academicJournals

Vol. 5(3), pp. 134-140, March, 2013
DOI 10.5897/IJWREE2013.0384
ISSN 1991-637x © 2013 Academic Journals
http://www.academicjournals.org/IJWREE

International Journal of Water Resources and Environmental Engineering

Full Length Research Paper

Physico-chemical and *Escherichia coli* assessment of selected sachet water produced in some areas of Minna, Niger State, Nigeria

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Accepted 20 February, 2013

Access to good quality drinking water in Minna and, indeed, other parts of Niger State is one of the biggest challenges to many households which have, for years, depended on other sources of water to augment the erratic supply made by the government. In an effort to ensure adequate supply, packaged water has been introduced to provide safe, hygienic and affordable drinking water. However, trends have implicated some packaged water as agents of disease transmission. In this work, the physicochemical and coliform analyses of selected packaged water, otherwise called "pure water" were carried out. Ten brands were collected from the packaging factories (5 samples per brand) and were analysed weekly for four weeks. Results obtained were compared with WHO and EPA standards for drinking and recreational water. Their pH values, except for Sabo Best (6.26 ± 0.02), were within the stated WHO/EPA standards (6.50 - 8.50). The coliform levels of FUTMin (75.00 ± 2.00), Happy Days (75.00 ± 2.00) and Carry More (23.33 ± 0.33), based on the most probable number (MPN), were unfit for potability since they could also contain other microorganisms implicated in gastro-intestinal water borne diseases. The respective 1.63 ± 0.10 and 1.54 ± 0.10 mg/dm^3 for Evershine and Supreme waters were above the 0.3 mg/dm^3 iron standard just as the respective copper and nitrate values of 1.19 ± 0.14, 1.27 ± 0.10, 1.48 ± 0.10 and 86.81 ± 0.62, 124.47 ± 1.36, 141.70 ± 0.00 mg/dm^3 for Golden Age, Supreme and Sabo Best were higher than the respective 1 and 50 mg/dm^3 standards for copper and nitrates. All other parameters were within the EPA and WHO values.

Key words: Packaged water, coliform, *Escherichia coli*, most probable number (MPN), potability, gastro-intestinal.

INTRODUCTION

Good quality water is odourless, colourless, practically tasteless and free from faecal pollution (Ezeugwunne et al., 2009). It is one of man's priceless resources but generally taken for granted until its use is threatened by reduced availability or quality. Environmentally, water is so important that its pollution becomes a serious problem since it affects the lives of many people throughout the world.

Pollutants in natural waters could be microbial or chemical in origin. The chemical pollutants are the organic and inorganic substances whose levels continue to rise due to increased discharge of chemical fertilizers,

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particles and pesticides from agricultural activities. The microbial pollutants, on the other hand, include coliform bacteria which are indicator organisms mostly used in bacterial water characterization. They are easily found in animal faeces, soils and raw surface waters (Ezeugwunne et al., 2009). Polluted water harms human, animal and plant lives resulting in high mortality rate especially if their sulphate-bicarbonate ratios are high causing cerebral haemorrhage, cardiovascular and other chronic diseases (WHO, 2004a; Kwakye-Nuako et al., 2007; WHO, 2008).

In the world, about 1.1 billion people do not have access to improved water supply while 2.4 billion do not have access to improved sanitation facility. In addition, over 2 million people, mostly children of less than 5 years age mainly from developing countries with poor implementation of sustainable water programmes, die every year of diarrhoeal diseases (WHO, 2011). Therefore, in order to accelerate development while enhancing environmental sustainability, it is opined that the proportion of people without access to sustainable safe drinking water and basic sanitation in the world should be reduced to half by the year 2015 (Teshamulwa, 2007). This is achievable only when water is supplied in its wholesome form from various sources like well, boreholes, springs, pipes, rivers and even the packaging factories.

In Nigeria, all governments claim that it is their duty to provide potable water to their citizens through government owned public water utilities. However, with increase in the country's population, the supply of water by these utilities is grossly inadequate both qualitatively and quantitatively. As a result, the emergence and proliferation of private water enterprises operating side by side government owned utilities become inevitable. In most cases, the supply of these enterprises reaches the consumers through various water vendors including the packaged water sellers.

Ideally, packaged water is meant to provide safe, hygienic and affordable instant drinking water to people thus bridging the gaps in water provision in most parts that lack access to adequate pipe borne water and providing a profitable business in Nigeria. It is also meant to improve the livelihoods of the vendors through self employment and reduce cholera disease of the people thus making its demand in many parts of the country insatiable. However, the quality of most packaged waters cannot be vouched for. Hence, laudable as their introduction into our markets may be, current trends suggest that some of them are a source of enteric pathogens (WHO/UNICEF, 2000; Teshamulwa, 2007). Consequently, these commodities are no longer wholesome and they prevent a great proportion of people from getting safe drinking water. This, in effect, makes the realization of the WHO's MDGs goal of providing pure and wholesome water by the year 2015 to about 88% of the people of the world a difficult task.

In Nigeria, it is the duty of the government to protect the health of her citizens and the National Agency for Food and Drug Administration and Control (NAFDAC) is the agency saddled with this responsibility. It licenses the water vending firms deemed fit to produce and sell water for public consumption. Although there are conflicting reports, it is on record that less than thirty percent of Nigerians have access to safe drinking water with the rest obtaining their water from contaminated sources (Sule, 2009; Tina, 2010; Tokumbo, 2010; Oyishi, 2011; Ameto, 2011; Ndagi, 2011; Ameto, 2012). The healthy states of these waters can be established through their physico-chemical and bacteriological characterization. Most of the packaged waters being produced in Minna have not been officially characterized. Therefore, this work examined the selected samples in order that the results obtained from there serve as a basis for the establishment of their portability or otherwise or as a basis for further work.

MATERIALS AND METHODS

Selection of sites for sampling

Packaged water samples were randomly purchased from ten different production companies (5 samples per brand) in Minna municipality and were appropriately taken to the laboratory for analysis. The pH values of the samples were all taken immediately they were conveyed to the laboratory.

Sampling procedure

All the glassware employed throughout the analyses were thoroughly washed with chromic acid and those with greasy substances were soaked in the acid overnight and thereafter thoroughly rinsed with distilled water. The samples were collected in 10 L 'unbreakable' plastic cooler in order to prevent them from breaking. Sampling was done between 9.00 am and 12.00 noon (the period within which changes in the physical and chemical parameters of the samples were thought to be minimal) (STME, 1997). Also, the colour of the samples was noted immediately after sampling.

Parameters determination

The pH and electrical conductivity of the samples were determined according to method described by STME (1997) while the chemical oxygen demand (COD) was determined using the methods described by EPA (2002) and FSB (2006). The biological oxygen demand (BOD), calcium and magnesium contents of the samples were analysed according to the methods described by Ademoroti (1996).

Bacteriological analysis

The bacteriological properties of the samples were determined as described by Bezuidenhout et al. (2002). The Most Probable Number-multiple tube technique was used for coliform count using Nutrient agar (NA) while *Salmonella-Shigella* agar, MacConkey agar (MCA) and Eiosine Methylene agar were used to determine *Staphylococcus aureus*, *Salmonella* spp and *Shigella* spp respectively. All plates were incubated at 37°C for 24 h. Colonies were confirmed by gram staining and biochemical reactions on each plate were given positive or negative scores. Isolates were confirmed by the conventional biochemical tests given by SCA (2002). At the end of the incubation period the colonies were counted and used as the results (SMEWW, 1999).

Trace elements analysis

The trace elements: zinc, iron, chromium and copper were determined spectrophotometrically using PyeUnicam atomic absorption spectrophotometer model PU 9100 series. Various standard solutions of the minerals were prepared and serially diluted according to the methods described by AOAC (2000). While zinc and iron were determined at 213.9 and 348.3 nm respectively, copper and chromium were analysed at 324.8 and 357.9 nm respectively (Peter and Bruce, 2001).

Determination of sulphates

The sulphates were gravimetrically quantified while the nitrates were analysed spectrophometrically at 420 nm as described by Ademoroti (1996). The chlorides were determined using the Mohr's method while the bicarbonates were quantified as described by Ademoroti (1996).

Statistical analysis

The data obtained were generated in triplicates and analyzed statistically using one way analysis of variance (ANOVA) with Duncan Multiple Range test at 95% confidence ($p \leq 0.05$).

RESULTS AND DISCUSSION

As shown, Table 1 described the coliform and physical parameters of the selected samples. From the result, none of the samples had any objectionable appearance, odour, colour or taste. While their pH values ranged from 6.26 ± 0.02 (Sabo Best) to 8.70 ± 0.02 (Ghalam) which implied that some of the samples required treatments that would adjust their pH values to the acceptable levels (AMC, 2006). Most of these values were generally in agreement with the standard pH range of 6.5 to 8.5 assigned by EPA (2002). However, Sabo best had a slightly lower pH thus making it possible for easy dissolution of metals most especially the heavy metals. Thus the pH of this water has to be adjusted in order to prevent it from being a possible health danger for portability. The electrical conductivity values of these samples which gave the measures of the ionized substances in the samples at a particular temperature (Akoto and Adiyiah, 2007) ranged from 110.00 ± 0.05 (Harka) to 160.00 ± 0.01 µScm^{-1} (Evershine) and these were all below the 2500 µScm^{-1} given for fresh waters by EPA (2011a) and WHO (2008).Thus implying that these samples probably did not contain much ionized metals especially those that could pose serious health hazards.

The chemical oxygen demand (COD) of the samples which gave the empirical values of their oxygen requirements for the oxidation of their organic matter with strong chemical oxidants ranged from 104.00 ± 2.00 to 206.53 ± 3.20 mg/dm^3 while the biochemical oxygen demand (BOD) which gave the relative oxygen requirements of their bacteria for the degradation of organic materials ranged from 45.76 ± 1.33 to 91.02 ± 1.31 mg/dm^3. These values were higher than the respective 10 and 5 mg/dm^3 reported as the maximum COD and BOD values of potable waters by Vinod (2008). These, thus indicated that there were probably both organic and inorganic pollutants in the samples suggesting that the efficiency of their treatment processes before production was low (FSB, 2006).

The maximum acceptable concentration (MAC) of pathogenic bacteria, mostly marked by the presence of faecal coliform or *Escherichia coli* in potable water, is none detectable coliforms per 100 cm^3 (EPA, 2003) although in villages and small towns, 5 CFU/100 cm^3 maximum counts are reported to be allowed for 90% of samples analysed for a year (Ezeugwunne et al., 2009). The coliform values of the samples in this study showed that some of the water samples were not fit for consumption as they had high coliform counts of 75.00 ± 2.00, 23.33 ± 0.33 and 75.00 ± 2.00 respectively for FUTMin, Carry more and Happy Days samples. The bacteria isolated from the samples in this work included *E. coli*, *S. aureus* and *Salmonella typhi*. These pathogens were probably transferred into the samples from the environment especially through sewage and other humic matters or sources related to unhygienic conditions (EPA, 2002; Ezeugwunne et al., 2009). The presence of these microorganisms in the samples was indicative of the presence of high organic and dissolved salts which could have come from human and animal wastes. Additional sources like seepage or discharge from septic tanks, sewage and natural soil that leaked into the pipes supplying the entrepreneurs could also be responsible.

A number of dissolved salts of certain metals like calcium and magnesium react with soap molecules in water forming scum thus preventing the soap from foaming easily.

Therefore, water hardness is best expressed in terms of the total concentration of calcium and magnesium ions when presented as the calcium carbonate content of the sample (AMC, 2006). The total magnesium contents of 16.81 ± 0.16 and 16.13 ± 0.89 mg/dm^3 which were statistically close were recorded for Sabo Best and Golden Age waters respectively and these were the highest magnesium values for the samples. The lowest value of 11.20 ± 1.00 was recorded for Zagbayi and FUTMin samples respectively. On the other hand, the calcium contents of the samples ranged from 0.30 ± 0.10 (Carry More) to 1.41 ± 0.07 mg/dm^3 (Golden Age) and all these were below the WHO permissible value for this metal. If the hardness is assumed to be mainly due to the

Table 1. The coliform and physico-chemical parameters of the selected packaged water samples.

Parameter	Samples										WHO/EPA Value
	Zagbayi	Evershine	FUTMin	Carry More	Harka	Ghalam	Golden Age	Supreme	Happy Days	Sabo Best	
pH	8.07 ± 0.05^{d}	8.58 ± 0.13^{gh}	8.46 ± 0.10^{fg}	8.22 ± 0.10^{de}	7.23 ± 0.13^{b}	8.70 ± 0.02^{h}	8.33 ± 0.20^{ef}	7.70 ± 0.09^{c}	8.21 ± 0.10^{de}	6.26 ± 0.02^{a}	6.50 - 8.50
Conductivity (µS/cm)	130.00 ± 0.00^{ab}	160.00 ± 0.01^{c}	130.00 ± 0.00^{ab}	140.00 ± 0.10^{b}	110.00 ± 0.05^{a}	140.03 ± 0.20^{b}	133.30 ± 0.05^{b}	113.33 ± 0.05^{a}	130.00 ± 0.10^{a}	140.00 ± 0.10^{b}	2500
COD (mg/dm^3)	104.00 ± 2.00^{a}	150.73 ± 1.52^{f}	112.33 ± 0.58^{b}	206.53 ± 3.20^{g}	113.60 ± 2.65^{b}	116.17 ± 1.52^{b}	128.33 ± 2.14^{c}	142.53 ± 2.20^{e}	126.20 ± 1.71^{c}	136.53 ± 5.51^{d}	< 10*
BOD (mg/dm^3)	45.76 ± 1.33^{a}	91.02 ± 1.31^{f}	49.95 ± 1.94^{b}	62.66 ± 0.98^{d}	56.37 ± 0.97^{c}	52.51 ± 1.39^{bc}	61.32 ± 1.10^{d}	55.67 ± 1.02^{c}	51.38 ± 0.99^{b}	66.65 ± 0.57^{e}	< 5*
Coliform (CFU/100 cm^3)	ND	ND	75.00 ± 2.00^{b}	23.33 ± 0.33^{a}	ND	ND	ND	ND	75.00 ± 2.00^{b}	ND	0
Calcium (mg/dm^3)	0.98 ± 0.09^{b}	1.43 ± 0.17^{d}	1.14 ± 0.06^{bc}	0.30 ± 0.10^{a}	0.12 ± 0.10^{b}	1.42 ± 0.04^{d}	1.41 ± 0.07^{d}	1.24 ± 0.10^{cd}	1.22 ± 0.20^{cd}	0.34 ± 0.10^{a}	75/65
Magnesium (mg/dm^3)	11.20 ± 1.00^{a}	12.80 ± 1.00^{abc}	11.20 ± 1.00^{a}	13.57 ± 0.32^{bc}	11.93 ± 1.10^{ab}	14.51 ± 2.80^{cd}	16.13 ± 0.89^{de}	12.46 ± 0.30^{abc}	12.18 ± 0.22^{ab}	16.81 ± 0.16^{e}	50/50
Iron (mg/dm^3)	0.24 ± 0.01^{a}	1.63 ± 0.10^{e}	0.35 ± 0.10^{ab}	0.43 ± 0.02^{b}	0.37 ± 0.05^{b}	0.61 ± 0.11^{c}	0.96 ± 0.03^{d}	1.54 ± 0.10^{e}	0.64 ± 0.04^{c}	0.34 ± 0.02^{a}	0.3/0.3
Zinc (mg/dm^3)	0.56 ± 0.11^{c}	2.41 ± 0.10^{e}	0.35 ± 0.10^{ab}	0.48 ± 0.04^{bc}	0.36 ± 0.02^{ab}	0.61 ± 0.10^{c}	0.29 ± 0.03^{a}	0.74 ± 0.02^{d}	0.28 ± 0.01^{a}	0.85 ± 0.10^{d}	3
Chromium (mg/dm^3)	ND	0.03 ± 0.01^{b}	ND	0.01 ± 0.00^{a}	0.01 ± 0.00^{a}	0.01 ± 0.00^{a}	0.01 ± 0.00^{a}	0.04 ± 0.01^{b}	0.03 ± 0.01^{b}	ND	0.05
Copper (mg/dm^3)	ND	ND	0.04 ± 0.01^{a}	ND	0.29 ± 0.05^{b}	0.48 ± 0.09^{c}	1.19 ± 0.14^{e}	1.27 ± 0.10^{e}	0.78 ± 0.11^{d}	1.48 ± 0.10^{f}	1
Sulphate (mg/dm^3)	32.00 ± 1.00^{a}	34.25 ± 0.99^{b}	80.65 ± 1.14^{i}	40.12 ± 1.06^{c}	32.38 ± 0.34^{a}	70.55 ± 0.50^{h}	60.85 ± 0.52^{f}	42.23 ± 0.17^{d}	53.43 ± 0.77^{e}	63.50 ± 1.34^{g}	500
Nitrate (mg/dm^3)	23.30 ± 1.10^{f}	55.83 ± 1.00^{g}	16.83 ± 1.76^{d}	12.90 ± 0.02^{c}	4.40 ± 0.30^{b}	40.47 ± 0.76^{f}	86.81 ± 0.62^{h}	124.47 ± 1.36^{i}	1.50 ± 0.30^{a}	141.70 ± 0.00^{j}	50
Chloride (mg/dm^3)	18.43 ± 0.99^{cd}	15.62 ± 1.01^{b}	19.86 ± 1.02^{d}	17.097 ± 1.02^{bc}	12.76 ± 0.90^{a}	15.62 ± 0.99^{b}	17.22 ± 0.72^{bc}	17.59 ± 0.74^{c}	17.12 ± 0.15^{bc}	15.63 ± 0.96^{b}	200/250
Alkalinity (mg/dm^3)	23.11 ± 0.11^{d}	35.76 ± 0.23^{g}	40.56 ± 0.33^{h}	16.93 ± 0.12^{b}	22.34 ± 0.35^{d}	69.58 ± 0.35^{i}	14.88 ± 0.32^{a}	18.78 ± 0.06^{c}	30.26 ± 0.74^{f}	27.32 ± 0.23^{e}	2500 μScm^{-1}

All values are means ± standard deviations of triplicate determinations and values bearing the same superscript in the same row are statistically not different at $p \geq 0.05$. *These values were reported by Vinod (2008); BOO = Biological Oxygen Demand; COD = Chemical Oxygen Demand; ND = Not Detected.

concentrations of calcium and magnesium salts, all the samples analysed were "soft" according to AMC's classification (2006). These samples could, therefore, be good for domestic purposes although they can easily dissolve such dangerous metals as lead, cadmium and chromium (Kendall, 2010).

Zinc is an essential element needed by the body and is commonly found in nutritional supplements and all foods. However, when taken in relatively large quantity over a period of time, zinc affects human health (PBC, 1998). Although drinking-water usually makes a negligible contribution to zinc intake, corrosion of pipes and fittings can make contributions from tap water to be up to 10% of the daily intake (WHO, 2003a; ATSDR, 2011). The zinc contents of the samples ranged from 0.28 ± 0.01 (Happy Days) to 2.41 ± 0.10 $mgdm^{-3}$ (Evershine) and these were below the maximum 3.0 $mgdm^{-3}$ value given by EPA and WHO for this metal in potable waters. Thus these samples were not expected to have any undesirable astringent taste or form opalescent and greasy film especially when boiled (WHO, 2003a).

Chromium exists in oxidation states of +2 to +6 but is almost always in the trivalent state when in solution or most of its salts. The distribution of its compounds in the +3 and +6 states depends on the redox potential, pH, presence of oxidizing or reducing agents, kinetics of the redox reactions, formation of chromium (III) complexes or insoluble chromium (III) salts and the total chromium concentration. In water, chromium (III) which is adsorbed at relatively high pH values exists as the hydroxides and complexes although its concentration depends on the type of water (WHO, 2003a). The chromium contents of the water samples in this study were from 0.01 ± 0.00 to 0.04 ± 0.01 mg/dm^3 (Supreme water) although this metal was not detected in three water samples (Zagbayi, FUTMin and Sabo Best waters). These levels were also below the highest limit set by either WHO or EPA (2011d).

Copper is a transition metal that is stable in its metallic state and forms monovalent (Cu^{+}) and divalent (Cu^{2+}) ions. It is an essential nutrient, required by the body in minute quantities. Dissolved copper sometimes imparts a light blueor blue-green colour and an unpleasant metallic, bitter taste to drinking water (ATSDR, 2002). It is a potential health hazard that causes various health problems when people are exposed to it at levels above the permissible value. Short periods of exposure can cause gastrointestinal disturbance, including nausea and vomiting while use of water whose copper level exceeds the maximum value over many years causes liver or kidney damage (EPA, 2011b; WHO, 2004b). Three water samples (Zagbayi, Evershine and Carry More) did not contain detectable copper in this study but the range of values obtained for the other samples was from 0.04 ± 0.01 (FUTMin) to 1.48 ± 0.10 (Sabo Best) mg/dm^3. As pointed out by MDH (2011), if Golden Age, Sabo Best and Supreme packaged waters were consumed for a number of years without checking their copper levels, they could cause some health problems. These samples probably had these copper levels due to the corrosive nature of their treatment systems which when kept under control, could minimize the level of this metal (EPA, 2011b).

The iron contents of the water samples used in this study, with the exception of Zagbayi water, were not in agreement with the EPA standard of 0.3 mg/cm^3 (EPA, 2002). This metal is not however, considered hazardous to health but in fact considered essential for good health because of its role on the transportation of oxygen in the blood. Thus the recommended limit of 0.3 mg/dm^3 for iron in water is based on taste and appearance rather than on any detrimental health effect. However, this can be used as a tool for the evaluation of water quality. For instance, when its level in water exceeds the 0.3 mg/dm^3 limit, red, brown, or yellow staining of laundry, glassware, dishes and household fixtures such as bathtubs and sinks occur. The water may also have a metallic taste and an offensive odour. Also, water system piping and fixtures can be clogged (DNR, 2003).

Chloride, in the form of sodium (NaCl), potassium (KCl) or calcium ($CaCl_2$) is one of the major inorganic anions in fresh and waste-water but in potable water, the salty taste produced by it varies and depends upon the chemical composition of the water. While some waters containing 250 mg chloride in a litre may have a detectable salty taste if the cation is 'sodium, others may not have if their dominant cations are calcium and magnesium. High chloride content may harm metallic pipes and structures as well as growing plants, cause hypertension and increased concentration of other metals in water (WHO, 2003). The chloride content or limit recommended by EPA is 250 mg/L and none of the samples analysed in this study had higher values than this limit.

Sulphates occur naturally in drinking water and health concerns regarding its level have been linked with diarrhoea due to its laxative effects especially when there is a change from drinking water with low to drinking water with high sulphate concentrations (EPA, 2011c). In drinking water, this ion has a secondary maximum contaminant level (SMCL) of 250 mg/dm^3 which is a value provided as a guideline for states and public water works (WHO, 2004a). The sulphate contents of the water samples in this study ranged from 32.00 ± 1.00 (Zagbayi) to 80.65 ± 1.14 (FUTMin) mg/dm^3. None of the samples had levels above the WHO limit for this ion.

Nitrates are readily converted to nitrites and vice versa and are present naturally in soils, water and foods. They get into water through chemical fertilizers, soil, foods, glass and explosives (ANL, 2005; WHO, 2007). These compounds are very soluble in water and can enter surface water when it rains or groundwater through leaching. Nitrate is a normal component of the human diet and it is relatively nontoxic but when swallowed, it is converted to nitrite which reacts with haemoglobin in the blood causing methemoglobin that could result in coma and death especially in infants. It also causes diuresis and haemorrhage of the spleen. Excess of it in water is used as an indicator of poor water quality (ANL, 2005).

The nitrate contents of the samples ranged from 1.50 ± 0.30 to 141.70 ± 0.00 mg/dm^3. Evershine, Golden Age and Supreme waters had higher nitrates than the 50 mg/dm^3 limit set by WHO (2004a). Thus their sources might have been contaminated by refuse dump runoff or human and animal wastes that might have leaked into the main pipes supplying the entrepreneurs.

SUGGESTION

It is obvious that the main aim of setting up potable water venture is, in addition to solving the perennial water problems of a community, to make profit. It is also generally evident that water borne diseases are due to improper disposal of refuse, contamination by sewage, surface runoff and other human activities. Therefore any of such a business outfit must be made to satisfy all the conditions required for portability and recreational purposes. To satisfy this, water vendors in Minna should be compelled to use protected ground water sources like sealed wells and boreholes in order to minimize contamination by faecal bacteria. Furthermore, producers of samples found not to have met the international standards for some parameters in this study should be compelled to properly treat their samples for conformity while those found fit should be routinely analysed. Finally, programmes should be organized to educate packaged water producers and the general populace on the proper disposal of refuse, treatment of sewage and the general need to purify water for drinking.

Conclusion

Since some samples in this study (FUTMin, Happy Days and Carry More) had coliform levels far above zero (0) or even five (5), they were unfit for portability because they could also contain other microorganisms implicated in gastro-intestinal water borne diseases. Also, the respective iron values for Evershine and Supreme waters were above the 0.3 mg/dm^3 standard limit. Thus these samples could stain glassware, dishes and some household utensils. They may also clog the water system piping and fixtures in the manufacturing companies of these packaged waters. They could also have metallic taste and offensive odour especially if kept for a long time. Furthermore, samples with high copper levels could have unpleasant metallic, bitter taste as observed by ATSDR (2002). These samples can also cause various health problems liver or kidney damage while those with high nitrate levels could result in coma and death especially in infants.

ACKNOWLEDGEMENTS

We are grateful to the sponsors of Innovators of Tomorrow, the Science and Technology Education Post Basic (STEP-B) for sponsoring this research. We also express our gratitude to the laboratory technologists of the departments of chemistry, microbiology and biochemistry, Federal University of Technology, Minna, Nigeria.

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