J. Environ. Res. 35 (2): 13-22

PHYSICOCHEMICAL AND MICROBIAL ANALYSIS OF TAP WATER, WELL WATER AND SACHET WATER FROM PARTS OF ABEOKUTA SOUTH LOCAL GOVERNMENT AREA IN NIGERIA

การวิเคราะห์ทางฟิสิกส์เคมี และจุลชีวในน้ำประปา น้ำบ่อ และน้ำใต้ดินจากอบิวคูตา บริเวณรัฐท้องถิ่นทางใต้ของไนจีเรีย

Anslem Diayi [1*], Ojo, L.O.[1], Gbadebo, A.M.[1] and Idabor, V.N.[2]

[1] Department of Environmental Management & Toxicology, University of Agriculture, Abeokuta, Ogun-State, Nigeria.

[2] National Biotechnology Development Agency, Owode Ogun State, Nigeria.

received : February 20, 2013 accepted : May 28, 2013

Abstract

Water samples were collected from taps, wells and in sachets (table water) from various locations in Abeokuta South Local Government Area. The samples were subjected to physicochemical analyses in order to determine the suitability of the waters for drinking purposes. pH, temperature and conductivity were determined using Hana Combo (HI 98129). Evaporation method was used for total solids determination while titration was employed for alkalinity. Trace metals were subjected to Atomic Absorption Spectrometry (AAS) while Multiple Tubed Fermentation Technique was used for the microbial examination of the water samples obtained. From the results obtained, Fe (mg L^{-1}) values obtained ranged from 0.25 -0.61 for tap water, 0.01-0.635 for well water and 0.09-0.35 for sachet water. Cu values obtained were lower than the WHO limit of 2.00 mg L^{-1}. All lead values for tap and well water were higher than the WHO 2008 standard of 0.001mg L^{-1}. Coliform was detected in well water samples from Elega, Adatan, Ake, Sapon, Ikereku and Kuto. Water samples for tap and sachet waters were free from coliform bacteria. From the results obtained, Sachet water is most suitable for drinking since coliform bacteria were not detected and the values obtained from the physicochemical analyses were lower than the WHO standards. Tap water should be well treated before distribution for public supply while well water should not be used for drinking purposes.

Keywords: Abeoukuta, water quality

บทคัดย่อ

ทำการเก็บตัวอย่างน้ำจากประปา น้ำบ่อตื้น และน้ำใต้ดินจากสถานที่ต่างๆ บริเวณอบิวคูตาของการปกครองตอนใต้ และวิเคราะห์ทางฟิสิกส์เคมีเพื่อดูความเหมาะสมของน้ำในการใช้ดื่ม รวมทั้งหาความเป็นกรดด่าง อุณหภูมิ และการนำไฟฟ้าโดยใช้เครื่อง Hana Combo

* corresponding author

E-mail : diayi.a@thechaircentrenigeria.com

(HI98129) การตรวจวัดของแข็งโดยวิธีระเหยแห้งและวิธีไตรเตรตเพื่อหาอัลคิลิตี้ สำหรับโลหะปริมาณน้อยใช้เครื่อง Atomic absorption spectrometry (AAS) และวิธี Multiple Tubed Fermentation เพื่อตรวจหาจุลินทรีย์ในน้ำตัวอย่าง ผลการศึกษาพบว่าธาตุเหล็กในน้ำประปา น้ำบ่อตื้น และน้ำใต้ดิน เท่ากับ 0.25-0.61, 0.01-0.635 และ 0.09-0.35 มก/ล ตามลำดับ ส่วนทองแดงพบต่ำกว่าเกณฑ์มาตรฐานขององค์การอนามัยโลก (2.00 มก/ล) ตะกั่วในน้ำประปาและน้ำบ่อตื้นสูงกว่ามาตรฐานขององค์การอนามัยโลกซึ่งเท่ากับ 0.001 มก/ล. ตรวจพบโคลีฟอร์มในน้ำบ่อตื้นจาก Elega, Adatan, Ake, Sapon, Ikereky และ Kuto แต่ไม่พบในน้ำประปาและน้ำใต้ดิน จากผลการศึกษาน้ำใต้ดินเหมาะที่สุดสำหรับใช้ดื่มเนื่องจากไม่พบแบคทีเรียโคลีฟอร์มและค่าทางฟิสิกส์เคมีต่ำกว่ามาตรฐานองค์การอนามัยโลก น้ำประปาควรได้รับการบำบัดก่อนแจกจ่ายสู่สาธารณะขณะที่น้ำบ่อตื้นไม่ควรใช้ดื่ม

คำสำคัญ: อบิวคูตา, คุณภาพน้ำ

Introduction

Water can be regarded as the most important solvent in the world because of its ability to sustain all life forms as well as its usage for domestic, recreational and industrial purposes.

Basically, water meant for human consumption should be clear, colourless, tasteless and odourless and should be neutral to litmus. In Nigeria today, most rural as well as urban dwellers do not have access to pipe borne water thus they tend to settle for alternative sources of water such as bore hole, streams, rain, well and in some cases, river water. The implication of this is that since these water sources are not well treated, the end users are prone to water borne diseases.

According to WHO [1], about 2.3 billion people suffered from diseases that we linked to water related problems. This continues to kill millions of people yearly thereby undermining developmental efforts[2, 3]. Aderibigbe et al.,[4] stated that globally, about 80% of all diseases and deaths in developing countries were water-related as a result of polluted water. The quality and quantity of rivers, streams and water-ways are usually affected by channel manipulation, modification of watershed characteristics, urbanization and pollution [5].

Water for public consumption should be potable. This means that the water should be free from disease causing organisms and chemical substances that are deleterious to human health. Water could be colourless, odourless and tasteless and yet contaminated with bacteria from man and higher organisms.

The objective of this research is to carry out a physicochemical and microbial examination of water samples which are consumed within Abeokuta South Local Government Area in order to determine their suitability for human consumption.

Experimentation

Collection of sample: Areas surveyed include Adatan, Ake, Saje, Elega, Ikereku, Itoku, Sapon, Kuto, Idiaba and Lantoro. The areas are urban settlements with schools, markets, residential and worship areas (Figure 1).

Sachet water sources are from bore hole water supply while well water samples were obtained from a depths ranging from 10-20 m. Around the Kuto, Adatan and Ake areas, some of the well water were situated close to soak away pits while for other locations, they were found in front of residential houses where there are no waste dumps or nearby toilets. The soils were basically sandy.

Samples were collected between February and May, 2005. Three samples were collected per location for each water type at two different times. Tap water samples were obtained using 2 liter plastic can which were stored in ice chested coolers for transportation to the laboratory. For Well water, a plastic can was lowered into the well with the aid of a rope while sachet water was obtained from vendors.

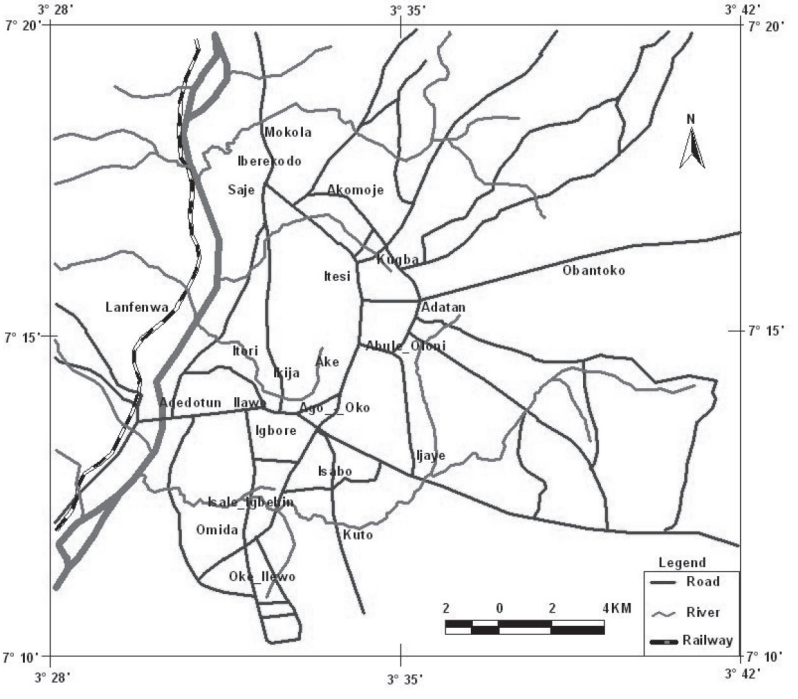

Figure 1 Map of the Abeokuta

Analytical method

Parameters such as pH, conductivity and temperature were determined in-situ using a Hana Combo. Total solids were determined using evaporation method while hardness was determined via EDTA method. Titration method was employed for the determination of water alkalinity. Metals like Zn, Pb, Cu, Mg, Ca and Fe were determined using Atomic Absorption Spectrometry (AAS) method. The Multiple Tubed Fermentation Technique method was used for the microbial examination of the water samples obtained. This method consists of the presumptive and confirmatory tests.

Results

Table 1 Physicochemical analysis of tap water from Abeokuta south local government area of Ogun-State

	Location										
Parameters	Adatan	Ake	Saje	Elega	Itoku	Sapon	Ikereku	Idiaba	Lantoro	Kuto	WHO
pH	7.50^{c}	6.96^{f}	7.45^{cd}	7.70^{b}	7.70^{b}	7.95^{a}	7.65^{b}	7.75^{b}	7.45^{cd}	7.30^{e}	Ns
Temp (^{o}C)	25.00^{b}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	Ns
Cond (µs)	118.00^{e}	119.00^{e}	128.50^{d}	128.50^{d}	129.00^{d}	128.00^{d}	131.00^{d}	139.00^{ab}	141.50^{a}	135.5^{c}	Ns
Alkalinity (mg L^{-1})	15.00^{bc}	13.25^{cd}	12.50^{de}	5.00^{g}	17.00^{a}	16.10^{ab}	5.00^{g}	5.00^{g}	10.00^{f}	10.00^{f}	Ns
Hardness (mg L^{-1})	20.00^{a}	20.00^{a}	19.00^{c}	19.50^{ab}	20.00^{a}	20.00^{a}	20.00^{a}	20.00^{a}	20.00^{a}	20.00^{a}	Ns
TS (mg L^{-1})	225.00^{a}	60.00^{b}	55.00^{bc}	20.00^{d}	21.00^{d}	59.00^{bc}	10.00^{e}	10.00^{e}	10.00^{e}	10.00^{e}	Ns
DS (mg L^{-1})	215.00^{a}	50.00^{b}	20.00^{d}	10.00^{e}	11.00^{de}	49.00^{c}	5.00^{f}	5.00^{f}	5.00^{f}	5.00^{f}	Ns
TSS (mg L^{-1})	10.00^{ab}	10.00^{ab}	10.00^{ab}	10.00^{ab}	10.00^{ab}	10.00^{ab}	5.00^{d}	5.00^{d}	5.00^{d}	5.00^{d}	Ns
Cl- (mg L^{-1})	11.00^{bc}	11.50^{b}	13.00^{a}	11.00^{bc}	11.00^{bc}	11.50^{b}	11.00^{bc}	11.00^{bc}	10.50^{d}	11.00^{bc}	Ns
Fe (mg L^{-1})	0.500^{bc}	0.370^{fg}	0.440^{cd}	0.400^{ef}	0.380^{gh}	0.610^{a}	0.400^{ef}	0.350^{hi}	0.250^{jk}	0.390^{ef}	Ns
Cu (mg L^{-1})	0.090^{ab}	0.013^{h}	0.013^{g}	0.091^{a}	0.081^{c}	0.015^{ef}	0.013^{g}	0.020^{de}	0.012^{i}	0.013^{j}	2.00
Zn (mg L^{-1})	0.014^{gh}	0.015^{fg}	0.015^{fg}	0.015^{hi}	0.082^{c}	n.d	0.115^{b}	0.950^{a}	0.005^{d}	0.034^{e}	Ns
Pb (mg L^{-1})	0.023^{k}	0.050^{ef}	0.041^{ij}	0.060^{de}	0.090^{c}	0.010^{l}	0.045^{gh}	0.045^{hi}	1.420^{b}	2.150^{a}	0.01
Ca (mg L^{-1})	1.815^{g}	2.000^{d}	1.900^{e}	2.400^{c}	1.820^{f}	2.560^{b}	4.410^{a}	1.820^{i}	0.0660^{g}	0.060^{h}	Ns
Mg (mg L^{-1})	0.802^{b}	0.0l5^{m}	0.740^{c}	0.620^{d}	0.130^{e}	0.052^{kl}	0.060^{hi}	0.059^{jk}	0.060^{ij}	0.810^{a}	Ns
Coliform (Col mL^{-1})	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00

Note: Values with identical letters were not significantly different from each other at 95% confidence level when subjected to Duncan Multiple Range Test. Values shown are mean or average values.

Table 2 Physicochemical analysis of well water from Abeokuta south local government area of Ogun-State

	Location										
Parameters	Adatan	Ake	Saje	Elega	Itoku	Sapon	Ikereku	Idiaba	Lantoro	Kuto	WHO
pH	7.40^{cd}	8.40^{a}	6.75^{g}	6.75^{g}	7.10^{e}	7.15^{e}	7.25^{be}	8.30^{ab}	7.40^{cd}	6.95^{f}	Ns
Temp (^{o}C)	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	26.00^{a}	Ns
Cond (µs)	1090.00^{a}	623.00^{b}	472.50^{d}	502.5^{c}	421.00^{e}	414.00^{e}	420.00^{e}	51.20^{i}	66.00^{h}	70.00^{g}	Ns
Alkalinity (mg L^{-1})	19.00^{f}	1.00^{k}	11.00^{i}	15.00^{gh}	5.00^{j}	75.00^{b}	50.00^{e}	65.00^{d}	70.00^{c}	100.00^{a}	Ns
Hardness (mg L^{-1})	49.50^{a}	30.00^{e}	31.00^{d}	34.00^{c}	22.00^{g}	17.00^{j}	18.00^{i}	20.00^{h}	24.50^{f}	48.00^{b}	Ns
TS (mg L^{-1})	156.50^{a}	43.00^{h}	79.00^{ef}	90.00^{de}	62.00^{gh}	65.00^{fg}	77.00^{ef}	126.00^{b}	104.00^{c}	153.50^{a}	Ns
DS (mg L^{-1})	150.00^{a}	40.00^{j}	70.00^{g}	80.00^{e}	60.00^{h}	60.00^{h}	74.00^{f}	120.00^{b}	100.00^{c}	150.00^{a}	Ns
TSS (mg L^{-1})	6.50^{b}	3.00^{f}	9.00^{a}	9.50^{a}	2.00^{h}	5.00^{c}	3.00^{f}	6.00^{b}	4.00^{d}	3.50^{ef}	Ns
Cl- (mg L^{-1})	80.75^{c}	82.00^{b}	41.50^{i}	45.50^{g}	44.00^{h}	55.00^{e}	45.00^{g}	53.00^{f}	86.50^{a}	73.50^{d}	Ns
Fe (mg L^{-1})	0.150^{hi}	0.560^{ab}	0.245^{de}	0.425^{bc}	0.060^{fg}	0.365^{cd}	0.090^{ef}	0.050^{gh}	0.010^{i}	0.635^{a}	Ns
Cu (mg L^{-1})	0.018^{fg}	0.065^{b}	0.013^{h}	0.085^{a}	0.030^{de}	0.017^{fg}	0.085^{a}	0.043^{c}	0.015^{fg}	0.017^{fg}	2.00
Zn (mg L^{-1})	0.013^{j}	0.005^{h}	0.024^{c}	0.036^{a}	0.014^{f}	0.018^{e}	0.004^{pq}	0.009^{g}	0.020^{d}	0.035^{b}	Ns
Pb (mg L^{-1})	0.035^{gh}	0.005^{h}	0.073^{cd}	0.163^{a}	0.034^{gh}	0.049^{ef}	0.060^{de}	0.043^{fg}	0.080^{bc}	0.155^{a}	0.01
Ca (mg L^{-1})	2.035^{b}	1.720^{e}	2.045^{b}	1.585^{f}	1.240^{i}	1.550^{g}	2.700^{a}	1.600^{c}	1.990^{c}	1.130^{h}	Ns
Mg (mg L^{-1})	0.133^{b}	0.090^{de}	0.032^{h}	0.084^{ef}	0.240^{a}	0.040^{g}	0.090^{c}	0.030^{i}	0.021^{j}	0.080^{fg}	Ns
Coliform (Col mL^{-1})	21.00^{c}	95.00^{b}	0.00^{d}	21.00^{c}	0.00^{d}	23.00^{c}	95.00^{b}	0.00^{d}	0.00^{d}	115.00^{a}	0.00

Note: Values with identical letters were not significantly different from each other at 95% confidence level when subjected to Duncan Multiple Range Test. Values shown are mean or average values.

Table 3 Physicochemical analysis of Sachet water from Abeokuta south local government area of Ogun-State

	Location										
Parameters	Adatan	Ake	Saje	Elega	Itoku	Sapon	Ikereku	Idiaba	Lantoro	Kuto	WHO
pH	8.22^{a}	8.20^{a}	8.20^{a}	8.20^{a}	8.18^{ab}	8.00^{bc}	8.07^{de}	8.130^{cd}	8.09^{de}	8.16^{bc}	Ns
Temp (°C)	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	25.00^{a}	Ns
Conductivity (µs)	117.00^{e}	147.50^{b}	147.00^{b}	144.00^{c}	142.50^{c}	151.00^{a}	148.00^{b}	138.00^{cd}	151.00^{a}	143.50^{b}	Ns
Alkalinity (mg L^{-1})	10.00^{b}	10.00^{b}	10.00^{b}	10.00^{b}	10.00^{b}	10.00^{b}	15.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	Ns
Hardness (mg L^{-1})	12.00^{ab}	10.00^{e}	10.00^{e}	11.50^{bc}	10.00^{e}	12.50^{a}	10.00^{e}	11.00^{d}	11.50^{bc}	12.00^{ab}	Ns
TS (mg L^{-1})	10.00^{a}	15.00^{a}	12.00^{a}	10.00^{a}	11.00^{a}	12.00^{a}	10.00^{a}	12.00^{a}	11.00^{a}	11.50^{a}	Ns
DS (mg L^{-1})	8.00^{bc}	14.00^{a}	10.00^{b}	9.00^{b}	10.00^{b}	10.00^{b}	8.00^{bc}	10.00^{b}	10.00^{b}	10.00^{b}	Ns
TSS (mg L^{-1})	2.00^{a}	1.00^{b}	2.00^{a}	1.00^{b}	1.00^{b}	2.00^{a}	2.00^{a}	2.00^{a}	1.00^{b}	1.50^{ab}	Ns
Cl- (mg L^{-1})	22.50^{c}	15.00^{g}	17.00^{e}	14.00^{h}	30.50^{a}	25.00^{b}	16.00^{f}	19.00^{d}	22.00^{c}	12.00^{c}	Ns
Fe (mg L^{-1})	0.300^{hi}	0.250^{ef}	0.160^{gh}	0.320^{ab}	0.090^{ij}	0.350^{a}	0.230^{fg}	0.140^{hi}	0.310^{bc}	0.28^{de}	Ns
Cu (mg L^{-1})	0.037^{b}	0.018^{f}	0.025^{de}	0.030^{c}	0.039^{b}	0.025^{de}	0.100^{a}	0.022^{de}	0.039^{b}	0.028^{cd}	2.00
Zn (mg L^{-1})	0.016^{fg}	0.021^{ef}	0.035^{bc}	0.040^{a}	0.012^{gh}	0.004^{j}	0.011^{hi}	0.022^{de}	0.042^{a}	0.030^{d}	Ns
Pb (mg L^{-1})	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.01
Ca (mg L^{-1})	0.280^{b}	0.014^{i}	0.110^{e}	0.030^{h}	0.240^{c}	0.100^{f}	0.020^{hi}	0.150^{d}	0.060^{g}	0.300^{a}	Ns
Mg (mg L^{-1})	0.192^{a}	0.014^{h}	0.108^{c}	0.031^{de}	0.130^{b}	0.097^{cd}	0.044^{g}	0.061^{f}	0.014^{h}	0.133^{b}	Ns
Coliform (Col mL^{-1})	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00

Note: Values with identical letters were not significantly different from each other at 95% confidence level when subjected to Duncan Multiple Range Test. Values shown are mean or average values.

Discussion

Table 1: Tap water pH values ranged from 6.95-8.40 while Iron values for tap water ranged from 0.25-0.610 mg L^{-1}. Values from Sapon (0.610mg L^{-1}), Adatan (5.00 mg L^{-1}) and Saje (0.44 mg L^{-1}) were higher than other Iron values obtained. Higher Iron tap water values from these areas can be attributed to the use of rusty pipes in the supply of water to residents. Although Iron is useful in the body for the transportation of oxygen from the lungs to the cells, energy production and catalase production (catalase is an enzyme that goes round the body to pick up free oxygen atoms called free radicals which protects the body from radical damage), Iron toxicity could lead to enzyme dysfunction due to the replacement of vital minerals with iron which also results in inflammation. Iron oxide which occurs when iron combines with several atoms of oxygen at once is not useful biologically hence, it is toxic to the body. As a result of its properties as an excellent oxygen transporter, iron tends to stimulate the growth of common bacteria. This is a significant cause for chronic infections Iron has an ability to enhance the hardness of arteries which causes blood pressure to rise [6]. WHO, 2008 had no standard for Fe in drinking water because levels in which they occur are of no health concerns. Zinc levels in tap water at Idiaba (0.95mg L^{-1}) and Ikereku (0.115mg L^{-1}) were higher than those of other locations sampled. Zinc is not of health concern in drinking water as indicated. Tap water Pb values except that of Sapon (0.01 mg L^{-1}) were observed to be higher that the WHO 2008 Pb in drinking water standard of 0.01mg L^{-1} especially those from Kuto (2.15mg L^{-1}) and Lantoro (1.42 mg L^{-1}). These results indicate toxic levels of lead in those areas. The use of leaded pipes for conveying water in those areas could have attributed to the high values recorded. Lead mimics calcium, thereby inhibiting neurotransmission [7-9]. A major physiological and biochemical impact of lead is inhibition of two key enzymes needed for the synthesis of haemoglobin, the iron-containing protein in red blood cells that binds with and transports oxygen to all cells in the human body. When these enzymes are inhibited and haemoglobin synthesis is disrupted, there is insufficient transport of oxygen and anaemia resulted. Anaemic children fatigue easily and are less able to learn well [7, 9, 10]. When lead concentrations in algae exceed 500 ppb, enzymes needed for photosynthesis are inhibited [11]. Fishes are more sensitive to lead than algae. When lead concentrations exceed 100 ppb, gill function is affected. Embryos and fry are more sensitive to the toxic effects of lead than adults. All tap water values had 0.00 Col mL^{-1} value when

subjected to microbial test. This indicates that the tap water samples are free from coliform bacteria that are deleterious to human health.

Table 2: Well water pH values ranged from 6.95-8.40. The highest well water conductivity value was obtained from Adatan (1090 μS cm^{-1}). High conductivity is an indication that the water sample contains more dissolved substances. Fe values ranged from 0.01-0.635mg L^{-1}. All Pb values except that of Ake(0.005 mg L^{-1}) were higher than the WHO 2006 Pb in drinking water standard of 0.001mg L^{-1}. Coliform counts from Adatan (21 col mL^{-1}), Ake (95 col mL^{-1}), Elega (21 col mL^{-1}), Sapon (23 col mL^{-1}), Ikereku (93 col mL^{-1}) and Kuto (115 col mL^{-1}) were higher than the WHO standard of 0.00 col mL^{-1} in drinking water. This shows feacal pollution and it indicates the presence of coliform bacteria that are deleterious to human health. Some wells in the areas sampled were located close to toilets/soak away pits. This could have accelerated the influx of coliform bacteria to the well water.

Table 3: Sachet water pH values ranged from 8.00-8.22. Fe values ranged from 0.09-0.35 mg L^{-1} while Cu values were lower than the WHO 2008 standard of 2.00 mg L^{-1}. Lead was not detected in the sachet water samples. This implies that there is no lead toxicity and that efforts were made by sachet water producers to provide lead free water for public consumption. Likewise, no coliform was detected from the sachet water samples. Sachet water samples from Adatan, Ake, Saje, Itoku, Ikereku, Idiaba and Kuto are safe for drinking purposes.

Dissolved solids in tap water were observed to be higher than those in well water samples. Infiltrations from broken pipes conveying water to these area, could have attributed to an increase in dissolved substance levels recorded for the tap water sampled. WHO 2008 had no guideline standard for dissolved solids in drinking water because it is not of health concern in values found in drinking water.

Conclusion

There is need to monitor lead in tap and well waters from Abeokuta South Local Government Area. This is in view of the effects of lead on children (mental retardation) as well as sensitive organs like the brain and kidney. Metal Iron/lead pipes should be replaced with plastics or materials that are anti-rust. This way metal corrosion that can increase Iron levels can be reduced. Wells within Abeokuta should be sited away from soak away pits in order to avoid contamination by coliform bacteria. From the results obtained, Sachet water is the safest and the recommended for water consumption in Abeokuta South Local

Government Area bearing in mind that values obtained from the physicochemical/ microbial analyses were lower than the WHO standards. This also means that they are potable- free from disease causing organisms (from microbial examination results). Residents in this Local Government Area should avoid drinking well water in view of the risks that can occur from lead toxicity and coliform values in the wells sampled. Tap water should be well treated especially, lead levels must be below the WHO limit before it can be supplied for public consumption.

References

(1) World Health Organization. 1997. Health and Environment in Sustainable Development. Five years after the earth summit. (WHO) Geneva, (WHO/EHG/97.8). p. 245

(2) Nash, L. 1993. Water Quality and health. In: Gleick, O., (ed). Water in Crisis: A guide to the world's fresh water resources. Oxford University Press, New York: pp. 25-39

(3) Olshansky S., Carnes B,. Rogers R. and Smith L. 1997. Infectious diseases - New and ancient threat to world health. Population bull. 52(2): 2-43

(4) Aderibigbe, S.A., Awoyemi A.O. and Osagbemi G.K. 2008. Availability, adequacy and quality of water supply in ilorin metropolis, Nigeria. Eur. J. Scientific Res. 23: 528-536

(5) Mrowka JP. 1974. Man's impact on stream regimen and quality. In: IR. Manners and MW. Mikesell

(6) Lawrence Wilson. 2011. Chronic Acquired Iron Overload- a Disease of Civilization The Centre for Development (eds). Perspectives on environment. Association of American Geographers, Washington, DC.

(7) Bradl, Heike. 2005. Heavy Metals in the Environment: Origin, Interaction and Remediation. Elsevier/Academic Press, London.

(8) Cunningham W P. and Cunningham M A. 2004. Principles of Environmental Science: Inquiry and Applications. McGraw Hill Publishers, New York, N.Y.

(9) World Health Organisation. 2008. Guidelines for drinking water. World Health Organisation (WHO) Geneva.

(10) Landis, W G. and Yu M H. 2003. Introduction to Environmental Toxicology: Impacts of Chemicals Upon Ecological Systems. CRC Press, Lewis Publishers, Boca Raton, Fl

(11) Taub, F B. 2004. Fish 430 lectures (Biological Impacts of Pollutants on Aquatic Organisms), University of Washington College of Ocean and Fishery Sciences, Seattle, WA.

(12) World Commission on Environment and Development (WCED). 1987. Our Common future. Oxford University Press; Oxford.

(13) Wright, David A. and Pamela Welbourn. 2002. Environmental Toxicology. Cambridge University Press, Cambridge, U.K.