JASEM ISSN 1119-8362

Full-text Available Online at www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage. September, 2010
Vol. 14 (3) 47 - 52

Potability Assessment of Selected Brands of Bottled Water in Abeokuta, Nigeria

[1]TAIWO, A M; [1]GBADEBO, A M; [2]AWOMESO, J A

[1.] Department of Environmental Management and Toxicology,[2]. Department of Water Resources Management and Agrometeorology, University of Agriculture, P.M.B. 2240, Abeokuta, Ogun State, Nigeria

Corresponding e-mail:taiwoademat2003@yahoo.com

ABSTRACT: This study was carried out to determine the potability of selected brands of bottled water in Abeokuta metropolis. Water quality parameters such as physical (Color, turbidity, total suspended solids (TSS), total dissolved solids (TDS), total solids (TS)), chemical (pH, total hardness, alkalinity, chloride (Cl^-), free chlorine, sulphate (SO_4^{2-}), nitrate (NO_3^-) and iron (Fe^{2+})) and microbiological (total coliform) were determined using standard procedures. The results obtained were subjected to statistical analysis for analysis of variance using SPSS 15.0. Mean values of water quality parameters were compared to World Health Organization (WHO) standards in drinking water. Results showed that water parameters like colour (< 7.0 Pt. Co.), TDS (<150 mg L^{-1}), free chlorine (<0.5 mg L^{-1}), Cl^- (<27 mg L^{-1}), SO_4^{2-} (15 mg L^{-1}), NO_3^- (<2.0 mg L^{-1}), Fe^{2+} (<0.1 mg L^{-1}) and total coliform (0.0 count mL^{-1}) were within WHO standards for drinking water indicating the potability of the bottled waters and hence, could be consumed without any possible health problems. @ JASEM

The importance of water to man cannot be over-emphasized due to its essentiality in body metabolism and proper functioning of cells (Buchholz, 1998). Water is also a useful resource for domestic, industrial and agricultural purposes. Though, water is abundant in nature occupying 71% of the earth surface (Gleick, 2006), only 1 % is accessible for human consumption (Lefort, 2006). Even the accessible drinking water would require series of treatments before it could be safe or fit for drinking. Bottled water as only reliable healthy drinking water in any parts of the globe cannot be overemphasized having undergone series of treatments. It is widely accepted as potable and thereby free from physical, chemical and microbiological contaminants that could initiate adverse health effects in humans when consumed. Wikipedia (2009) defined potable water as the water of high quality that could be consumed without risk of acute or chronic harm or injury. It is reported that over one billion people in the world lack potable water (US. Center for Disease Control and Prevention, 2006). In Nigeria, most folks depended absolutely on shallow wells and surface water for their survival. Unfortunately, most of these wells and surface water are polluted and unfit for human consumption (Adekunle et al., 2007, Taiwo, 2010, Orebiyi et al., 2010). One of World Health Organization primary goals is access to adequate supply of safe drinking water for all (WHO, 2006). This goal is far from achievement in most developing countries especially in the rural and peri-urban areas as over 5 million people die annually of water-borne diseases such as cholera, typhoid, diarrhea, polio and meningitis (Lefort, 2006, WHO, 2008). In Nigeria, many companies were into production of bottled water with different processes of treatment and packaging. The National Agency for Food and Drug Administration Agency Control (NAFDAC) has therefore mandated these companies to register with the Agency in order to ensure qualitative production of potable water for the populace. However, there were influxes of fake brands of bottled water into the markets, which in one way or the other has been posing threat to people's health. Analysis of these bottled waters is therefore pertinent for qualitative examinations since water from various sources (groundwater, spring, distilled and tap) is bottled, packaged and sold to the vulnerable masses. Abeokuta remains one of the big markets for many brands of bottled water in Nigeria especially in the cycle of the middle and high income social classes due to its relative high cost as a litre is sold between 80 and 100 naira. The low-income class folks depended absolutely on untreated groundwater for their drinking water supply. Despite the high cost of bottled water, the global bottled water market has grown since 2006 (King, 2008). The main objective of this paper is to assess the potability of mostly consumed brands of bottled water in Abeokuta, Southwest Nigeria by determining their physico-chemical and microbiological properties.

MATERIALS AND METHODS

The seven different brands of bottled water (A, B, C, D, E, F and G) were purchased from the public markets in Abeokuta located on longitude 03^o 15′ E and latitude 07 ^{o} 30′ N (Fig. 1) with a landmass of 1,256 square kilometer in Ogun state, Nigeria. From each brand, three samples were analyzed for physical, chemical and microbiological properties.

pH and TDS were determined using pH/TDS meter (Combo Hi 98130), colour, turbidity, TSS, and iron were analyzed spectrophotometrically using UV-Visible spectrophotometer (Hach DR/4000, UK)). TSS was determined by gravimetric method while total solids were calculated by summation of TDS and TSS values.

Chloride, alkalinity and hardness (Ca, Mg and total hardness) were analyzed by titration method (APHA, 1989). Chloride was measured by placing 100 mL of bottled water sample into a conical flask and adding potassium chromate solution (1 mL) as indicator. Titration was then carried out against silver nitrate solution, until the slightest reddish coloration was formed. For alkalinity, 100 mL water sample was measured into a conical flask and 2-3 drops of phenolphthalein indicator was added and later, few drops of methyl orange indicator was introduced and resulting solution titrated against 0.05 M H_2SO_4 until colour changed from yellow to orange while hardness was determined by measuring exactly 25 mL of water sample into a conical flask and 1 mL of buffer solution was added followed by 3-4 drops of Eriochrome Black T (EBT) indicator and titrated with 0.05 M ethylenediaminetetracetic acid (EDTA) solution until the colour changed from deep purple to blue colour.

Free chlorine determination was carried out using HACH test kit in which 5 mL water sample was placed into a cell bottle, free chlorine reagent powder pillow was added, the mixture swirled and the value of free chlorine was estimated with HACH Color Comparator kit. Nitrate was measured using Ademoroti (1996) sodium-salicylate method by flocculating the water sample with 0.2 g mercury (II) chloride crystal to remove interfering organic and metallic substances and pH adjusted to between 11 and 11.5 with 50% NaOH. Filtration followed and 2 mL was accurately pipetted into 50 mL evaporating dish, exactly 1 mL of 1% sodium salicylate solution was added and then evaporated to dryness for at least 30 minutes in a drying oven at 105^{o}C. The sample residue was then removed from oven, cooled and 2 mL concentrated H_2SO_4 was added and quickly mixed well by swirling. The solution was allowed to stand for 10-15 minutes while swirling occasionally to ensure dissolution of all solids. When cold, 15 mL nitrate-free distilled water was added into the sample residue and 15 mL sodium-hydroxide-potassium-sodium tartrate solution was pipetted into the solution as yellow colour was developed. Blank sample was prepared in the same manner and the absorbance read on a Jenway UV/Visible Spectrophotometer (Model 6405, UK) at 420 nm. Nitrate values were determined from calibration curve by extrapolation. Total coliform was determined by total viable cell count method (Ademoroti, 1996) in which 0.1 mL of each water sample was transferred into the petri dish containing a solidified agar (Ethylene Myosin Blue) and incubated at 37^{o}C in Sanyo Gallenkamp incubator (Inc. 200 230T, Artisan Scientific, UK) for 24 hours for coliform growth.

Statistical analysis of data was carried out using SPSS 15.0 for window evaluation version software for analysis of variance and Duncan multiple range test and the results presented in tables.

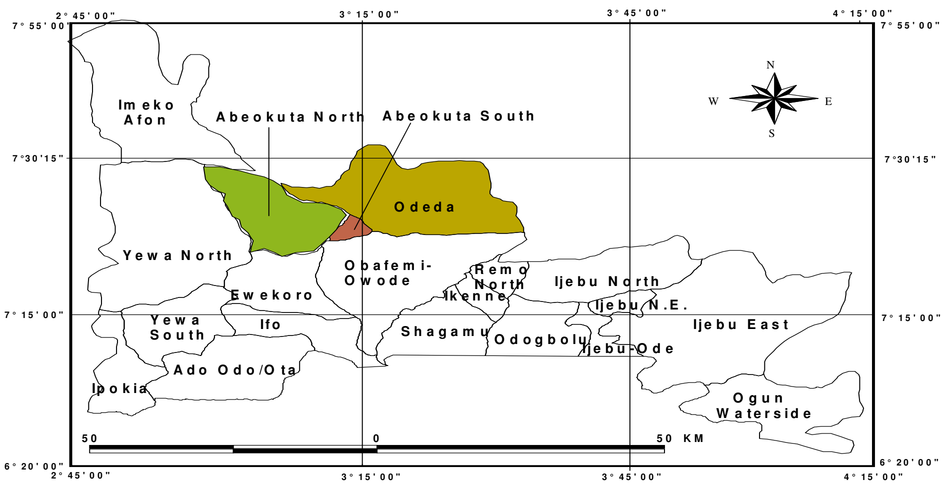

Fig 1: The map of Ogun State showing Abeokuta metropolis

RESULTS AND DISCUSSIONS

Table 1 showed the mean values of the physical compositions of the analyzed brands of bottled water.

Brand F and G recorded the highest colour mean value of 6.6 TCU while brand A had a zero color value. However, there is no significance ($p<0.05$) in the colour values of the seven brands of bottled water. Colour in drinking water may be due to the presence of coloured organic substances and metals such as iron, manganese and copper or highly coloured industrial wastes (FAO, 2010). The mean values of colour of the bottled waters were within the WHO limit of 15.0 TCU.

Table 1: Physical properties of different brands of bottled water

PARAMETERS	A	B	C	D	E	F	G	WHO
Colour (TCU)	0.00 ± 0.0 a	0.66 ±1.1 a	2.0 ±2.0 a	6.0 ±6.92 a	1.0 ±1.73a	6.66 ±6.42 a	6.66 ±9.07 a	15
Turbidity (NTU)	2.0 ±2.6 a	0.33 ±0.57 a	1.33 ±1.15 a	6.66 ±4.72 a	0.00 ±0.00 a	6.33 ±5.13 a	5.66 ±7.23 a	5
TSS (mg L^{-1})	0.00 ±0.00a	0.66 ±1.15a	2.66 ±1.52 a	6.33 ±6.80a	1.66 ±2.88 a	7.0 ±4.0a	6.66 ±10.69a	
TDS (mg L^{-1})	148.43 ±65.8 c	85.63 ±18.29 b	16.23 ±19.38 ab	73.76 ±21.09 a	38.93 ±9.58 ab	56.4 ±48.1 ab	62.6 ±25.41 ab	500
Total Solids (mg L^{-1})	148.86 ±65.41 b	86.3 ±18.25 ab	18.90 ±18.01 a	80.10 ±22.43 a	40.6 ±8.60a	63.4 ±50.37 a	69.26 ±33.8 a	1000

Means in the same row followed by the same alphabets are not significant at $p<0.05$ according to Duncan Multiple Range Test, TSS-Total suspended solids, TDS-Total dissolved solids

The mean turbidity of 6.66, 6.33 and 5.66 NTU from brands D, F and G respectively were higher than WHO standard of 5.0 NTU set for drinking water (WHO, 1993) while other brands were within the WHO standard. Turbidity measures the relative clarity or cloudiness of water and an indication of effectiveness of filtration of water supply (Hauser, 2001). High turbidity may be associated with disease-causing microorganism such as viruses, bacteria and parasites (APHA, 1998). However, no trace of coliform was found in any of the bottled water.

TSS mean values of the bottled water samples were generally low with sample F recording the highest value. TDS of these bottled water samples could be described as excellent being greater than 300 mg L^{-1} (Bruvold and Ongerth, 1969). Both the TDS and TS results are still within the WHO standards. However, the values of TDS and TS were very high in brand A compared to the others. There was a notable significance ($p<0.05$) in the means of both TDS and TS of brand of bottled water samples. High TDS could impact taste in drinking water while water of very low TDS may be unacceptable because of flat inspirable taste (Bruvold and Ongerth, 1969).

Results of the chemical analysis of brands of bottled water were presented in Table 2. The mean values of bottled water pH showed that samples A, B, C, & G were within the WHO pH range of 6.5-8.5 while samples D, E & F values fall below the standard and were slightly acidic. An acceptable range for pH in drinking water is 6.5 - 8.5 (WHO, 2008). Low pH has implication on the solubility and thus the bioavailability of other substances especially the heavy metals which are deleterious to humans (EPA, 2003).

The values of free chlorine in the brands of bottled water were relatively lower than WHO limit of 5.0 mg L^{-1} (WHO, 2008). High concentration of free chlorine in drinking water may cause cancer in man as free chlorine may combine with ammonia in water to form chloramines, which is a potential carcinogen (Dychdala, 1977). In natural water, free chlorine is present at range concentration 0.2 - 1.0 mg L^{-1} (White, 1978). The health concern of chlorine according to Cantor (1987) is the risk of bladder cancer and also its effect on lipid level in the body (Zeighami, 1990).

Low alkalinity values were observed in all the samples (< 100 mg L^{-1}) except brand A with a mean value of 140.86 mg L^{-1}, which was significantly higher ($p<0.05$) than the other brands. However, the values still fell within WHO standard of 500 mg L^{-1} in drinking water (WHO, 1993). No health implication has been identified with alkalinity. In natural water, high alkalinity values act as buffer against acid rain and other acid laden wastes that could cause a sudden change in water pH and thereby posing threats to aquatic life.

Table 2: Chemical and microbiological compositions of different brands of bottled water

PARAMETERS	A	B	C	D	E	F	G	WHO

pH	7.17 ±0.18 c	7.23 ±0.39 c	6.94 ±0.34 c	5.69 ±0.38 b	5.52 ±1.14 b	5.33 ±1.05 a	6.91 ±0.66 c	6.5-8.5
Free Chlorine (mg L^{-1})	0.02 ± 0.00 a	0.02 ±0.01 a	0.02 ±0.01 b	0.01 ±0.02 a	0.05 ±0.03 a	0.01 ±0.02 a	0.02 ±0.02 a	0.3-2.0
Alkalinity (mg L^{-1})	140.86 ±57.0 b	49.33 ±16.28 a	10.0 ±8.71 a	34.0 ±44.22 a	45.33 ±13.01 a	29.33 ±47.38 a	44.66 ±9.86a	500
Ca Hardness (mg L^{-1})	78.66 ±103.19 a	23.33 ±25.00a	3.33 ±5.77 a	14.0 ±10.0 a	14.66 ±9.01 a	12.66 ±12.05 a	18.0 ±18.3 a	250
Mg Hardness (mg L^{-1})	28.667 ±9.45 c	9.33 ±5.03 ab	4.0 ±6.92 bc	11.33 ±4.61 a	18.0 ±3.46 ab	9.33 ±8.08 ab	7.33 ±7.57 ab	
Total Hardness (mg L^{-1})	107.33 ±110.8 b	32.667 ±29.48 ab	7.33 ±12.70 ab	26.0 ±14.42 a	32.66 ±12.05 ab	22.6 ±20.03 ab	35.33 ±27.3 ab	500
Chloride (mg L^{-1})	22.63 ±18.5 a	26.33 ±13.53 a	15.06 ±14.14 a	16.73 ±10.94 a	16.6 ±7.67 a	5.33 ±9.23 a	1.33 ±2.30 a	250
Sulphate (mg L^{-1})	11.33 ±8.5 a	12.66 ±20.20 a	1.0 ±0.0 a	1.66 ±0.57 a	0.66 ±0.57 a	13.13 ±13.07 a	14.56 ±1.28 a	250
Nitrate (mg L^{-1})	0.86 ±0.92 c	1.5 ±2.59 c	0.53 ±0.32c	1.36 ±2.11 b	0.33 ±0.15 b	1.33 ±0.577 a	1.26 ±1.20 c	10
Iron (mg L^{-1})	0.01 ±0.02 abc	0.03 ±0.01 c	0.02 ±0.00 abc	0.01 ±0.01 bc	0.01 ±0.01 abc	0.02 ±0.01 a	0.01 ±0.01 ab	0.3
Total Coliform (Count mL^{-1})	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00	0

Means in the same row followed by the same alphabets are not significant at $p<0.05$ according to Duncan Multiple Range Test

The values of Ca hardness were generally higher than the values of Mg hardness. Acceptable range of calcium in water has been given as 25-100 mg L^{-1} (Wurts and Masser, 2004), as all the observed mean values of Ca fell within this range. Therefore, the values of hardness in these brands of water samples may be due to Ca salts rather than Mg salts. However, while Ca showed no significant difference among the brands, Mg showed a level of significance as brand A is significantly higher ($p<0.05$) than the other brand. Total hardness mean results in all the samples were below 70 mg L^{-1} could be described as soft water except for sample A where hardness value is greater than 70 mg L^{-1} but less than 120 mg L^{-1} is moderately hard water (Environment Canada, 1977). Water supplies with hardness greater than 200 mg L^{-1} are considered poor, but have been tolerated by consumers; those in excess of 500 mg L^{-1} are unacceptable for most domestic purposes (WHO, 1993). Water hardness (very high value) may cause an adverse health effect in humans (WHO, 2003). Studies have shown weak correlations between cardiovascular health and water hardness (Marque *et al.,* 2003).

Chloride concentrations of the analyzed bottled waters were generally low and fell within WHO standard for chloride of 250 mg L^{-1} in drinking water. In drinking water, sources of chloride could be from dissolving salt deposits, salting of highways to control ice and snow, effluents from chemical industries, oil well operations, sewage, irrigation drainage, refuse leachates, sea spray and seawater intrusion in coastal areas (Department of National Health and Welfare, Canada, 1978). However, no health risk has been associated with high chloride concentration in water.

Sulphate values in these analyzed brands of bottled water were also low, and fell below the permissible sulphate limit of less than 250 mg L^{-1} in drinking water with sample B recording the highest value. Sulphate is one of the least toxic anions in water. However, high sulphate could contribute to undesirable taste in water (NAS, 1977). According to Bertram and Balance (1996), when sulphate concentration in drinking water exceeds 500 mg L^{-1}, urgent action must be taken by appropriate authorities as concentration between 800 mg L^{-1} and 1200 mg L^{-1} could result into health effect such as diarrhea (Heizer et al., 1997).

Nitrate values were generally low in all the brands of the bottled water and fell within WHO permissible standard of 50 mg L^{-1} in drinking water (WHO, 2008). Short-term exposure to nitrate drinking water above the permissible standard could lead to health problems in infants below six months leading to a disease known as methemoglobinemia or baby-blue syndrome, which is characterized by cyanosis, bluish mucous membranes, digestive and respiratory problems. High methemoglobin levels may lead to anoxia, brain damage or death (McCasland et al., 2007. Nitrate in form of nitrogen-nitrate level between 19-26 mgL^{-1} has been reported to cause a spontaneous abortion in women (MMWR, 1996).

The values of iron concentration in the bottled waters all fell within the WHO permissible limit. The brand B mean was significantly higher ($p<0.05$) than the other brands but still within the permissible limit of 0.3 mgL^{-1} that is based on taste and appearance rather than detrimental health effect (WHO, 2008). Iron is not considered hazardous to health. In fact, instead it is an essential element for good health because it transports oxygen in the blood. Iron is considered a secondary or aesthetic contaminant (WHO, 2008). The IDPH (Illinois Department of Public Health) (2008) has established a maximum concentration for iron in drinking water of 1.0 mg L^{-1}.

The zero values of total coliform counts in the bottled water were indications of effective disinfection process during treatment. Although, most coliforms do not cause disease, but their presence has a potential for disease-causing strains of bacteria, viruses and protozoan, which are capable of causing diarrhea, nausea, vomiting and fever (Oregon Department of Human Service, 2002). The bottled water samples were free from coliforms and microbiologically certified for human consumption.

Conclusion: The results of physico-chemical and microbiological parameters of the bottled water samples showed that all the brands of bottled water analyzed were potable and fit for human consumption without any fear of contacting any water-borne or water-related diseases. Although, there were variances in the values of pH, TDS, TS, alkalinity, Ca, nitrate and iron for different brands of the bottled water; by and large, the water samples still met the required limits set by World Health Organization in drinking water. However, two brands of the bottled water (D & F) slightly deviated from WHO standard in terms of their turbidity and pH values. All the water samples met the conditions set for microbiological properties and are free from microbial contaminations.

REFERENCES

Adekunle, IM, Adetunji, MT, Gbadebo, AM, Banjoko, OB (2007). Assessment of groundwater quality in a typical rural settlement in southwest, Nigeria. *Int. J. Environ. Public Health*, 4(4): 307-318.

Ademoroti, CMO (1996). Standard methods for water and effluents analysis. Foludex Press Ltd., Ibadan, pp.32-
118.

APHA (1998). Standard Methods for the Examination of Water and Wastewater (17th ed.), American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington, DC.

Bertram, J, Balance, RA (1996). Practical guide to the design and implementation of freshwater, quality studies and monitoring programmes. Published on behalf of United Nations.

Bruvold, WH, Ongerth, HJ (1969). Taste quality of mineralized water. *Am. Water Works Assoc.*,
61:170.

Buchholz, RA. (1998). Principles of environmental management. The Greening of Business, 2nd. Prentice-Hall,
London, UK, 448p.

Cantor, K (1987). Bladder cancer, drinking water source and tap water consumption. A case study control. J.
National Cancer Institute, **79**:1269-1279.

Department of National Health and Welfare (Canada). Guidelines for Canadian drinking water quality. Supporting documentation. Ottawa, 1978.

Dychdala, GR (1977). Chlorine and chlorine compounds. In: Black SS, Ed. Disinfection, Sterilization and
Preservation 2ed. Philadelphia, PA, Lea and Fabinger, pp.167-195.

Environment Canada (1977). Surface water quality in Canada — an overview. Water Quality Branch, Inland
Waters Directorate *Am. Water Works Assoc.*EPA (2003). Drinking water infrastructural needs survey, Fact sheet 816F05014.

FAO (2010). Corporate Document Repository. Fishery Harbour Manual on the Prevention of Pollution.

Gleick, PH (2006). The world's water. The Biennial Report on Fresh water Resources. Washington. Island Press.
ISBN13:978159261050

Hauser, BA (2001). Drinking water chemistry, A laboratory manual. Turbidity herp II, Lewis Publishers, A CRC
Press Company, Florida, USA p.71.

Heizer, WD (1997). Intestinal effects of sulfate on drinking water in normal human subjects. *Digestive Diseases*
and Sciences, **42** (5):1055–1061.

IDPH (Illinois Department of Public Health) (2008). Environmental Health Fact sheet. http://www.idph.state.il.us/envhealth/factsheets.

King. M (2008). Bottled Water - Global Industry Guide - New Research Report on Companies and Markets.
No.688919.

Lefort, R (2006). Down to the last drop. UNESCO Sources. No. 84, p.7.

Marque S, Jacqmin-Gadda, H, Dartigues, JF, Commenges, D (2003). Cardiovascular mortality and calcium and
magnesium in drinking water: an ecological study in elderly people. *Eur. J. Epidemiol.* 18(4):305-9.

McCasland, M, Trautmann, NM, Robert, RJ and Porter, KS (2007). Center for Environmental Research and
Natural resources. Cornell Cooperative Extension Nitrate: Health effects in drinking water. http://pmep.cce.cornell.edu/facts-slides-self/facts/nit-heef-grw85.html. Accessed May 15, 2009.

MMWR (Morbidity and Mortality Weekly Report) (1996). Spontaneous abortions possibly related to ingestion of nitrate contaminated well water-LaGrange County, Indiana, 1991-1994. MMWR 45: 569-572

NAS (1977). Food ingredients. Washington, DC, National Academy of Sciences, Subcommittee on Research of
GRAS (Generally Recognized As Safe) List (Phase II) (DHEW No. FDA 70-22).

Orebiyi, EO, Awomeso, AJ, Martins, O, Idowu, AO, Oguntoke, O and Taiwo, AM (2010). Assessment of Pollution Hazards of Shallow Well Water in Abeokuta and Environs. *Am. J. Environ. Sc*. 6 (1): 50-56.

Oregon Department of Human Service (2002). Health effects information. Technical Bulletin. Pp 2-4.

Taiwo, AM (2010). Environmental Impact of Poultry Farm Operations on Alakata Stream Isolu In Abeokuta,
Nigeria. Masters Dissertation. Department of Environmental Management and Toxicology, University of Agriculture, Abeokuta. 108p.

U.S. Center for Disease Control and Prevention, Atlanta GA (2006). Safe water system: a low-cost technology
for safe drinking water.Fact Sheet, World Water Forum 4 Update. March 2006.

White, GC (1978). Current chlorination and dechlorination practices in treatment of potable water, wastewater
and cooling effect. In: Ann Arbor, MI, Ann Arbor Science, pp 1-18,

WHO (1993). World Health Organization, Guidelines for drinking water quality-I, Recommendations, 2nd Ed. Geneva.

World Health Organization (2008). Guidelines for drinking water quality, Geneva WHO 2008. www.lentech.com /WHO-drinking-water-standards06.htm. Accessed 9/01/2008.

Wurts, WA, Masser, MP (2004). Water hardness-Calcium and Magnesium. Southern Region Aquaculture Center Publication No. 400.

Zeighami, EA., Watson, AP, Craun, GF (1990). Serum lipid levels in neighboring countries with chlorinated and non-chlorinated drinking water. Fundamental and applied Toxicology, 6:421-432.

Wikipedia (2009). Water Wikipedia. http://en.www.wikipedia.org.wiki/water. Accessed 09/11/2009.