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Toxicological evaluation and health implication of private borehole water consumption in satellites towns of Abuja, Nigeria

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Abstract

Heavy metals besides coliforms in water meant for human consumption is of worldwide community health concerns and it renders water vulnerable and unhealthy for drinking. This is a two pronged toxicological study of the chemical and microbiological quality of samples of borehole water collected from several locations across Satellites Towns of the Federal Capital Territory, Abuja, Nigeria for comparison with WHO stipulated standards for drinking water. Ten locations in all the satellites towns scarcely supplied with public pipe-borne water supply were randomly selected and two sampling points per location were investigated. The water samples collected were subjected to elemental and microbiological analysis using standard procedures. The chemical assay indicate the concentration in part per million (ppm) of lead (Pb) ranges from 0.2635 – 3.828; cadmium (Cd) ranges from 0.0094 – 0.0335; magnesium (Mg) ranges range from 0.0029 – 1.3800; and copper (Cu) ranges from 0.0028 – 0.0776. Microbiological assay showed that the water sample with the highest level of total coliform count ranges from 0–460 CFU/ml; further bioassay revealed the presence of Klebsiella pneumonia, Klebsiella planticola, Salmonella arizona, Citrobacter preundi and Escherichia coli. The study opined that the mean concentration of Pb and Cd to be higher than the WHO maximum acceptable limits while Cu and Mg were within limits. This leaded water samples were with confirmed unacceptable levels of coliforms (E. coli). Pollution in microbiological and chemical quality of these borehole water investigated poses grave public health consequences to the water consuming population of the Satellites Towns assessed.

Keywords: Toxicological evaluation, Health implication, Heavy metals, Iead, cadmium, Copper and Magnesium.

Introduction

With bourgeoning world populations of 7.5 billion in 2017, it is projected that by 2025, 50% of global population might be at risk of water related diseases. Inaccessibility to drinking water by up to 1.2 billion people has been reported[1]. Report indicates that one of every six people in the world could not access drinking water[2]. Sub-Saharan countries are among the worst water stressed countries[3]. Water related diseases constitute a major burden on human health[4]. Children die of water related illnesses every 20 seconds with diarrhea incriminated as the leading source of death in children below 5 years with annual mortality of about 1.5 million[5]. With change in knowledge, technology and funding, abstraction of water from unground rather than the surfaces sources become preponderant. Ground water supplies provide about 50% of all drinking water sources globally. Potable water from underground water sources provide about 1.5 billion world inhabitants daily and has proven to be the most dependable resources for actualizing rural water needs in most countries in sub-Saharan Africa[6]. Borehole or deep well water is generally considered of good quality; if they meet stipulated standards of chemical or biological constituents[7]. Sources of drinking water can become contaminated during collection or distribution to the home[8]. Groundwater is usually polluted by pathological agents originating from defective sewage disposal systems, haphazard or indiscriminate disposal of precarious domestic products, noxious agricultural toxicants, etc.[8].

Microbiological and parasitic organisms are a potential threat most especially the presence of coliform bacteria[8]. Potentially toxic chemicals such as tri-halomethanes, insecticides, fungicides, pesticides, volatile organic chemicals (such as adhesives, degreasers and fuels additives, etc.), heavy metals and inorganic pollutants (nitrates from fertilizers, sewage, and animal wastes) have been traced to the "blue baby syndrome" in infants; radon a radioactive contaminant in water is also associated with lung cancer and are of concern to public health due to chronic health implications, liver and kidney damage, birth defects, cancer, central nervous system disorders, etc.[8]. Opportunistic organisms can provoke an attack in immune-compromised individuals who are exposed to water related diseases[9]. To assess the quality of water for drinking purposes indicators of fecal pollution such as *Escherichia coli*, fecal coliforms and *fecal streptococci* are the most commonly evaluated organisms[9] and it is the major cause of diseases spread through fecal transmission[10]. Microbial and chemical evaluation of water using WHO standards for drinking water in Nigeria is common[11-15].

The justification of the study is that Abuja, the Nigerian federal capital is a fast growing and rapidly emerging city of the world[16]. With the ever-increasing satellites population and accompanying bourgeoning stress on infrastructure and public utilities, it becomes more expedient to evaluate the chemical and microbiological worth of drinking water with the preponderance of drinking water boreholes drilled in Abuja suburb. This study will likely elucidate prospective health hazards posing public health threats in the instant future and monitor for compliance with WHO standards for portable water.

Materials and methods

Description of study area: Abuja is geographically and strategically situated at the center of the land space called Nigeria. Abuja is regarded as a fast emerging city and is located between the longitude 6° 47\` S and 7° 20\` E; latitude of 8°30\` N and 9° 15\` W. Abuja is bounded by Kogi State to the South, by Nasarawa and Niger State to the East, by Kaduna to the West and the North. In 2006 national census, the population of Abuja was estimated at 776,298 (putting it within the top 10 most populous cities of the country). Since this period, a huge influx of people has infiltrated Abuja provoking an overflow with the development of satellite towns and some additional minor settlements recording a huge population growth. It is estimated unofficially that the metropolitan population of Abuja is well over three million persons but demographic data extrapolates a 2012 population of Abuja to be 2,245,000 which make Abuja the fourth largest urban area in Nigeria (Online Nigeria, Community Portal of Nigeria)[17].

Equipment for chemical and microbiological assay: Atomic Absorption Spectrophotometer (AA 6800 Shimadzu, Japan), magnetic stirrer – (Model 78HW-1, Bran Scientific and Instrument Ltd, England), Incubator (Precision Scientific Incorporation, 3737W Cortland Street, Chicago), Water Bath (M.HH W21 Cr42 II 5mm, England), Hot air Oven (Schutzart Din 40050-IP20, Memmert Schwabach, Western Germany), electronic Balance (Model AE54, Mettler Toledo AB Switzerland), fume cabinet.

Materials: Culture Media for Bacteriological Assay such as MacConkeyAgar (No.1, BN 1146464, Fluka, 70143, Germany), Nutrient Agar, BN 057293, Antec M8, UK).

Assay Reagents: conc. Sulphuric acid (H_2SO_4) – Hopkin & W., England; Nitric Acid – H & W Ltd, England (ANALAR), Perchloric Acid – BDH Ltd., England (ANALAR).

Water collections points: The various towns and locations where samples of water were collected across the FCT and their Labels are shown in Appendix-1.

Water sampling: The sampling of water was executed at two points in each satellite and coded as depicted in Appendix-1. Water collection from various boreholes took place from August to September 2012, adopting the procedure of Akoto and Adiyiah[18] with modification. Nestle bottled water® (50cl) was procured and bottles opened (to empty contents) only at the point of collection. At each borehole collection point, water to be sampled was used to rinse both the bottles and the bottle caps thrice during water sampling. The rinsing of the bottles and caps were done thrice after the water had run for three minutes. The water samples were directly obtained from the borehole taps after the taps had been flushed for five minutes by running water. The obtained samples were afterward stored at about 0°C prior to analysis to reduce physicochemical changes.

Microbial analysis of water: Microbiological analysis followed the procedures of Agbabiakaand Sule[19]. The coliform bacteria conventionally utilized as the primary indicator for the suitability of domestic drinking water as well as for industrial and/or other uses were evaluated. The multiple-tube fermentation procedure otherwise called Most Probable Number (MPN) which utilizes multiple-tube test and direct plating methods which allowed direct counting of coliform colonies were executed utilizing Nutrient Agar and MacConkay Agar prepared following standard procedures to detect fecal coliforms and *Escherichia coli* in 24-hour (Table-1).

Table-1: Bacteriological analysis of different borehole water samples in satellites towns of FCT.

Sample Location	Total Aerobic Count (cfu /100 ml)	Total Coliform Counts (MPN 100 ml)
Gwagwa Karimo	3.28×10^{-5}	11
Lugbe	2.68×10^{-5}	9
Karu	N/A	N/A
Nyanya	2.38×10^{-5}	11
Mararaba	3.58×10^{-5}	8
Kubwa	3.50×10^{-5}	11
Masaka	1.46×10^{-5}	10
Gwarinpa	2.60×10^{-5}	10
Dutse	2.35×10^{-5}	8

Coliform count determination – presumptive coliform count: The coliform count determination followed the methodology of Okonko et al.[20]. For this assay, 20 samples of the water collected were tested for microbial activity. Double strength (50ml) and single (10ml) strength of MacConkey Broth each were challenged against the water samples. In addition

5mls of single strength MacConkey Broth was used to screen the same water samples. A total of 1000 milliliter of MacConkey broth double strength was used across the 50mls sets for the total of 20 samples screened. Similarly 200 milliliter for the 10mls double strength of MacConkey broth was also used for each samples and 100mls for the 5mls single strength. The preparations of the MacConkey broth (double and single strengths) were autoclaved at 121^0C for 15mins and then allowed to cool. The samples were introduced before sterilization was carried out. These broths are distributed in various volumes using Durhams tubes and then sterilized.

Incubation of the samples after introducing the water samples was done at 37^0C both at 24hr as well as 48hr time point. The positive results (+) were distinguished through the production of acid and gas, while the negative ones were without any gas formation. The presumptive count was done in reference to the McCrady's table to obtain the number of coliform/100ml of sample and compared with standard guidelines (Table-2).

Table-2: Microorganisms characterized biochemically from media culture.

Test Media	Organisms Identified
MacConkey Agar	*Klebsiella pneumonia*
	Salmonella arizona
	Citrobacter preundi
	Esherichia coli
Nutrient Agar	*Esherichia coli*
	Klebsiella planticola

Microbial isolation and identification: The standard confirmatory water analysis for the presence of coliform bacteria was employed only for those which yielded positive results from the presumptive test. The viable count was done by introducing a serial dilution ranging from 10^{-1} to 10^{-6}. One ml of each solution was then introduces into 20ml of nutrient agar in a petridish in both clockwise and anticlockwise directions. These were allowed to set, cool and incubated for 37^0C for 24 hours and another for 48 hours. The readings from the slides were taken by identifying and counting the number of isolates of microorganisms present in the plates. The readings were taken twice and the average for each set recorded. From the plate counts, reading for both the highest and lowest number of microorganisms were sampled and noted.

Chemical analysis of water: Digestion of water samples: Chemical analysis of water followed standard procedure of American Public Health Association (APHA)[21]. It was executed from August to September 2012. The water samples collected were digested by wet decomposition method for the evaluation of several metals. Firstly, distil water was used to wash all the glass wares utilized in the analysis and secondly, it was rinsed with deionized water followed by nitric acid, after which it was allowed to dry. Five milliliters of every water sample was titrated into a 50mls conical flask. Then 5mls of nitric acid was added to the water in the conical flask, followed by 1.2mls of percloric acid and finally 1ml of sulphuric acid in that order. The mixture was then allowed to stand for few minutes, after which it was digested by heating on a hot plate for about 2hours at 70^oC. A stock solution of nitric acid, perchloric acid and sulphuric acid was prepared in the ratios of 5:1.2: 1 respectively. The stock was added to the mixture continuously during the heating period to avoid the mixture drying up completely. After 2 hours, the mixture was removed from the hot plate and allowed to cool. The mixture was then, filtered into a 50ml volumetric flask. The filtrate obtained was made up to volume with deionized water.

Spectrophotometric assays: The equipment used to establish the presence and quantity of the heavy metals is the Atomic Absorption Spectrophotometer (AAS) of the National Research Institute for Chemical Technology (NARICT), Zaria in Kaduna State. Prior to its use, a standard solution for calibration was used to evaluate the heavy metals in the water samples following established procedure[23]. This was by digesting each of the water samples. The stock solutions for the elemental elucidation were prepared from reagents of analytical grade and highest purity. Working solutions for heavy metal illumination were prepared from distilled water for the various elements in view.

The AAS machine was allowed to warm for 30 minutes after which a hollow cathode lamp for each of the element is loaded in. The current is regulated to the respective wavelengths standard for each. The prepared water samples were then thrust through the flame and the respective absorbance noted. The absorbance result for each sample per metal is documented and measured up to standards from which the concentrations of the elements are extrapolated. The results were then compared to the standard guideline.

Statistical analysis: The data obtained from this investigation were subjected to statistical analysis and the result obtained compared to World Health Organization recommended specification. The analytical package used was the statistical INSTAT® to establish the mean, the standard deviation, standard error of mean and analysis of variance (ANOVA). For cadmium: P value obtained is <0.0008; for lead: P value is <0.0644; for copper: P value is < 0.0001; for magnesium: P value is < 0.0001. P value < 0.05 is consider significant.

Results and discussion

Antimicrobial assay of borehole water: The test results of the of the antimicrobial assay of sample water (Presumptive Coliform Count) using MacConkey broth to conduct a preliminary screen for the presence of coliform bacteria is seen in Table-1 and 2. The results shows activity across both double and single strength preparations of the broth cultured against the 50, 10 and 5mls preparation of the broth. The results below show how many cultures out of 5 cultured tubes for each ml set showing active coliform presence. Besides water samples each from Gwagwa – Karimo, Bwari and Karu, showed coliform presence although in varying proportion. The results of further evaluation of the samples showing high viable counts are screened under different dilutions to obtain the average viable count. The result shows that even with several dilutions, microbial activity persists. The organisms isolated from McCokay agar includes: *Klebsiella pneumonia, Salmonella Arizona, Citrobacter preundi* and *Esherichia coli;* the organism isolated from Nutrient agar are: *Esherichia coli* and *Klebsiella planticola.*

Chemical assays of borehole water: The average concentration for each sample (after running it thrice through the AAS machine) was obtained to get the mean concentration per sample. The Table-3 shows the concentration of each of the screened heavy metal per sample from their corresponding absorbance from the evaluation readings. The concentration of the heavy metals across most of the metals investigated are in line with WHO standard except for lead and cadmium which is consistently high across all the samples when compared with the highest permissible limits of 0.001 and 0.003 ppm respectively. The limits for copper and magnesium are 2.000 and 125.000 ppm respectively. As such the water samples seem to be safe for the essential metals (Cu and Mg) but not at all for the non-essential metals.

Table-3: The levels of Chemical Constituents (ppm) in the borehole water Sample.

Location	Sample	Lead (Pb)	Cadmium (Cd)	Magnesium (Mg)	Copper (CU)
Gwagwa – Karimo	A	N/A	0.0227±0.0083	0.1071±0.0540	0.0317±0.0046
	N	1.2510±0.6892	0.0252±0.0033	1.2450±0.0103	0.0498±0.0053
Lugbe	B	1.0915±1.0100	0.0168±0.0046	0.9845±0.1279	0.0286±0.0066
	R	0.0568±0.984	0.0115±0.0020	0.0840±0.0187	0.0776±0.0038
Bwari	C	0.9854±1.8090	0.0199±0.0085	0.2385±0.0083	0.0176±0.0075
	P	0.9285±0.3699	0.0099±0.0049	0.6585±0.0077	0.0304±0.0043
Karu	D	1.1559±2.0150	0.0225±0.0559	0.4664±0.0172	0.0146±0.0069
	T	1.6860±1.0550	0.0110±0.0018	1.3160±0.0177	0.0296±0.0090
Nyanya	E	2.5010±0.3979	0.0335±0.0049	0.0029±0.0027	0.0298±0.0043
	L	1.9140±0.5769	0.0115±0.0011	0.6990±0.0238	0.0472±0.0053
Mararaba	F	2.5390±1.4090	0.0147±0.0076	0.4733±0.0770	0.0279±0.0114
	M	1.9900±0.7391	0.0132±0.0060	0.7700±0.0101	0.0309±0.0072
Kubwa	G	1.4210±0.5053	0.0248±0.0047	0.5881±0.0562	0.0028±0.0042
	S	0.2653±0.4595	0.0094±0.0031	1.3710±0.0190	0.0206±0.0065
Masaka	H	3.8280±1.3340	0.0101±0.0058	0.3949±0.5119	0.0141±0.0048
	Q	1.6680±0.9260	0.0225±0.0042	1.3800±0.0102	0.0364±0.0090
Gwarinpa	I	1.0990±1.3970	0.0176±0.0044	0.1214±0.0106	0.0076±0.0035
	K	1.7240±1.2520	0.0115±0.0035	0.3733±0.0180	0.0166±0.0086
Dutse	J	2.4070±1.4830	0.0239±0.0035	0.1274±0.0051	0.0261±0.0041
	O	0.9285±0.7198	0.0172±0.0072	1.0310±0.0233	0.0292±0.0044

WHO Limit in Concentration of Heavy Metals Permissible for Drinking Water are: lead (Pb)=0.001; Copper (Cu)=2.000; Cadmium (Cd)= 0.003; Magnesium (Mg)= 125.000.

Discussions: Abuja indeed is fast growing and rapidly expanding city in Africa. The high cost of public utilities lead to the emergence of satellites towns and suburbs with paucity of infrastructures. In addressing the acute shortage of portable water, self -help boreholes were excavated without recourse to sanitary standards. Accessing the chemical and microbiological standards of these borehole water sources could provide clues to water quality and its likely impact on public health. Water of low quality is reported to underpin water related diseases in the local community hospitals[15]. In evaluating some samples of water used for domestic consumption, high total coliform counts and other pathogenic bacteria were reported[11,19]. The high bacterial and presumptive coliform levels in the evaluated samples when compared to the WHO standards indicate the presence of pathogenic contaminant with health implication. This corroborates other findings on chemical and microbiological evaluations of borehole water used for local consumption[6,20,23,24]. The implication is the unsuitability of the water sources for consumption in accordance with standards set for acceptable drinking water. The results are rather not unexpected especially considering the high population density of Abuja satellite towns and its impact on the environment in which the borehole water samples were collected. The location of septic tanks close to human settlements as well as poor sanitary disposal systems may in part be probable sources of contamination and compromise of borehole water quality. Subjecting the water samples to further microbiological evaluations, five genera of bacteria belonging to the *Enterobacteraeceae* family were isolated. Three of the bacteria, *Klebsiella, Citrobacter* and *Salmonella,* are traceable to water habitat and two, *Escherichia* and *Salmonella* to human habitats. *Escherichia coli* found in these water samples reveal the presence of recent fecal contamination from indirect human or animal contacts such as seepage from poor septic tank and insanitary exposures. Similar borehole water screenings report in the Federal Capital Territory (Abuja) reveal gross microbial and heavy metal contamination[25]. Juxtaposition of private boreholes and septic tanks are commonplace in the satellites towns of the FCT which might as well influence the levels of contamination. The identified organisms highlight and further reflect the potential health risks posed by consuming water contaminated with human waste and the attendant infections. For example, *E. coli* when found outside its natural habitat (the human gut for example), it causes a variety of health issues or diseases such as urinary infections, bactericemia and meningitis[19,26]. The presence of *Salmonella arizona,* although a non-typhoid causing organism in water, has the tendency to cause septicemia and bacteremia in children as well as enteric fever, gastroenteritis and other issues which can lead to death[27].

Similarly, *Citrobacter* is found naturally in water, food, soil, human or animal feces as well as human urine and thus exists as an environmental contaminant. Though there is paucity of report on *Citrobacter preundi*, but it has been associated to or linked with meningitis and abscesses in infants. Immune compromised or immune suppressed individuals are at high risk of these infections as well as children below 5 years and diabetic patients.

Generally, WHO reported that any water showing the presence of coliform is unfit for human consumption[4]. The presence of coliform and viable bacteria count obtained suggests gross contamination. *Escherichia coli* counts can be relied on as an indicator of water pollution. This is largely because it is typically associated with large quantum of feces in man and other warm blooded animals. As such even with considerable dilution of water samples, they are still detected[28].

There are conventional typical and atypical forms of coliform bacteria. The typical forms have their origin from faecal sources such as the *E.coli* while the atypical type may have their origin from other natural sources such as the *Enterobacter aerogenes* found in the soil and vegetation. For the later, their presence is never indicative of fecal contamination or pollution but hydrocarbon contamination[29]. However, the presence of typical coliform in water reflects fecal pollution and considered critical because these bacteria usually do not thrive well outside its human host[28]. Bacterial pollution may also originate from contacts with a clinical state of the disease or carriers who are asymptomatic. Therefore to preclude the extent of possible water related diseases in these locations chemical treatment (chlorination) of this water would be essential and as ad on educating the populace on the need of boiling the water before consumption.

When evaluating drinking water for heavy metals in comparison with WHO standards, it is pertinent to consider variation of social, economic, dietary, cultural, environmental and extraneous factors which can undermine water quality. In emergent and developed countries, professionals in water sector most probably knows the amount of toxicants present in substantial quantities for water sourced domestically as well as municipal water processed. This local data gathered over the years by practical experience is invaluable management of water quality. As such some national guidelines may have standards different from the international standards or guidelines[4].

Chemical analysis of the various water samples indicate that most of the elements in focus besides lead (Pb) and Cadmium (Cd) are within the approved WHO limits. Though Pb and Cd exceeded the WHO accepted limits, chiefly as a result of plumbing and piping. This also corroborates the findings of Ogbuagu *et al.*[31]. Nevertheless the risks posed by this prevailing state across these sub-urban settlements of the FCT include chronic Pb poisoning[4]. Lead is principally the chief component in the manufacture of acidic lead batteries, weld and amalgams. Organ leaded materials like tetraethyl and tetramethyl compounds are also commonly used in the extensive production of anti-knocking and lubricating agents used in petrol processing, though its uses in many countries is out-lawed and being gradually phased out. Drastic reduction of Pb concentrations in air and food as well as its intake from drinking water hinge on gradual phasing out of lead enclosing additives in premium motor spirit as well as solder containing lead in the food handling establishment[4].

It is rare to find leaded tap water from natural sources; however household plumbing systems which consist of lead in its piping's, soldering, fittings or facility networks to homes have become primarily sources of contamination. When plumbing materials such as lead pipes, coatings and fittings are used, high concentrations of lead in domestic water might be the aftermath. Furthermore, the extent of lead dissolution from the plumbing connections is dependent on extraneous factors such as standing time of the water, temperature, pH and water hardness. Besides, soft and acidic water is thought to be the most Pb dissolving solvent. Acidic waters dissolves Pb in lead piping, fittings, or soldering and ultimately elevated Pb concentrations in drinking water leading to potential neurological deficits. Lead fittings and coatings which serve as connections or plumbing within buildings are the usual sources of the Pb in drinking water[31].

Already reports indicate that borehole water samples from Abaji and AMAC areas of FCT are slightly acidic with pH of 6.9 and 6.95 respectively while in Bwari areas the pH is 7.5[26]. With acidity reported to substantially increase the solubility of lead particularly with reduced pH below 8[4]; therefore leaded water might be common in areas with acidic water like Abaji and AMAC. Lead can corrode more rapidly and released into solvent when coupled to copper[4]. Substantially high levels of lead consumption in public water and the consequential chronic accumulation over time, is reported to be harmful especially in children and likely to cause permanent brain and kidney damage, impairment in reproductive ability of men and women, digestive disorders, hypertension, hearing dysfunction, growth malfunction, head, muscle and joint pains. Besides stunting a child's growth, there could also be damage to the nervous system which present as behavioral and cognitive developmental deficits such as attention hyperactivity disorders in which there is memory and concentration impairment, which culminate in learning disabilities. Lead poisoning is now also associated with crime and anti-social behavior in children which can similarly trail this population[31].

In addition, the chemical analysis of the water samples shows that Cadmium (Cd) concentration across all samples and areas evaluated are well above the approved level of 0.003mg/l. This is an alarming state considering the severe health effects of cadmium intoxication. Cadmium is generally used in the steel and plastic industries for the production of water pipes (PVC) and iron pipes, which transport borehole water into collection points by taps[30,32,14]. Cadmium may cause health challenges like kidney dysfunction, liver, prostate and lung cancers, pulmonary edema and respiratory distresses following accumulation from chronic ingestion[4].

Cadmium as a metal has found use in the steel and plastic industries, in the production of batteries, commonly found in wastewater, as impurities from galvanized pipes; solders and some metal fittings are incriminated as sources of Cd pollution of domestic water. Packaging materials for food and smoking is the probable source of potential cadmium exposure[4]. The organ which accumulates Cd most is the kidney. Cadmium biological half-life in man is known to be up to ten to thirty five years. Though evidence to support cadmium carcinogenicity abounds through inhalation route of exposure however no data are available to support its carcinogenicity when ingested orally. The kidney largely remains the suspect organ targeted in cadmium intoxication[4].

In the majority of the water samples assessed, copper (Cu) was observed to be below the recommended WHO limit. Copper is an essential metal though largely observed in water samples from corroded copper pipes and hot water copper cylinders. Their release into water system can be observed as azure water or blue or emerald tint of lavatory fixtures and occasional cause change in taste of water. Generally, soft and acidic water with a pH lower than 6.5 and hardness beneath 60 mg of $CaCO_3$ per liter is coppero-solvent. The solvency of copper is underpinned by gross elevation of total inorganic carbon and pH, as a decrease in the concentration of copper has been reported with elevation of pH but elevated with increased level of carbon species. Elevating the pH of water samples containing high level of copper to between 8 and 8.5 has proved to be a successful procedure to overcome these difficulties[4].

Underground water with carbon dioxide concentration of above 5 mg per liter and high levels of dissolved oxygen is the bane of pitting corrosion in copper pipes and attendant abrasion and leakages due to negligible loss of metal[4]. This state can further predispose water source to microbial contamination. However, these concentrations are low to cause these effects.

Magnesium (Mg) is another essential heavy metal to health, however its concentration were shown to be quite low across all the water samples. With most individuals not meeting the physiological demand for Mg in staple diet, Mg deficiency is quite common amongst African especially African Americans and the elderly are usually managed by taking magnesium to prevent or treat the deficiency. In addition, its use as a laxative in constipation and to prepare client or patient bowel for surgical or diagnostic procedure has been long standing. This quality is largely attributed to magnesium having the capacity to neutralize acidity in the stomach whilst at the same time increasing motility to move stool along the intestinal path. Thus it commonly serves as an antacid for acid indigestion[33].

Magnesium generally is used for the treatment of a number of health issues such as blood pressure, diabetes, etc. Being amongst the vital minerals required for essential biochemical reactions including protein synthesis, its functions extend to maintaining nerves, bones and the heart. It also fortifies the immune system in its teeming list of benefits. Magnesium deficiency on the other hand may lead to poor functioning of kidneys as well as the digestive system. Therefore magnesium is needed as ad-on to body reserve for these organs to function properly. Nevertheless, when intake is excessive beyond the body needs, it may produce many side effects such as muscle seizures and abdominal spasms. They may also cause heart palpitations as well as breathing problems. Irregularity in heart beats and kidney malfunctioning are side effects of excessive magnesium in blood. Hypotension, distorted vision, sleepiness and diarrhea are other side effects common with magnesium supplements. Therefore, accumulation in the blood may be detrimental to individuals having cardiac or kidney problems. Even when used as laxative and antacids, clients are prone to increased blood magnesium levels. Nevertheless pharmaceutical companies having realized how essential the product is, have included magnesium supplements in the control of diabetes, blood pressure, asthmatic attacks, heart diseases, multiple sclerosis, fibromyalgia, fatigue, pregnancy induced hypertension, attention deficit hyperactivity disorder (ADHD), migraine, kidney stones, etc. Most importantly in addition, magnesium also helps to preserve zinc, calcium, copper and potassium levels of our body[33].

When magnesium is deficient in concentration within a body system it is easily characterized by fatigue leading to other effects such as heart tremors, muscle paroxysms, irregularity in heartbeats convulsions, lack of sensation, irritability and other behavioral aberrations. Due to the fact that magnesium helps to regulate the body's potassium and calcium levels, its deficiency can cause hypocalcaemia and hypokalemia. However, with these water samples showing low Mg content, concerns would rather be if the target populations even derive enough of the element from other dietary sources. Otherwise, it would be wise to track the same population in the distant future to seek for effects of Mg deficiency.

Conclusion

The investigation of chemical and microbial contents of sampled borehole water across satellites towns of the FCT not only revealed that the water sources are not exclusively safe for drinking and domestic use but with inherent health implication. Although the water sources appears safe for two of the essential metal elements (copper and magnesium), the presence of lead and cadmium in substantially high levels is alarming. The low levels of Cu and Mg is exacerbated by the increased presence of microbial contamination, which possess significant threats and challenge to public health.

There would be need to have better regulation on the composite nature of plumbing pipes as this is the source of high concentrations of toxic heavy metal contents across the water samples evaluated. Awareness campaign on the use of iron and steel pipes as well as plastic pipes without fittings of accessories made of these metals is important. The general public must also be enlightened on heavy metals and microbial contaminants as well as their health implications.

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Appendix 1: Code of Sampling Points

a) Gwagwa – Karimo
- A – Suleiman Memorial House, Opposite Customary Court, Jiwa, Gwagwa – Karimo
- N – Anglican Church, Opposite Police Station, Gwagwa, Gwagwa – Karimo.

b) Lugbe
- B – Shekina Nursery and Primary School, Tudun Wada, Lugbe
- R – DeoGrantas School, Phase II Federal Housing Estate, Lugbe

c) Bwari
- C – Payless Supermarket, Peyi, Bwari
- P – Sylva Agwula's Residence, Beside British International School, Peyi, Bwari

d) Karu
- D – Dokidiri Hotel, Opp. Chief's Palace, Beside Karyu Market, Karu
- T - NNPC Filling Station, Keffi Road, Karu

e) Nyanya
- E – 1st Bank, Karu Road, Nyanya
- L – General Hospital, Phase II, Nyanya

f) Mararaba
- F – 1st Bank, Opposite New Health Pharmacy, Keffi Road, Mararaba
- M – New Health Pharmacy, Keffi Road, Mararaba

g) Kubwa
- G – Movida Suites, Dasuki Rd, Kubwa
- S - Mr Marks Residence, Opposite Customary Court of Appeal, Arab Road, Kubwa

i) Masaka
- H – Delas Pharmacy, MasakaU-Turn, Keffi Road. Masaka
- Q – Lomina Hotel, Keffi Road, Masaka

j) Gwarinpa
- I – 1st Bank, 1st Avenue, Gwarinpa
- K – 2nd Avenue, Ibrahim S. Str, Gwarinpa

k) Dutse
- J – Fecad Food Restaurant, BwariRaod, Dutse
- O – PHC Dutse – Makaranta, Bwari Road, Dutse

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