Journal of Medical Sciences

ISSN 1682-4474

Research Paper

J. Med. Sci., 5 (4): 260-265
October-December, 2005

JMS (ISSN 1682-4474) is an International, peer-reviewed scientific journal that publishes original articles in experimental & clinical medicine and related disciplines such as molecular biology, biochemistry, genetics, biophysics, bio-and medical technology. JMS is issued four times per year on paper and in electronic format.

For further information about this article or if you need reprints, please contact:

N.P. Okolie
Department of Biochemistry
Faculty of Science
University of Benin
P.M.B 1154, Benin City
Nigeria

Tel: 234-8038350087

Toxic Chemicals and Microbes in Some Nigerian Water Samples

[1]M.E. Ukhun, [1]S.B. Tobi and [2]N.P. Okolie

Some conventional and non-conventional sources of drinking water in Nigeria were screened for Fe, Zn, Cu, Mn, cyanide, nitrate, nitrite, nitrosamines, total coliform, *E. coli* and fecal streptococci, using standard analytical methods. Results obtained showed that water samples from overhead tanks and those from rivers in industrialized areas had iron levels far in excess of WHO permissible concentrations; while in all samples, Cu, Mn and Zn were within safe limits. There was a wide range (42.2 to 179.8) in % coefficient of variation, CV of the minerals between samples, suggesting that sample source influenced mineral levels. The range of values for nitrate, nitrite and nitrosamines were 83±32 to 21,720±590, 14.5±5.0 to 52.0±14.0 and 0.10±0.01 to 0.56±0.03 g L^{-1}, respectively. Surface and overhead tanks had nitrate levels twice the US EPA recommended maximum contaminant limits. The %CV values for nitrate, nitrite and nitrosamines were 157.0, 49.5 and 13.0%, respectively, implying locational variability in these parameters. Cyanide was not detected in any of the samples. Fecal contamination of all samples was indicated by presence of fecal coliform (range 3 to 1,100 cells/100 mL) and fecal streptococci (range 3 to 240 cells/100 mL). The public health significance of these results underscore the need for adequate disposal of human and industrial wastes and the importance of regular monitoring of all drinking water sources.

Key words: Drinking water, iron, nitrate, fecal contamination

ANSInet
Asian Network for Scientific Information

[1]Department of Chemistry
[2]Department of Biochemistry, Faculty of Science,
University of Benin, P.M.B 1154, Benin City, Nigeria

INTRODUCTION

Increasing industrialization and urbanization has led to increasing chemical and microbial stress on the terrestrial, aquatic and aerial environment. In the industrialized nations functional regulatory agencies are in place to enforce environmental laws. In the developing nations however, this is usually not the case. Regulatory agencies, where they exist, are largely ineffective as a result of various socio-economic and technological constraints. Consequently, both the environment and humans become victims. In Nigeria for instance, the upsurge in industrial and economic activities due to an 'oil boom' has led, in part, to environmental deterioration, especially in the oil producing areas. Because of acute shortage of water supply, drinking water is obtained from conventional sources such as pipe-borne water and occasionally from non-conventional sources such as lakes, streams and rivers. Since many of the microbial and chemical contaminants of drinking water arise as leachates from polluted sites[1], the indiscriminate waste disposal habits of city dwellers in Nigeria may compromise the quality of some of these water sources. Literature on the toxicological status of water supply in Africa in general and Nigeria in particular are scanty, although some studies have been reported[2-6].

In the present studies, water samples from various sources in Nigeria were analyzed for iron, zinc, copper, manganese, nitrate, nitrite, nitrosamines, cyanide, total coliform counts, *E. coli* and fecal streptococcal levels. It appears that, currently there is little or no information on the aspects covered in the present investigations.

MATERIALS AND METHODS

Polyethylene bottles, which had been cleansed by acid wash and rinsed thoroughly with distilled water, were used for sample collection from various sources (rivers, streams, taps, surface and overhead water tanks and industrial areas). In the river sites, water samples were collected downstream 3-10 cm below the water surface after thoroughly rinsing the containers with the water at point of collection. Taps were allowed to run for a while before actual water collection to allow standing water in the taps run off.

Pessu Waterside, Warri: This is the water front which is used, more or less, as a harbor for boats from the riverine areas of Warri town. The water runs through the Warri port into the Atlantic Ocean.

Delta Steel Complex Harbor: The harbor is used by ships transporting materials to and from the Delta Steel Complex, which is one of Nigeria's multi-million dollar investments.

Effurun Water Works: Potable water from this station is usually treated with hydrated lime and chlorine to achieve a chlorine level of 3 to 5 mg L^{-1} and a pH of 6.5 to 7.5.

Nigerian National Petroleum Corporation Refinery, Ekpan: Waste water runs from the refinery into a stream.

Ethiope River, Sapele: The river flows from Abraka, passes under the bridge through the Sapele Port into the Atlantic Ocean. Water samples were collected from the foot of the bridge.

Ologbo Waterside: This water source is used by fishermen and farmer settlers around the river for their laundry, waste disposal and sometimes as car wash sites.

Ikpoba Water: The river is a source of water for laundry, car wash, bathing, waste disposal and in periods of acute water scarcity, a source of drinking water. There is a dam built on it which, however, does not meet the water needs of the people.

Surface Tanks: These tanks made of flat steel sheets were of dimensions 1.5x1.5x1.5 m and placed on the ground surface.

Overhead Tanks: These were similarly constructed from flat steel sheets and had the same dimensions as the surface tanks (1.5x1.5x1.5 m). Overhead tanks receive water from the surface tanks; the water is then channeled into homes through metal pipes for batch withdrawals via water taps.

Ugbowo Water Works: Water from this station is pre-treated to a chlorine level of 3 to 5 mg L^{-1} and a pH of 6.5 to 7.5, before being channeled into homes as potable water.

After collection, samples were immediately taken to the laboratory for subsequent analyses. When this was not possible, they were stored at 4°C in ice coolers or refrigerators. The levels of iron, zinc, copper and manganese, in triplicate pre-filtered (Whatman No. 1) samples obtained from each of the sources were determined by atomic absorption spectrophotometry using a Perkin Elmer 403 atomic absorption spectrophotometer. Nitrate, nitrite, coliforms, *E. coli* and

Table 1: Levels of mineral elements (mg L^{-1}, means±standard error of at least triplicate readings) in some Nigerian water samples

Source of water samples	Fe	Zn	Cu	Mn
Pessu Waterside, Warri	0.48±0.02	0.07±0.02	0.02±0.01	0.02±0.01
Delta Steel Co. Alaja Harbor	0.82±0.08	0.04±0.01	0.03±0.01	0.02±0.01
Effurun Water Works	0.13±0.04	1.35±0.01	0.04±0.01	0.02±0.01
N.N.P.C. Refinery, Warri	0.16±0.01	0.26±0.02	0.01±0.00	0.01±0.00
Ethiope River,Sapele	0.20±0.07	0.05±0.01	0.02±0.01	0.02±0.01
Ologbo Waterside, Ologbo	0.32±0.08	0.04±0.01	0.01±0.01	0.02±0.00
Ikpoba River, Benin City	0.35±0.03	0.06±0.02	0.02±0.00	0.01±0.00
Surface water tank	0.26±0.03	0.13±0.01	0.02±0.01	0.02±0.01
Overhead water tank	0.44±0.03	0.07±0.02	0.02±0.01	0.01±0.00
Ugbowo Water Works, Benin	0.17±0.03	0.08±0.01	0.01±0.00	0.02±0.01
CV (%)	62.1	179.8	48.8	42.2

streptococcal levels were assayed for by methods described by the American Public Health Association, APHA[7]. Nitrosamine levels (measured as nitrosodiethanolamine) were determined colorimetrically[8] while cyanide was quantified spectrophotometrically[9]. Coefficient of variation (CV%) results were computer-generated at the Computer Center of the University of Benin, Benin City, Nigeria.

RESULTS AND DISCUSSION

Iron levels ranged between 0.13±0.04 and 0.82±0.08 mg L^{-1}. Zinc values ranged between 0.04±0.01 and 1.35±0.01 mg L^{-1}. Copper levels were between 0.01±0.00 and 0.04±0.01 mg L^{-1} while values for manganese ranged between 0.01±0.00 and 0.02±0.01 mg L^{-1} (Table 1). The elements Fe, Zn, Cu and Mn among others are considered trace elements because they are present in living tissues in small amounts. These elements are nutritionally essential in enzyme functions and in promoting general well being. However, toxic effects could result from excessive intakes[10] The water samples obtained from Delta Steel Company Alaja, Pessu Waterside, Warri and the overhead tanks had iron levels which exceeded the WHO recommended level of 0.3 mg L^{-1}[11] (Table 1). The high level of iron in the Delta Steel Company harbor reflects the negative consequences resulting from mutual impact between the ecosystem and industries. Yet, the Delta Steel Company Alaja Nigeria's attempt at modern steel production. Apparently the disposal of bye-products from the company deserves greater monitoring and scrutiny. Of all the water samples examined in the present studies, the Steel Company harbor water sample had the highest level of iron (0.82±0.08 mg L^{-1}). Of equal importance was the observation that the iron levels in the over-head tank water samples exceeded those recommended by WHO. The use of surface and over-head tanks is the most popular method of domestic water storage in Nigeria. The suspicion had always been that as a consequence of the fact that the tanks were constructed with corrodible materials, leaching of iron from tank to water could occur. Thus, most Nigerians could become victims of iron poisoning over a period of time (if this has not already started to happen). Apart from siderosis, disease conditions such as primary hepatocellular carcinoma and generally enhanced malignancy in experimental animals have been associated with excess iron intake[12]. The levels of zinc in the water samples did not exceed WHO recommended level of 5.0 mg L^{-1}. That was desirable in view of the documented toxicity of excessive zinc intake in humans. However, in a previous study of water quality of some boreholes in Benin City, zinc values ranging from 0.98 to 8.50 mg L^{-1} were reported[5]. Excess zinc intake in humans is linked to risks of coronary heart disease, hypercholesterolemia and hypertension[13]; prostate and other types of cancers[14]; as well as diabetes and reduced growth[15]. Acute toxicity of zinc is fatal and results in extensive necrosis of kidney and liver, impaired copper absorption and hematological derangements[16]. Again, it is desirable that the levels of copper and manganese in all the water samples analyzed did not exceed the WHO recommended limits of 1.0 and 0.1 mg L^{-1} respectively. Copper is a very toxic heavy metal involved in many metabolic pathways: its toxicity is thus complex[17]. Gastrointestinal distress as well as liver and kidney damage are among the toxic effects thought to be associated with elevated copper intakes[1]. With respect to non-optimal manganese levels, some of the reported effects are cell-mediated cytotoxicity, mutagenicity and genotoxicity in short-term tests[18] and coronary heart disease[19]. With a percentage coefficient of variation that ranged between 42.2 and 179.8, the sources of the water samples, in statistical terms, significantly affected the levels of mineral elements (Table 1). Among several other factors, variations in the inherent ecochemistry, degree of industrial pollution, leaching phenomena, agronomic practices and accumulation via waste disposal by

Table 2: Levels of nitrate, nitrite and nitrosamine (μg L^{-1}; means±standard error of at least, triplicate readings) in some Nigerian water samples

Sources of water samples	Nitrate	Nitrite	Nitrosamine
Pessu Waterside, Warri	2360±1021	39±8	0.45±0.06
Delta Steel Co. Alaja Harbor	1770±590	52±14	0.38±0.03
Effurun Water Works	297±175	18±5	0.16±0.08
N.N.P.C. Refinery, Warri	1966±341	24±2	0.56±0.03
Ethiope River, Sapele	1573±1228	21±4	0.54±0.02
Ologbo Waterside, Ologbo	83±32	35±6	0.21±0.01
Ikpoba River, Benin City	1376±901	51±7	0.40±0.02
Surface Water Tank	21270±590	20±2	0.39±0.05
Overhead Water Tank	20483±341	26±6	0.37±0.07
Ugbowo Water Works, Benin	120±60	14±5	0.10±0.01
Coefficient of variation(CV%)	157	49.5	132

Table 3: Total coliform, *E. coli* and fecal streptococcal counts (per 100 mL) of some Nigerian water samples

Sources of water samples	Total coliforms	*E. coli*	Fecal streptococci
Pessu Waterside, Warri	2,400	1,100	240
Delta Steel Co. Harbor, Alaja	2,400	460	3
Effurun Water Works	4	3	3
N.N.P.C. Refinery, Warri	1,100	240	4
Ethiope River, Sapele	460	150	4
Ologbo Waterside, Ologbo	1,100	150	15
Ikpoba River, Benin City	240	93	11
Surface Water Tank	3	3	3
Overhead Water Tank	3	3	3
Ugbowo Water Works, Benin	3	3	3

individuals and whole communities, could account for differences in the levels of the elements in the water samples studied.

Toxicologically, nitrates, nitrites and nitrosamines are related by the fact that nitrates are reducible to nitrites which can react with secondary amines to produce carcinogenic nitrosamines[20]. Nitrates in drinking water have been linked with infant methemoglobinemia (blue baby syndrome) apparently because the reduction products of nitrates ie nitrites are capable of oxidizing hemoglobin to methemoglobin[21, 22].

The US Environmental Protection Agency has set the maximum contaminant level of nitrate nitrogen and nitrite nitrogen in drinking water at 10 and 1 mg L^{-1}, respectively[1]. The nitrate levels in the water samples (Table 2) ranged between 83±32 and 21270±590 μg L^{-1}. Samples obtained from the surface and overhead tanks had nitrate concentrations higher than the recommended level of 10,000 μg L^{-1}. The proximity of tank pipes that convey water to septic and suck-away tanks, including the aerial deposition of microbes and nitrogenous substances and the inherent nitrate contents of the tank may account for the high nitrate levels. In Nigeria, water in storage tanks is either pipe-borne, or supplied by commercial vendors who obtain it from other sources such as streams, lakes and rivers, especially in periods of scarcity. Nitrites were detected in all the samples at levels that ranged between 14±5 and 52±14 μg L^{-1}. Nitrosamine was also detected in the water samples; this ranged between 0.1±0.01 and 0.56±0.03 μg L^{-1}. In an earlier study[23], an inverse relationship was observed between nitrate and nitrite levels in cassava products. This was attributed to reduction of nitrates to nitrites and possible transformation to nitrosamines. Similar inverse relationships have been reported recently by other workers[24]. However in the present study, it appears that there was no clear-cut relationship between nitrate and nitrite concentrations. A clear-cut relationship between nitrate and nitrite levels in a sample might be blurred by the fact that although nitrites are good reducing agents, they may be oxidized to nitrates by strong chemical oxidants or by bacteria such as those in the water samples examined (Table 3). With coefficients of variation (%) of 157, 49.5 and 13, respectively for nitrate, nitrite and nitrosamine levels (Table 2), it is apparent that locational variations also significantly affected the concentrations of these toxic components in the water samples. Moreover, when the results obtained in this study were pooled with those obtained in previous studies[23,25] it appears that the Nigerian population may be assimilating toxic levels of nitrates, nitrites and nitrosamines through diverse sources such as foods, water and plants. This is of public health significance. It has been suggested that cumulative intakes of nutrients (toxic and non-toxic) from various sources may be more important nutritionally and from the public health perspective, than single and isolated intakes from what is traditionally regarded as good sources of various nutrients[25]. Cyanide was not detected in the present studies.

Total coliform counts ranged between 3 to 2,400 cells/100 mL (Table 3). The low levels of coliform in the surface and overhead tank water samples could be partially responsible for their low nitrite contents. Consequently, the higher coliform counts of the river samples could explain, in part, their higher nitrite contents via nitrate reduction to nitrite. The US EPA recommends a zero contamination level for coliform in drinking water[1]. The *E. coli* (fecal coliform) counts ranged from 3 to 1,100 cells/100 mL; while fecal streptococcal counts ranged from 3 to 240 cells/100 mL. The presence of these organisms strongly point to fecal contamination of the water samples. The fecal streptococcal loads of the Pessu waterside, NNPC, Ethiope River, Ologbo waterside and Ikpoba River samples are in excess of the WHO recommended zero level. A lot of human activities take place in these areas and the poor or non-existent toilet facilities may result in people defecating directly into the water or in nearby bushes. In addition, some ground water samples in Benin are contaminated by presence of *E. coli* and streptococci[5]. The comparatively high levels of fecal streptococci in the water samples from Pessu waterside, NNPC, Ethiope river, Ologbo waterside and Ikpoba river appear consistent with their higher nitrosamine levels. Studies have shown that fecal streptococci can produce nitrosamines in the presence of nitrites and secondary amines[26].

This study has shown the presence of various toxic chemicals and microbes in Nigerian water samples. Due to the dynamic nature of the human environment, regular monitoring of the various water supplies in the country is imperative. It is to be noted that in a country where potable water is grossly inadequate, any source of water is potentially a source of drinking water. The scenario is probably true of many other developing and war-ravaged countries.

REFERENCES

1. Anonymous, 2005. List of drinking water contaminants and their MCLs. United States Environmental Protection Agency guidelines.
2. Gbodi, T.A. and S.E. Atawodi, 1987. Nitrate contents of well, raw, treated and pipe-borne water in Vom, Plateau State, Nigeria. Vet. Human Toxicol., 29: 151-152.
3. Ohagi, S.Q. and C.N. Akujieze, 1989. Iron in borehole water sources in Bendel State, Nigeria. J. Nig. Assoc. Hydrogeol., 1: 192-196.
4. Hassan, A.A.M., E. Benfarati and R. Fanneli, 1996. Detection and quantification of trihalomethanes in drinking water from Alexandria, Egypt. Bull. Environ. Contam. Toxicol., 56: 397-404.
5. Erah, P.O., C.N. Akujieze and G.E. Oteze, 2002. The quality of groundwater in Benin City: A baseline study on inorganic chemicals and microbial contaminants of health importance in boreholes and open wells. Trop. J. Pharm. Res., 1: 75-82.
6. Ogbu, I.S.I. and V.C. Echebiri, 2003. Nitrate and nitrite content of well water in Enugu, Southeast Nigeria. Arch. Environ. Health, 58: 590-591.
7. Anonymous, 1976. Standard methods for the examination of water and waste water. 13th Edn. American Public Health Association, NY, pp: 233-237, 240-243.
8. Telling, G.M. and P.C. Dunnett, 1981. The determination of N-nitrosodiethanolamine (NDELA) at trace levels in shampoos and skin creams by simple rapid colorimetric method. Intl. J. Cosmetic Sci., 31: 241-248.
9. Williams, H.J. and T.G. Edwards, 1980. Estimation of cyanide with alkaline picrate. J. Sci. Food Agric., 31: 15-22.
10. Moore, M.N., 1985. Cellular response to pollutants. Mar. Poll. Bull., 16: 143-149.
11. Anonymous, 1984. Guidelines for Drinking Water Quality. Health criteria and other supporting information, WHO, 2: 1-15.
12. Stevens, R.G., R.P. Beasley and B.S. Blumberg, 1986. Iron-binding proteins and risk of cancer in Taiwan. J. Natl. Cancer Inst., 76: 605-610.
13. Klevay, L.M., 1975. Coronary heart disease: The Zn/Cu hypothesis. Am. J. Clin. Nutr., 28: 764-774.
14. Kolonel, L.N., C.N. Yoshigama and J.H. Hankin, 1988. Diet and prostrate cancer: A case study in Hawaii. Am. J. Epidemiol., 127: 999-1012.
15. Kong, F.X. and Y. Chen, 1995. Effect of aluminum and zinc on enzyme activities in the green alga *Selenastrum capricornutum.* Bull. Environ. Contam. Toxicol., 55: 759-765.
16. Bennett, D.R., C.J. Baird, K. Chan, P.F. Crookes, C.G. Bremner, M. Gottlieb and W. Naritoku, 1997. Zinc toxicity following massive coin ingestion. Am. J. Forensic Med. Pathol., 18: 148-153.
17. Sorensen, E.M., 1991. Metal Poisoning in Fish. CRC Press Inc, Florida, pp: 374.
18. Rassman, T.G., M. Molina and L.W. Meyer, 1984. The genetic toxicology of metal compounds. 1.Induction lambda prophage in *E. coli* (lambda). Environ. Mutagen., 6: 59-69.
19. Manthey, J., M. Stoeppler, W. Morgenstern, E. Nussel, D. Opherk, A. Weintraut, H. Wesh and W. Kubler, 1981. Magnesium and trace metals: Risk factors for coronary heart disease? Association between blood levels and angiographic findings. Circulation, 64: 722-729.
20. Hongning, Z. and K.H. Tom, 1998. Tobacco-specific Nitrosamine, Alpha Particles and Mutagenesis in Mammalian Cells. Ann. Rep. Centre Radiol., Res., CRR. Columbia University, USA.
21. Anonymous, 2001. Nitrate in drinking water and human health. IOWA Fact Sheet, University Extension, IOWA State University.
22. Anonymous, 2003. Case studies in environmental medicine: Nitrate/ nitrite toxicity. Agency for Toxic Substances and Disease Registry Public Health Statement.

23. Ukhun, M.E. and D.O. Iwenor, 1988. Toxic and potentially toxic constituents of garri and beef marketed in Nigerian traditional markets. Bull. Environ. Contam. Toxicol., 42: 548-552.
24. Uhegbu, F.O. and E.N. Maduagwu, 1995. Occurrence of nitrosatable amines in some Nigerian medicinal plants. Bull. Environ. Contam. Toxicol., 55: 643-649.
25. Ukhun, M.E. and E.N. Dibie, 1990. The ascorbic acid contents of selected marketed foods and influence of water activity (A_w) during storage. Food Chem., 41: 277-283.
26. Collins-Thompson, D.L., N.P. Sen, B. Aris and L. Schwinghamer, 1972. Non-enzymatic *in vitro* formation of nitrosamines by bacteria isolated from meat products. Can. J. Microbiol., 18: 1968-1979.