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Full Length Research Paper

Quality of packaged drinking water produced in Warri Metropolis and potential implications for public health

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Five brands of popular packaged water produced in Warri have been screened for coliform, physical and selected chemical characteristics, including cadmium, chromium and lead for the objective of determining potability using appropriate methods. Sachets and bottled water samples were collected from production plants, wholesale outlets and street hawkers. The results were in the following range: pH, 7.1 to 8.2; Total dissolved solids (TDS), 2.26 to 89.6 mg/l; Turbidity, 0.45 to 2.55 NTU; Calcium, 0.11 to 1.21 mg/l; Magnesium, 0.03 to 0.31 mg/l; Sulphate, 0 to 1.21 mg/l; chloride, 0.5 to 3.1 mg/l; nitrate, 0.2 to 0.25 mg/l. Cadmium was detected in three brands in both sachets and bottles and ranged from 0.001 to 0.002 mg/l. Lead detected ranged from 0.001 to 0.003 mg/l and chromium: 0.001 to 0.002 mg/l. While all parameters are well below regulatory guidelines, attention is drawn to the predominantly low Total dissolved solids (TDS) which indicates that the packaged water in Warri is demineralized. Prolonged consumption of demineralized water has been shown from elsewhere to result in micronutrient deficiencies, especially in calcium and magnesium that have been associated with high incidence of ailments including, dieresis, hypertension and coronary heart disease among others. Cohort-epidemiological studies are recommended in Warri and environs where packaged water is the most important drinking water source in order to establish any such health related linkages. Study results would guide water supply policy and regulatory action.

Key words: Packaged water, low TDS, heavy metals, public health, Warri, water policy.

INTRODUCTION

The port city of Warri, (latitude 5°30'N - 5°35'N; longitude 5°29'E - 5°48"E) is the hub of the oil and gas industry in the western Niger Delta as well as the most populous industrial and commercial center of Delta state, Nigeria. The city has grown from a small rural town of less than 20,000 people in 1933 to an agglomeration of the several major towns of Effurun, Ekpan, Enerhen, Edjeba, Ogunu, Jakpa, Ovian –Aladja, Udu and other smaller communities such that it now covers an area of more than 100 km^2 (Efe, 2005) and with a population of an estimated 500, 000 people in 2006 (Ojeh and Ojoh, 2011). This growth in population has outstripped infrastructural development, including public water supplies. Most residents, industry and commercial establishments rely on shallow water wells for self supplies. Leachates from unregulated garbage dumps are also a constant source of nutrient loading to ground water in Warri (Abimbola et al., 2002). Pathogens, elevated cadmium and lead levels have thus been reported from shallow groundwater in Warri (Akpoborie et al., 2000; Ejechi et al., 2007). Traces of Benzene and Toluene have also been reported from dug wells in the vicinity of a refinery and industrial chemical complex located on the northwest corner of the city (Akpoborie et al., 2008). Packaged water is therefore the drinking water of choice by consumers in Warri, and is used in homes, offices, served in all hotels, various categories and social levels of eating houses, lowly and as well as sophisticated elite restaurants and fast food outlets.

In addition, Warri is located at the western edge of the difficult to access wetland physiographic terrain that

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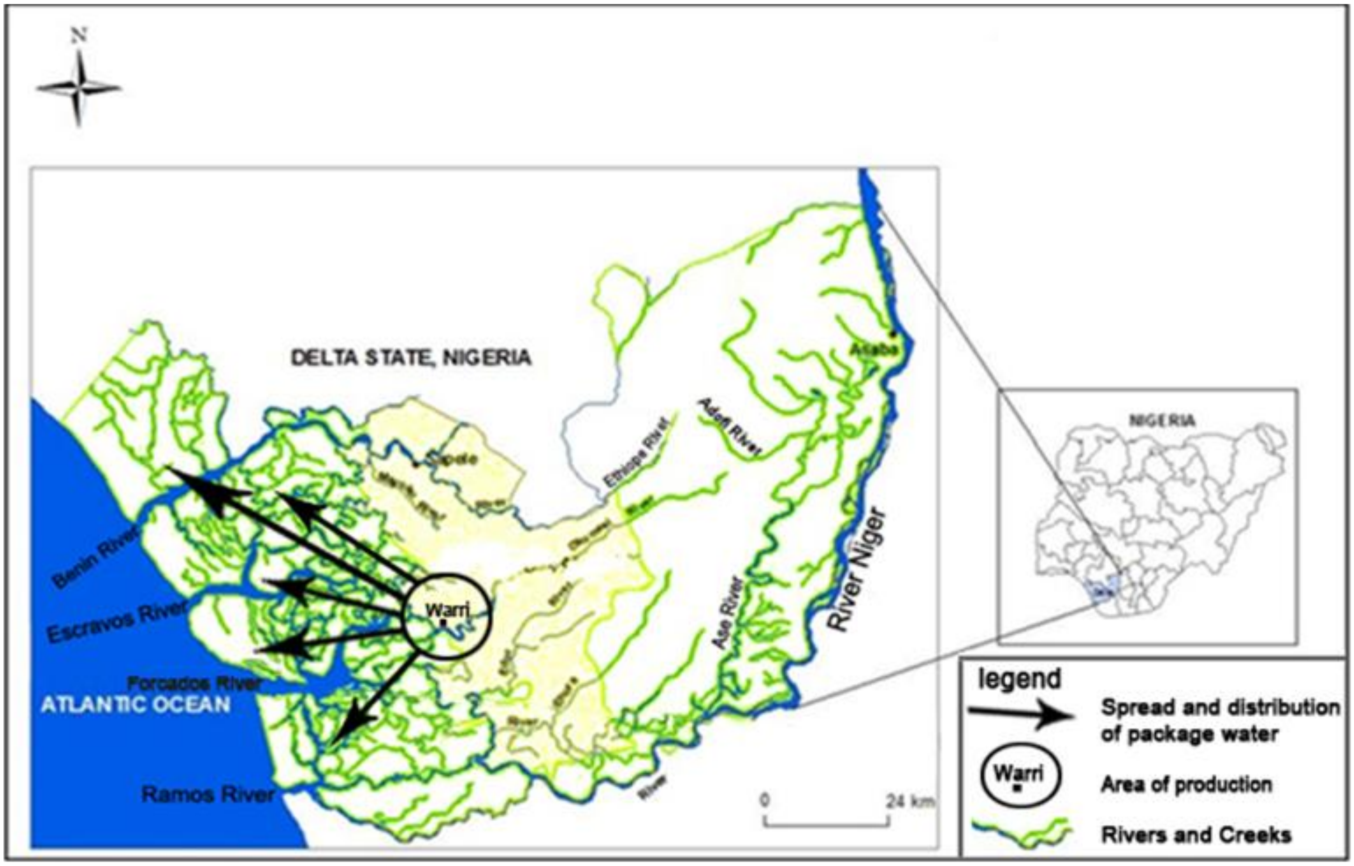

Figure 1. Drainage Map of Delta State, Nigeria showing the reach of processed water packaged in Warri (circled).

covers the five local government areas (LGA's) of Bomadi, Burutu, Warri South, Warri South West and Warri North, which in land mass constitute more than a third of Delta State Nigeria (Figure 1).

Warri is thus the port from which water craft ferry all manner of goods and supplies including packaged drinking water to the communities that are located in the interior wetlands.

The quality of processed water produced in Warri is therefore of paramount interest not only to the consumers in the city of Warri but also to the additional hundreds of thousands of inhabitants of the various dispersed communities in the wetlands who rely almost exclusively on packaged water sourced from Warri for drinking. The water processed in all the production plants visited during this study is obtained from boreholes that tap the upper layers of the Benin Formation. The raw water is passed through a combination of filtering media including in some cases, activated charcoal and Millipore or equivalent filters before disinfection with ultraviolet irradiation. Processed water is packaged with automatic filling and sealing equipment in conditions that appeared to be clean and hygienic.

The quality of packaged water may however not be taken for granted. Dada (2009) reports previous but unrecorded disease outbreaks associated with packaged water consumption. Rosenberg (2003) also reports that though rare, disease outbreak has been associated with bottled water consumption in other parts of the world. Studies from different cities have documented the lack of purity of processed drinking water in Nigeria. Dada (2009) for example, reports 22% non compliance with regulatory standards from 100 samples of 10 brands of sachet water in Lagos. One study from Ibadan (Ajayi et al., 2008) showed that bottled water sampled was in compliance but 30% of sachet water sampled did not comply. Indeed, 5% of 78 samples showed positive coliform counts. In the second study from Ibadan Oyedeji et al. (2009) examined sixteen brands that included samples from Ile-Ife. One brand of bottled water in the study showed positive coli counts while all sachet water brands showed bacterial growth. From Abeokuta, Taiwo et al. (2010) report that all bottled water sampled complied with regulatory standards. Orisakwe et al. (2006) report the high levels of lead and cadmium in sachet water from several locations in eastern Nigeria. Kalpana et al., (2011) also show that all the sachet water sold at the Kebbi State University campus and the nearby city market contain pathogens, while Onifade and Ilori (2008) found that all sachet water sampled in the city of

Ondo had high microbial loads. Indeed, a study from Abakaliki (Afiukwa et al., 2010) also showed that all twenty brands of sachet water sampled there contained eleven strains of bacteria some of which are multi-drug resistant. At Asaba, Akpoborie et al. (2007) show that the fifty samples of sachet water tested showed positive coliform counts that were higher in samples obtained from street vendors than those obtained directly from the production plants.

Thus due to the nationwide concerns raised about the quality of packaged water, the primary objective of this work is to determine the suitability for drinking, the packaged water offered for sale by production plants in Warri not only to the residents of the city, but also to the widely dispersed and surrounding wetland communities.

METHODOLOGY

Production plants in Warri package water in three ways for sale and distribution: in 50 to 150 cl clear plastic bottles, hermetically sealed thin plastic 25 to 30 cl sachets and 20 litre carboys. The bottles and sachets are the most popular because they are affordable and convenient. Bottles are packaged for wholesale distribution from production plants in packs of 6, 12 or 24 units. The sachets are packed in sealed bags of 20 sachets. Distribution to wholesale and retail shops, commercial houses, industries and offices is done directly from production plants usually by truck. Consumers also have access to and buy bags and packs directly from the production plants or wholesale distributors. Street hawking of ice cold packaged water is common and prevalent at markets, interstate bus terminals, traffic jams and other public places. Opportunities for contamination after the product leaves the plant are therefore many.

In recognition of this and because Akpoborie et al. (2007), and Dada (2009) have suggested possible linkage in sachet water contamination to retailing and street hawking, sampling in this study was undertaken as follows. Five selected popular brands designated as A, B, C, D and E were chosen for the study. First, several packs of bottled product and bags of sealed sachets were randomly selected and purchased from each production plant, assigned batch numbers and sent to the laboratory. Second, the same was done for each brand from randomly selected wholesale outlets. Third, at least ten individual sachets and bottles of each brand were purchased from street hawkers in different parts of the city and as before sent immediately to the laboratory within an hour. The choice of production plant for brand A which packages water only in sachets and has no facility for bottling was deliberate because it represents the numerous and less sophisticated plants that produce the cheapest and more widely distributed sachet water type. At the laboratory, one sample each from each batch and brand was randomly selected for physical examination and chemical analysis. In all, twenty seven samples were selected in this manner. The external features of each water sachet and bottle including product information were recorded. Specific odour and appearance were also noted. Samples were thereafter subjected to bacteriological and physicochemical analyses.

Electrical conductivity and total dissolved solids (TDS) were measured with the HACH conductivity/TDS meter. The pH of each sample was measured with the Schott Gerate model pH meter. Nitrate concentration was determined with the HACH spectrophotometer while the sulphate content was determined by the turbidimetric method. Major ions Ca^{2+}, Mg^{2+}, Cl^{-}, NO^{3-} and heavy metals Pb^{2+}, Cd^{2+} and Cr^{2+} were determined with the appropriate titrimetry, flame photometric and atomic absorption spectrometric methods (APHA, 1992).

In order to determine the presence of total and fecal coliform, 100 ml of each water sample were passed through a membrane filter consisting of uniform pore diameter of 0.45 nm. The membrane filter was then placed in a petri-dish containing Mac-Conkey Agar and Eosin-Methylene blue Agar, in duplicate with the grid side up and incubated at 35 and 45°C for 18 - 24 h respectively so as to recover total and fecal coliform where present. Bacteria colonies if present were counted and expressed as numbers of coliform per 100 ml of water.

RESULTS

Labels and nutritional information

All samples were devoid of labeling requirements specified in the Nigerian Industrial Standard, NIS 345:2008 for packaged water by the Standards Organization of Nigeria (SON). The specified information in the standard includes the production batch number, nutritional information, production date and best use before/expiry date. Only the National Agency for Food and Drug Administration and Control (NAFDAC) registration number, name and address of producers were displayed on all sachets and bottles in the sample as specified. Indeed, the absence of batch numbers somewhat handicapped the research design as the initial plan was to track a specific batch through the distribution and retail chain.

Physico-chemical analysis

Results of laboratory analyses are presented in Tables 1a, 1b, 2 and 3. The WHO (2006) guidelines for drinking-water quality and the maximum permitted limits (MPLs) specified in the Nigerian Industrial Standard for packaged water, NIS 345: 2008 (SON, 2008) are placed alongside for comparison.

Acidity in all samples, pH at 7.1 to 8.2 is within the range specified in both guideline and standard. Total dissolved solids (TDS) range from very low at 2.26 mg/l (Brand B) to 89.6 mg/l (Brand “A”). All water is clear, colorless and without particles as reflected by the low values of Turbidity which ranges from 0.45 to 2.55 NTU. Sachet water brand “A” consistently returned the highest levels of all parameters. No coliform bacteria were isolated in all samples. With respect to the major ions as shown in Table 2, all brands show very low ionic content. Calcium ranges from 0.11 to 1.21 mg/l; Magnesium, 0.03 to 0.31 mg/l; Sulphate, 0 to 1.21 mg/l; chloride, 0.5 to 3.1 mg/l. Nitrate ranged from 0.2 to 0.25 mg/l and was detected only in Brand A, one plant that packages water exclusively in sachets. All parameters are well below MPLs specified in the SON drinking water standards and WHO guidelines. When sachet water and bottled water from the same brands are compared, there does not seem to be much disparity in quality. This should be so because at the production plant, it is the same processed

Table 1a. Physical and biological characteristics of sachet water.

Brand	pH	TDS (mg/l)	EC (µs/cm)	Turbidity (NTU)	Fecal coliform (Mpn/100)
Ap	7.4	86.3	172.9	2.55	0.00
Aw	7.9	89.4	178.2	1.06	0.00
Ah	7.5	88.8	177.3	0.84	0.00
Bp	8.0	4.9	9.6	0.73	0.00
Bw	8.2	2.26	4.5	0.53	0.00
Bh	7.3	2.59	5.1	0.68	0.00
Cp	7.9	38.8	77.7	0.59	0.00
Cw	8.0	39.5	79.1	0.39)	0.00
Dh	7.8	39.6	79.6	0.42	0.00
Dp	7.5	65.8	132.1	0.68	0.00
Dw	7.9	67.6	134.4	0.65	0.00
Dh	7.6	69.6	140.0	0.63	0.00
Ep	7.1	12.8	25.7	0.57	0.00
Ew	7.6	12.1	24.2	0.47	0.00
Eh	8.0	16.1	?	0.45	0.00
WHO/SON	6.5-8.5	500	1000	5	10

A, B, C, D, and E: Packaged water brands. p = production plant; w = wholesale outlet; h = street hawkers.

Table 1b. Physical and biological characteristics of bottle water.

Brand	pH	TDS (mg/l)	EC (µs/cm)	Turbidity (NTU)	Fecal coliform (Mpn/100)
A[a]	-	-	-	-	-
Bp	7.2	2.80	5.6	0.29	0.00
Bw	7.3	2.77	5.5	0.39	0.00
Bh	7.4	2.47	4.9	0.47	0.00
Cp	6.6	33.9	67.8	0.33	0.00
Cw	6.6	36.1	72.2	0.31	0.00
Dh	7.2	37.2	74.4	0.36	0.00
Dp	6.9	53.3	106.6	0.50	0.00
Dw	8.2	62.3	124.4	0.58	0.00
Dh	8.0	60.9	121.8	0.52	0.00
Ep	7.1	13.9	27.6	0.46	0.00
Ew	6.6	14.0	28.1	0.48	0.00
Eh	8.1	15.9	31.8	0.50	0.00
WHO/SON[b]	6.5-8.5	500	1000	5	10

Notes: A, B, C, D, and E = Packaged water brands. p = production plant; w = wholesale outlet; h = street hawkers. a: No bottle packaging for Brand A. b: WHO (2006); SON (2008).

water that is used in filling both bottle and sachet. Comparison of same brand sampled from hawkers and wholesale outlets do not show remarkable differences in quality either. This is interesting because it should be noted that samples purchased from these outlets were produced in an earlier batch than those obtained from the production plant, yet the quality indices are similar.

Heavy metal presence in packaged water is shown in Table 3. Cadmium levels in three brands “A”, “C” and “D” range from 0.001 to 0.002 mg/l where the MPL is set at 0.003 mg/l in the WHO guidelines and SON (2007) drinking water standards. This implies that cadmium level in these brands is dangerously close to the MPL. However, the applicable MPL specified in the Nigerian Industrial Standard, NIS 345: 2008 (SON, 2008) is 0.01 mg/l. It is not clear why the same regulatory agency would have different standards for a parameter, especially one that by its own description (SON, 2007) is toxic to the kidneys. Lead and chromium were not detected in some samples but occurred in others and were within the following range: lead, 0. 001 to 0.003 mg/l and chromium, 0.001 to 0.002 mg/l.

Table 2. Chemical characteristics of packaged water (mg/l) produced in Warri.

Brand	Sachet					Bottle				
	Ca	Mg	SO_4	Cl	NO_3	Ca	Mg	SO_4	Cl	NO_3
Ap	0.73	0.21	1.14	3.10	0.25	-	-	-	-	-
Aw	0.61	0.14	1.12	2.81	0.20	-	-	-	-	-
Ah	0.82	0.31	1.10	3.03	0.25	-	-	-	-	-
Bp	0.11	0.09	0.00	0.32	0.00	0.15	0.03	0.0	0.44	0.00
Bw	0.14	0.06	0.00	0.16	0.00	0.15	0.10	0.0	0.11	0.00
Bh	0.12	0.08	0.00	0.31	0.00	0.11	0.08	0.0	0.41	0.00
Cp	0.56	0.21	0.62	0.85	0.00	0.44	0.18	0.32	1.00	0.00
Cw	0.48	0.19	0.42	0.92	0.00	0.21	0.09	0.41	0.87	0.00
Ch	0.61	0.22	0.18	1.92	0.00	0.28	0.05	0.28	2.41	0.00
Dp	0.73	0.31	1.00	1.89	0.00	0.41	0.13	0.49	2.61	0.00
Dw	0.54	0.17	1.21	3.08	0.00	0.66	0.28	1.11	1.05	0.00
Dh	0.58	0.23	0.85	1.44	0.00	0.71	0.32	1.06	1.56	0.00
Ep	1.00	0.09	0.11	0.71	0.00	0.25	0.10	0.13	0.91	0.00
Ew	0.92	0.03	0.15	0.53	0.00	0.15	0.11	0.00	0.45	0.00
Eh	1.21	0.03	0.26	0.82	0.00	0.12	0.08	0.10	0.31	0.00
WHO/SON[a]	-	-/2.0	-/200	-/250	50/45	-	-/2.0	-/200	-/250	50/45

a: WHO (2006); SON (2008). SON (2007) contains following guideline values: $S0_4$ = 100 mg/l; NO_3 = 50 mg/l; Mg = 0.2 mg/l. Other notations as in Table 1a.

Table 3. Selected heavy metal levels in packaged water in Warri (mg/l).

Brand	Sachet				Bottle			
	Fe	Cd	Cr	Pb	Fe	Cd	Cr	Pb
Ap	0.02	0.001	0.002	0.001	-	-	-	-
Aw	0.01	0.001	0.001	0.003	-	-	-	-
Ah	0.03	0.001	0.001	0.001	-	-	-	-
Bp	0.00	0.00	0.000	0.00	0.00	0.00	0.000	0.000
Bw	0.00	0.00	0.000	0.00	0.00	0.00	0.000	0.001
Bh	0.00	0.00	0.000	0.00	0.00	0.00	0.000	0.000
Cp	0.02	0.000	0.001	0.001	0.00	0.001	0.001	0.001
Cw	0.01	0.001	0.001	0.001	0.02	0.000	0.001	0.001
Ch	0.01	0.001	0.001	0.001	0.01	0.000	0.001	0.000
Dp	0.03	0.001	0.001	0.002	0.01	0.001	0.001	0.001
Dw	0.01	0.002	0.001	0.001	0.00	0.001	0.000	0.001
Dh	0.01	0.001	0.001	0.000	0.00	0.000	0.001	0.001
Ep	0.00	0.000	0.000	0.000	0.01	0.000	0.000	0.000
Ew	0.00	0.000	0.000	0.000	0.00	0.000	0.000	0.000
Eh	0.01	0.000	0.000	0.000	0.00	0.000	0.000	0.000
WHO	-	0.003	0.05	0.01	-	0.003	0.05	0.01
SON (2008)	0.05	0.01	0.05	0.05	0.05	0.01	0.05	0.05

Notations as in Table 1a.

DISCUSSION

The results show that packaged water produced and consumed in Warri metropolis as well as in outlying areas is of very low mineral content, indeed so low that some brands could be described as distilled water. The water treatment process while successfully ridding the raw water of coliform bacteria has at the same time effectively stripped it of virtually most of the micronutrients including sodium, potassium, magnesium and calcium that are critical for some essential physiological body functions. These micronutrients are usually ingested with food and supplemented with that contained in drinking water. WHO has closely examined this problem (Cotruvo and Betram, 2009; WHO, 2006) and conclude that both calcium and magnesium are essential to human health. Inadequate intakes of calcium have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Most of these disorders have treatments but no cures. Low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of C-reactive protein and decreased insulin sensitivity. Low magnesium status has been implicated in hypertension, coronary heart disease, type 2 diabetes mellitus and the metabolic syndrome.

Specifically, Kozisek, (2005) cites Lutai (1992) who in a cohort-epidemiological study from the Ust-Ilim region of Russia compared health indicators from a population of 7658 adults, 562 children and 1582 pregnant women and their newborns in two areas supplied with water different in TDS. One of the areas had access to low mineral water (mean values: TDS 134 mg/L, calcium 18.7 mg/L, magnesium 4.9 mg/L, bicarbonates 86.4 mg/L) and the other water higher in minerals (mean values: TDS 385 mg/L, calcium 29.5 mg/L, magnesium 8.3 mg/L, bicarbonates 243.7 mg/L). The population of the area supplied with water lower in minerals showed higher incidence rates of goiter, hypertension and ischemic heart disease, gastric and duodenal ulcers, chronic gastritis, cholecystitis and nephritis. Children also exhibited slower physical development and more growth abnormalities while pregnant women suffered more frequently from edema and anemia. Higher morbity in newborns were also observed. The lowest morbidity was associated with water having calcium levels of 30 to 90 mg/L, magnesium levels of 17 to 35 mg/L, and TDS of about 400 mg/L (for bicarbonate containing waters) which were subsequently recommended as physiologically optimum. Choon Nam Ong (2005) also cites a study from South Africa which suggests that there was a significant protective effect of magnesium intake from drinking water on the risk of cerebrovascular disease.

Aweto and Akpoborie (2011) have recently drawn attention to the occurrence of soft ground water that is low in calcium and magnesium in the upper layers of the Benin Formation aquifer that underlies the Sombreiro-associated with its use for domestic and drinking water purposes as is the case in much of the Plain that under-lies more than half of Delta State, Nigeria. The problem is exacerbated when consumer’s dietary habits are deficient in foods, especially milk and other beverages, which are traditional sources of these micronutrients. An additional complication it appears is that drinking water of TDS that is lower than 100 mg/l has associated problems. Kozisek (2006) summarizes reports that were prepared for the WHO (1980) which showed in effect that low TDS water consumption is linked in humans with increased diuresis (almost by 20%, on average), decreased serum potassium concentration and increases the elimination of sodium, potassium, chloride, calcium and magnesium ions from the human body. These results are supported by independent studies conducted by the German Nutritional Society, and as a result of which the Society published a warning against drinking demineralized water (DgfE, 1993). Another crucial conclusion from the same review is that when used for cooking, soft water with low TDS was found to cause substantial losses of all essential elements from food (vegetables, meat, cereals). Such losses may reach up to 60% for magnesium and calcium or even more for some other microelements (e.g., copper 66%, manganese 70%, cobalt 86%). Since most nutrients are ingested with food, the use of low-mineral water for cooking and processing food may cause a marked deficiency in total intake of some essential elements that is much higher than expected with the use of such water for drinking only. This conclusion has crucial implications for the health of consumers that use ground water obtained from shallow boreholes and dug wells for cooking in Warri and other areas with similar groundwater conditions of combined soft water and low TDS.

With respect to the heavy metals, so described because their density is at least five times that of water, most of the samples show the presence cadmium, leadand chromium albeit at levels that are well below MPLs. Their presence even at low levels in drinking water has serious health implications because of their high toxicity, carcinogenicity and mutagenicity even at low concen-trations (Ifegwu and Anyakora, 2012). Only Orisakwe et al. (2006) appears to have screened and detected their presence in sachet water in all the previous studies cited herein and they found that lead, chromium and copper were above specified MPLs in the sachet water samples they tested from various parts of eastern Nigeria.

In Warri, their presence in packaged water is possibly related to the source water that is treated before packaging. Shallow ground water in Warri and indeed the upper part of the Benin Formation aquifer that under-lies the area has been reported from several studies to contain elevated levels of cadmium, chromium and lead at least one order of magnitude higher than the specified MPL’s (Aweto and Akpoborie, 2011; Akpoborie, 2011;Akpoborie et al., 2000; Nduka and Orisakwe, 2007; 2009; Ifeagu and Anyakora, 2012). Egboh et al. (2000) have also shown that sediment from open storm water drainage gutters in Warri contain elevated levels of lead and cadmium of up to 1.4 and 0.6 mg/kg respectively and which they suggest is derived from vehicular traffic and industrial emissions. These drains are a constant source of direct recharge to the unconfined Benin Formation Aquifer as well as to nearby creeks and water courses in Warri that are also contaminated (Emonyan et al., 2007). Screening of ground water and surface water sources at

Ogulagha, Obotobo II, Odimodi and Burutu, some of the communities that receive packaged water from Warri has also revealed elevated levels of these heavy metals (Richdrill, 2009) that is well above the guideline MPLs.

The implication of this is that packaged water in Warri requires close surveillance and monitoring for heavy metals. Routine and very irregular monitoring of drinking water sources by the Delta State Ministry of Water Resources Development does not include the heavy metals in the list of parameters that are screened (Akpoborie et al., 2009). An indication that monitoring of the packaged water industry is not taking place in Warri either has been shown by the fact that even the rudimentary but mandatory product labeling specifications are routinely ignored by all producers. However, an interesting finding that became apparent in the process of sample collection was that the management of every production plant visited expressed a desire to be informed about the results of our findings and appeared to genuinely want to produce water that was safe for drinking in all respects.

The general perception in Warri and possibly all over the country is that packaged water is the safest drinking water source. The results presented here tend to indicate that this confidence may well be misplaced. Furthermore, the production plant that uses the less sophisticated and smaller system to produce only sachet water turns out to be the one brand that has the highest TDS as well as the highest levels of calcium and magnesium. Though these levels are low, sachet water is the more affordable packaging that is favoured by the poor and less affluent that may have the dietary challenges that would trigger calcium and/or magnesium deficiency. The WHO recommends that demineralized water be fortified with essential minerals after processing before distribution to the public, and that nutritional information be clearly displayed on all packaging, both issues that are ignored by producers as well as the regulatory agencies.

Conclusion

All the packaged water samples collected from production plants, distributors and hawkers in Warri appears to be of good quality and meets the SON and WHO specifications for drinking water quality. This conclusion Warri Deltaic Plain and the increased health risks is qualified because drinking water guidelines and standards while setting upper limits for possible ions in drinking water omit to set lower limits. Unfortunately, emerging research is indicating that long term dependence on demineralized water of low TDS that is also low in certain nutrients that include calcium and magnesium could lead to a condition of deficiencies in these minerals especially in the presence of poor dietary habits. These deficiencies have the potential of causing among others and in the case of magnesium and calcium deficiency, higher incidence rates of goiter, hypertension, ischemic heart disease, gastric and duodenal ulcers, chronic gastritis, cholecystitis and nephritis. All packaged water sampled in Warri falls in the category of low TDS and low micronutrients.

While some brands appear to be of better quality than others in terms of lower ionic content, all brands were coliform free. Sachet water and bottled water produced by the same plants invariably have the same quality and which quality is retained down the distribution chain. Sachet water produced by the one production plant which packages water only in sachets (Brand A) consistently showed the highest total dissolved solids when compared to the others. The same sachet water brand also showed higher levels of lead, cadmium and chromium although at levels that are below the MPLs specified by the WHO and the regulatory agencies. Bottled and sachet water is consistently better in quality with respect to the absence of coliform than water available from different sources in Warri and the outlying wetland areas for drinking purposes. Because packaged water is easily the most important safe drinking water source in Warri and environs consistent regulatory monitoring of the industry and its products is recommended. In addition, cohort-epidemiological studies are recommended in the area in order to establish the presence or absence of the health related problems that have been linked elsewhere with prolonged ingestion of demineralized water of low TDS and which is also virtually devoid of calcium and magnesium. Study results would guide water supply policy and regulatory action.

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