL) of 0.01mg/L set by World Health Organization (WHO) and agreed by Standard Organization of Nigeria (SON) therefore, the sources were found to be contaminated with abnormal concentration of arsenic and consumers are vulnerable to severe health hazards. The high arsenic concentrations could be attributed to both natural and anthropogenic processes such, as erosion, undersurface weathering, toxic chemicals, improper waste and sewage disposal, wastes from industries, agricultural activities and vehicular emissions.

Key words: *Arsenic, Wells and Boreholes, drinking water, Kaduna, northern Nigeria.*

1. INTRODUCTION

Water covers almost 70% of the earth's surface the quantity and the quality of water are equally important. Water is always referred to as a universal solvent because it can dissolve many types of substances, but human require water that contains less impurities. Drinking water comes from ground sources such as ground water and aquifers. It can also be obtained from surface water body such as rivers, streams and glacier other sources including rain, hail and snow, biological sources such as plants and sea through desalination surface water picks up deferent minerals resulting from the presence of animal or human activities. While for the ground water, the contaminants come from leachate, landfills and septic systems. Similarly, haphazard disposal from agricultural chemicals and household cleaning products. The contaminants in ground water take more time to be cleaned because it moves slowly and isn't exposed to the natural cleansing benefits of air, sunlight and micro-organism [1].

Generally, the quality of drinking water is determined based on the appearance, taste, colour and odour of the water. The appearance, taste, colour and odour do not really tell if the water should be free from hazardous compounds. The environmental protection agency (EPA) and world health organization (WHO) set a maximum contaminant level in drinking water supplied to municipal or population. When a standard or guideline is exceeded in the municipal or community water system, the state is required to take proper action to improve water quality level including treating the water through filtration or aeration blending water from several sources to reduce contaminants including inorganic chemicals such as salts, metals and mineral. These substances occur naturally in geological structures or sometimes caused by mining, industrial and agricultural activities. These chemical can badly affect human health when they are consumed in large amount [2].

There are two main sources of water supply that are available to man, surface water, that includes: lakes, stream, drainage areas which funnels water toward the holding reservoirs and the method of catching and holding rain water and secondary, ground water which includes well, springs and horizontal galleries. Hence the source of impurities, since water is a good solvent, it will dissolve a greater variety of substance than any other liquid due to it high solvation and auto-protonation properties. The water resources are stressed by a number of factors, including cattle grazing, pollution and rapidly-growing urban areas. More than 1 billion people don't have access to recommended daily safe freshwater globally

[3]. A necessary concern therefore seeks a complete sustainable balance between the purity of our currently available fresh water and proper usage. Thus, speciation of water contaminants, especially heavy metals like Mercury (Hg), Arsenic (As) etc is vital due to their associated health hazards.

Arsenic is an identified key contaminant (Eugene, 1979) for many decades that occurs in a variety of minerals including Arseno pyrite (FeAsS), Realgar (As_2S_2), Orpiment (As_2S_3), Arsenolite (As_4O_6), native Arsenic in ores of Copper, Lead, Cobalt, Nickel, Zinc, Silver, Tin and also as nickel glance (NiAsS) or mispickel [4]. Arsenic is chemically very similar to its predecessor phosphorus, so much that it will partly substitute for it in biochemical reactions and is thus poisonous. When heated it rapidly oxides to arsenous oxide, which has a garlic odour. Arsenic and some arsenic compounds can also be sublime upon heating, converting directly to a gaseous form. Elemental arsenic is found in two solid forms; yellow and grey limetallic, with specific gravities of 1.97 and 5.73 respectively.

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The toxic substance can be detected by several tests, including marsh test developed by James marsh [5]. This test combines hydrogen formed by the reaction between zinc and sulphuric acid with the sample suspected to contain arsenic. If As_2O_3 (which is poisonous) is present reacts with hydrogen to form toxic gas called arsine (AsH_3), when arsenic gas is heated, it decomposes to form arsenic, which is recognized by its metallic luster. The most toxic of arsenic compounds are those in which the element lost all its three 4p electrons, that is when it exist in the +3 oxidation state (As^{3+}) [4, 6]. One of the major mechanism by which Arsenic exerts its toxic effect is through an impairment of cellular respiration by inhibition of various mitochondrial enzymes and the uncoupling of oxidative phosphorylation [5,7]. The level of arsenic in natural waters varies between land 2mg/l [4, 8]. Concentrations may be elevated however, in areas containing natural sources value as high as 12mg/L have been reported [5].

The current study reports a determination of mean arsenic concentration in drinking water sourced from wells and boreholes from eight Local Governments that comprise Kaduna Northern Senatorial district of Kaduna State, Nigeria, with the aim to ascertain whether the level of arsenic contaminant in the drinking water is sufficient to cause health hazards to the inhabitants.

2. EXPERIMENTAL

2.1 Sample Collection and Sampling Sites

One hundred and twenty water samples were collected from two different types of water sources namely; Hand Dug Wells and Hand Pump Operated Boreholes randomly from Ikara, Kubau, Kudan, Lere, Makarfi, Sabongari, Soba and Zaria (figures 1a and b) and were evenly spread. Boreholes were operated for at least five minutes before sample collection. The samples were collected in pre-cleaned plastic sample bottles and analyzed within one hour after collection.

Figures 1a & b: Geopraphical maps showing the location of Kaduna state, Nigeria and the various sampling sites respectively

2.2 Materials

In preparation of reagents, BDH chemicals of analytical grade purity and distilled water were used. All weighings were carried out on analytical weighing balance (Gallenkamp Metler Model H3O). Standard solutions of iodine (0.1M to 0.0001M) and starch were prepared according approved chemical procedures [5].

2.3 Arsenic Concentration Determination

A standard titrimetric procedure that was previously validated by Garba et al. [5] was employed. The procedure considers both organic and inorganic Arsenic to exist as initial As_2O_3 species that are equally available to the iodine molecules [4, 5]. 25cm^3 of each water sample was pipetted into a 250cm^3 conical flask and a spatula full of sodium bicarbonate was added followed by the addition of a 3 to 4 drops of starch indicator. The resulting solution was titrated against 0.0001M iodine solution to the first appearance of deep blue color which marked the end point. The experiment was repeated 3 times within each sample.

Equations of the reaction:

$$\mathbf{As_2O_3 + 2H_2O + 2\,I_2 \longrightarrow As_2O_5 + 4H^+ + 4I^-}$$

3. PRESENTATION OF RESULTS

As earlier indicated, two categories of water samples, underground wells and boreholes water samples were analyzed. The underground wells were to the depth of about 3-8m while the boreholes were from 100-700 m below the surface. A total of one hundred and twenty (120) samples comprising both the underground wells and boreholes were analyzed by titrimetric method of analysis. Figure 2 reports the results for all the water samples analyzed showing the mean arsenic concentration (mg/L) for both the wells and boreholes from all the local governments while figures 3-10 shows the results as obtained in each local government.

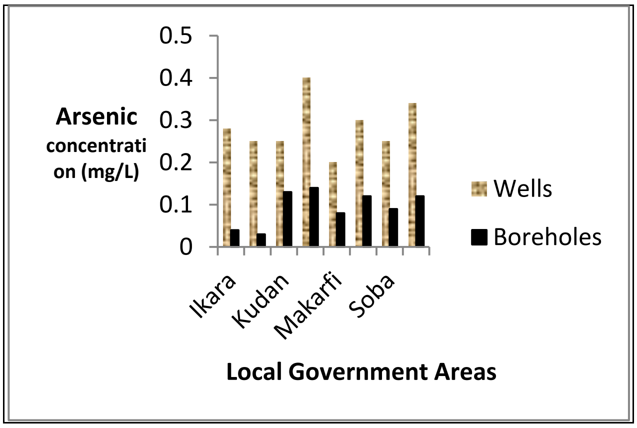

Figure 2. Mean arsenic concentration of both wells and boreholes water from eight Local Government Areas of Kaduna State constituting the Northern Senatorial District of the State

The frequency distribution pattern for arsenic from the wells in the eight Local Government Areas that comprise Kaduna North Senatorial Zone is normal with a mean of 0.28mg/L. The frequency distribution pattern for arsenic from the boreholes in Kaduna North Senatorial Zone has a mean of 0.09 mg/L.

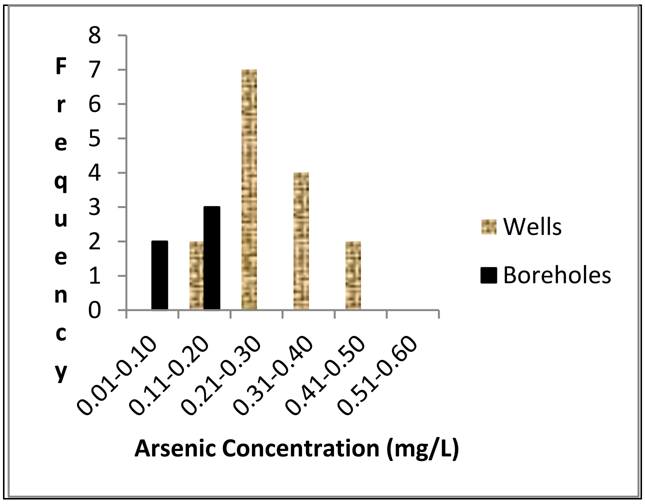

Figure 3. Mean arsenic concentration of both wells and boreholes from Sabongari Local Government of Kaduna State

Figure 3 showed the results obtained from Sabongari Local Government Area with mean arsenic concentrations of 0.30 and 0.12mg/L from the well and borehole samples respectively, both greater than the Maxi mum Concentration Limit of 0.01mg/L set by World Health Organisation [9, 10].

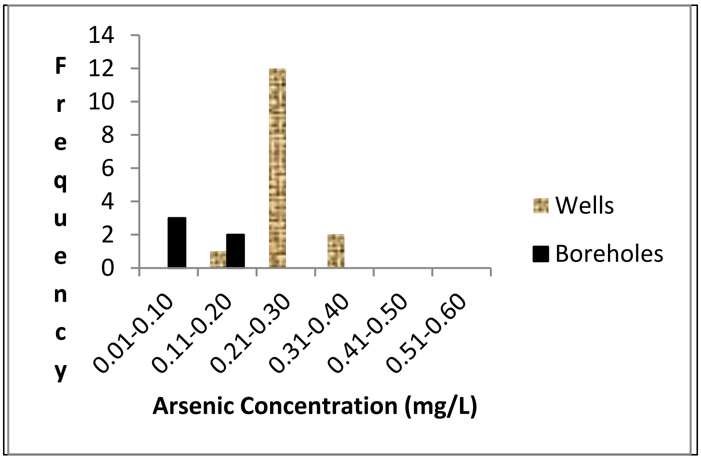

Fig 4. Mean arsenic concentration of both wells and boreholes from Soba Local Government of Kaduna State

Figure 4 showed the results obtained from Soba Local Government Area with mean arsenic concentrations of 0.25 and 0.09mg/L from the well and bor ehole samples respectively, both greater than the Maximu m Concentration Limit of 0.01mg/L set by World Health Organisation [2, 11].

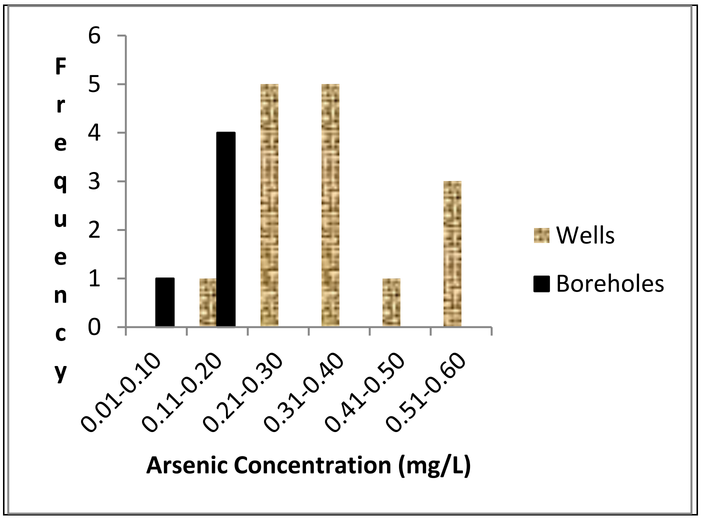

Figure 5. Mean arsenic concentration of both wells and boreholes from Zaria Local Government of Kaduna State.

Figure 5 showed the results obtained from Zaria Local Government Area with mean arsenic concentrations of 0.34 and 0.12mg/L from the well and borehole samples respectively, both also greater than the Maximum

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Concentration Limit of 0.01mg/L set by World Health Organisation [2, 11].

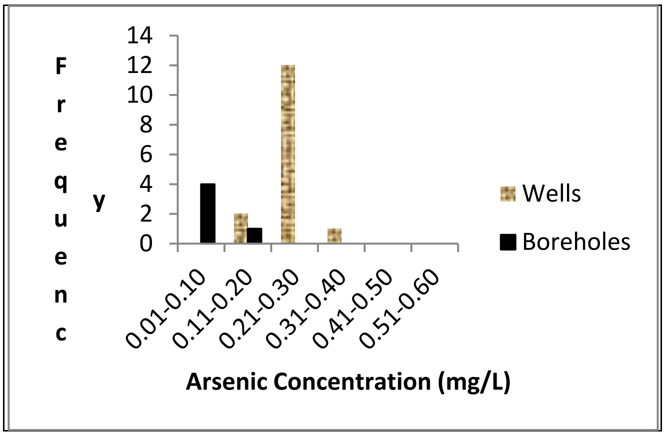

Figure 6. Mean arsenic concentration of both wells and boreholes from Ikara Local Government of Kaduna State

Figure 6 showed the results obtained from Ikara Local Government Area with mean arsenic concentrations of 0.28 and 0.04mg/L from the well and borehole samples respectively, both also greater than the Maximum Concentration Limit of 0.01mg/L set by World Health Organisation [9, 10] but a concentration of 0.04mg/L from the boreholes was closer to the Maximum Concentration Limit than others.

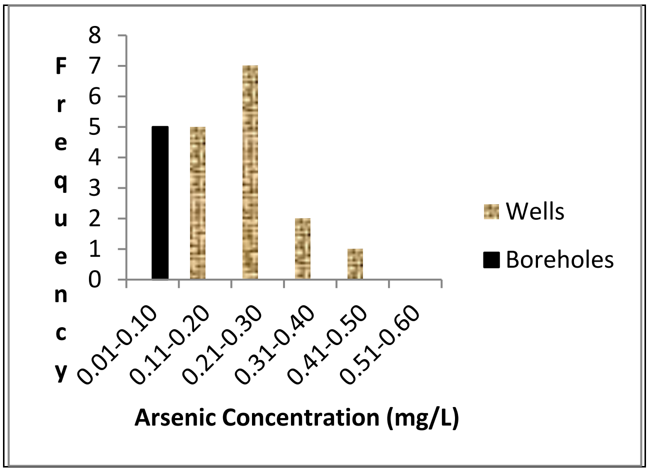

Figure 7. Mean arsenic concentration of both wells and boreholes from Kubau Local Government of Kaduna State

Figure 7 showed the results obtained from Kubau Local Government Area with mean arsenic concentrations of 0.25 and 0.03mg/L from the well and borehole samples respectively, both also greater than the Maximum Concentration Limit of 0.01mg/L set by World Health Organisation but a concentration of 0.03mg/L from the boreholes was the closest to the Maximum Concentration Limit of 0.01mg/L set by World Health Organisation [9, 10].

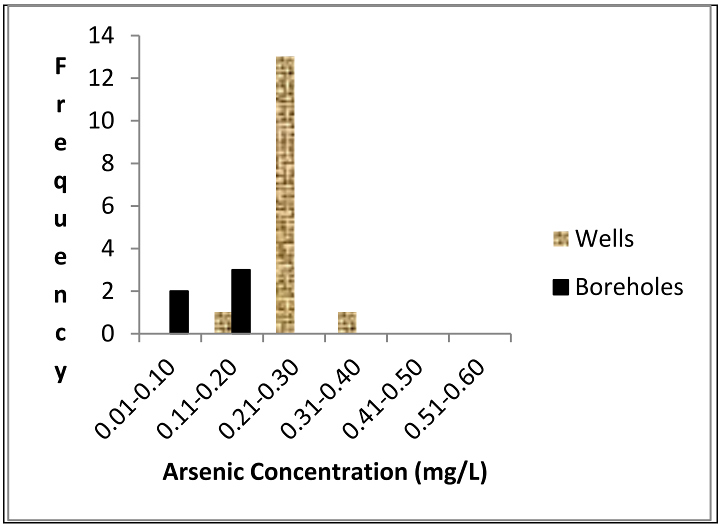

Fig 8. Mean arsenic concentration of both wells and boreholes from Kudan Local Government of Kaduna State

Figure 8 showed the results obtained from Kudan Local Government Area with mean arsenic concentrations of 0.25 and 0.13mg/L from the well and borehole samples respectively, both similarly greater than the Maximum Concentration Limit of 0.01mg/L set by World Health Organisation [2, 11].

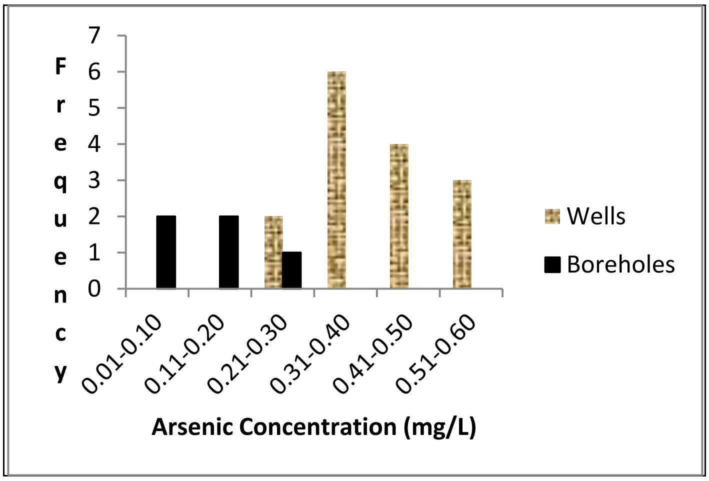

Figure 9. Mean arsenic concentration of both wells and boreholes from Lere Local Government of Kaduna State

Figure 9 showed the results obtained from Lere Local Government Area with mean arsenic concentrations of 0.40 and 0.14mg/L from the well and borehole samples respectively, both likewise greater than the Maximum Concentration Limit of 0.01mg/L set by World Health Organisation [2, 11].

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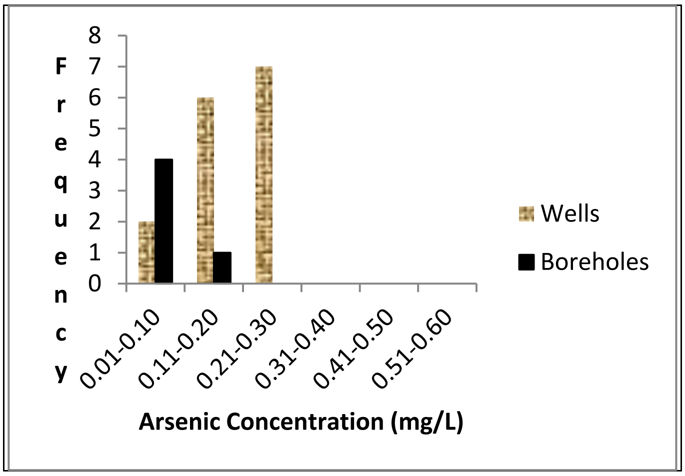

Figure 10. Mean arsenic concentration of both wells and boreholes from Makarfi Local Government of Kaduna State

Figure 10 showed the results obtained from Makarfi Local Government Area with mean arsenic concentrations of 0.20 and 0.08mg/L from the well and borehole samples respectively. The concentration from well water samples is slightly lower than others but both are also greater than the Maximum Concentration Limit of 0.01mg/L set by World Health Organisation [9, 10].

4. DISCUSSION

Arsenic concentration in water depends much on source of arsenic contamination which may be as a result of natural processes, industrial or agricultural activities and increase in human activities in the area where the wells are located. Different works have been reported by many researchers on arsenic concentrations in wells and boreholes water. Musa *et al.*, [12] reported a mean arsenic concentration of 0.02 to 0.51mg/L in Zaria city. Garba *et al.*, [4, 5] from their research findings, reported high level of arsenic concentration of 0.81mg/L in Kutama and 0.77 mg/L in Getso, Gwarzo Local Government area, Kano State, both of which are above the Maximum Concentration Limit (MCL) of 0.01mg/L. They attributed these high concentrations to likely be due to disposal of arsenic containing materials, burning of solid wastes, natural processes and human activities [5, 12]. High concentration of arsenic was recorded in wells from the sampled areas because most of them are open and the areas where they are located have high human, agricultural activities and natural processes.

From the forgoing, it can be stated that arsenic is widely distributed in the environment and many of its compounds e.g. arsenic oxide (As_2O_3), arsenous acid [$As(OH)_3$] are soluble in water and are usually low, except in some geothermal waters.

The mean arsenic concentration in both the wells and the boreholes were higher than the maximum allowed in drinking water by both Standard Organization of Nigeria (SON) and World Health Organization [2]. This may be due to the wide distribution of its compound in the environment, soils and the natural water [13].

Drinking arsenic-rich water over a long period can lead to arsenicosis, resulting in various health conditions, including skin problems (such as changes in skin color and hard patches on the palms and soles of the feet), skin cancer, cancers of the bladder, kidney and lung and diseases of the blood vessels in the legs and feet [14].

Symptoms of chronic arsenic poisoning can take 5-15 years to reveal themselves depending upon the amount of arsenic ingested. According to a recent field study conducted jointly by the Bangladesh Rural Advancement Committee (BRAC), and the International Centre for Diarrhoeal Diseases and Research, Bangladesh, 25-77 million people in Bangladesh are today ingesting dangerously high levels of arsenic in their drinking water [14].

Current options for providing safe drinking-water include: obtaining low-arsenic groundwater by accessing safe shallow groundwater or deeper aquifers (deeper than 200 metres), rain water harvesting, pond-sand-filtration, household chemical treatment, and piped water from safe or treated sources [15-24].

5. CONCLUSION

The arsenic concentration in wells and boreholes water samples from Northern part of Kaduna State has been determined. Data obtained from the study shows that the mean arsenic concentration from the well water samples (0.28mg/L) was higher than that from the borehole water samples (0.09mg/L) and both exceeded the Maximum Concentration Limit (MCL) of 0.01mg/L set by World Health Organization (W.H.O.) and adopted by the Standard Organization of Nigeria (S.O.N.). It is expected that the people of Kaduna North Senatorial District of Kaduna State, Nigeria may likely suffer because the arsenic concentrations in both the well and the borehole waters are high enough to cause the above mentioned diseases as they are taking the water directly without proper treatment. Studies have shown that as Vitamin A and C concentrations increase, the toxicity of arsenic decreases, therefore eating of sufficiently containing food is recommended. Nigerian Environmental Agencies should also consider serious and appropriate actions.

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