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A Review on Packaged Drinking Water, Quality Regulations and Public Health: Exploring Potability and Safety Gap Implications for Public Health in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors UUE, EDA, NNE, OFE and BOO designed the study. Author UUE wrote the protocol and the first draft of the manuscript. Authors UUE and BOO managed the review process and scale-up of the study. Authors UUE, EDA and BOO managed the literature searches, updates and final write up. All authors read and approved the final manuscript.

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ABSTRACT

Background: Many Nigerians in towns and villages depend on packaged water for their daily water need. Contaminated water is a major source of distribution of pathogens. The increasing prevalence of water borne diseases has created a need to explore the state of packaged water meant for public consumption and underline the gaps for interventions.
Objective: This study discussed the state of packaged water in Nigeria to generate evidence and information for interventions, planning, and policy towards the provision of potable drinking water for the public.

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Methods: The study was a narrative overview of relevant literature from verifiable sources published in the English Language and lasted from January 2015 to April 2017. Literature search utilised PubMed, Medline, Embase and Google Scholar to identify studies that explored the quality of packaged water. The search terms included potable water, packaged water, quality, regulations, pathogens and Nigeria, used individually and in series where necessary, with relevant link words and truncations. We used cross-referencing to identify additional articles. Only articles published in the English Language with standard methods were included in the study.
Results: Over 4.6% of Nigerians consume water packaged in sachets or bottles. A bacteriological survey of packaged water in western Nigeria showed contamination with *Salmonella species* and/or *Escherichia coli* in 94 out of 108 samples. Out of 11 sachet and 6 bottled water brands randomly selected from commercial sellers during a study in Nsukka, south-east Nigeria, two bottled water brands met the zero criterion for presence of coliforms as recommended by the World Health Organization (WHO). Other brands of sachet and bottled water had varying levels of total coliforms, with the highest levels of 14/ml and 29/ml seen in 1 bottled and 1 sachet brand.
Conclusion: Packaged drinking water for commercial consumption in Nigeria has good physical properties but not totally free from contaminants and pathogens.

Keywords: Potable water; packaged water; quality; regulations; public health; Nigeria.

1. INTRODUCTION

Potable drinking water is one of the basic necessities for human life, vital to its sustenance and required for positive health and well-being. Water is the most abundant constituent of the human body, required for digestion, absorption, transportation, nutrient dissolution, elimination of waste products and thermoregulation [1]. In humans, the total body water varies with age, gender and degree of obesity, decreasing as one grows older or increases in weight. The elderly and women tend to have a higher amount of body fat than their respective counterparts do. Therefore, their total body water is less [2]. The total body water for a term infant is 75% of its birth weight; for an adult male and female, it is 60% and 50% respectively, increasing by about 11-14% during pregnancy [1-3].

Water is abundant in nature, existing in solid, liquid, and gaseous forms. Of the 3% of water in nature available as freshwater, most occurs as snow and ice, leaving less than 25% available as ground and surface water [4]. Although surface water is readily accessible from streams, lakes and rivers, it is very often polluted from diverse sources, human and non-human. Ground water is generally of good quality, as it undergoes filtration during its passage through several layers of soil although it usually has to be tapped by various means such as boreholes, springs, and deep wells. To address the purity concerns of water from these diverse sources, it is often necessary to subject raw water found in nature to various purification processes to make it safe for human consumption. Safe or potable drinking water implies drinking water with microbial, chemical, and physical characteristics that meet the World Health Organization (WHO) guidelines or national standards on drinking water quality [5]. Globally, the consumption of packaged water has increased steadily over the years. Nigeria and several other countries in Western Africa have also witnessed a surge in consumption of drinking water from this source. As many as 4.6 percent of the population of Nigeria consume water packaged in sachets or bottles; the majority of which are found in the urban than rural areas [6]. In Nigeria, these packages are available in sachet-also known as 'pure water'- and bottle forms. Consequent to the increase in consumption, concerns about the quality of these drinking water sources have arisen. This study discussed the state of packaged water in Nigeria to generate evidence and information for other studies, interventions, planning, and policy towards the provision of portable drinking water for the public.

2. METHODS

The study was a narrative overview of relevant literature from verifiable sources written in the English Language. The study lasted from January 2015 to April 2017. Literature search utilised PubMed, Medline, Embase, and Google Scholar for studies that explored the quality of packaged water. The search terms included potable water, packaged water, sachet water, bottled water, quality, regulations, pathogens, and Nigeria, used individually and in series where necessary with relevant link words and truncations. We used cross-referencing to

identify additional articles. Out of 65 articles obtained for the study, 32 met the inclusion criteria for the study.

3. RESULTS AND DISCUSSION

3.1 Public Health Importance of Contaminated Drinking Water in Nigeria

The United Nations (UN) recognizes safe drinking water as a human right, essential for the enjoyment of all other human rights [7]. Its importance underscored the earmarking of two separate decades, 1981-1990 and 2005- 2015, for drinking water and its related issues [7,8]. Consumption of safe water is necessary in order to prevent disease, promote health, and ensure sustainable development. Together with adequate sanitation and good nutrition, provision of safe drinking water is necessary for the achievement of the health-related Sustainable Development Goal 3 (SDG 3) [9,10]. Drinking water may be contaminated by microbial and chemical impurities. Diseases linked to microbial and chemical contamination of drinking water supplies are major public health issues. WHO estimates that 842,000 people lost their lives from causes related to water, sanitation, and hygiene in 2012. Diarrheal diseases killed an estimated 1.5 million people in the same year [11-13]. This is especially true for under-five children in whom the burden of diarrheal diseases is greater than the combined burden of Acquired Immune Deficiency Syndrome, measles and malaria [14]. In 2012, 622,000 under-five children died from diarrheal related causes; inadequate water, sanitation and hygiene (WASH) accounted for 361,000 of these deaths, about 1000 child deaths per day [15]. Cholera is a recurring disease in Nigeria with recent outbreaks leaving scores of people dead in several states in the country [16]. The high prevalence of these diseases is traceable to drinking unsafe water, and poor hygiene. A study carried out in Anambra State south-east Nigeria observed that there were 101 maternal admissions into health care facilities in two communities in Nnewi between October 2010 and April 2011, due to water-related diseases [17]. Research has shown that the sachets used in bagging ‘pure water’ are potential vehicles for transmitting cholera and other water-borne diseases [18]. Therefore, the norm of tearing sachet water bags with the teeth before drinking is a potential source of microbes. Bottled water use has also been associated with diarrheal conditions [19]. This is alarming, considering that the public often see these brands of water as being ideal for infant feeding. Some of these microbial contaminants are resistant to antibiotics, thus posing treatment challenges for physicians [20,21]. Although the major health risk arises from the consumption of water contaminated with faecal matter, chemical contamination is no less a risk, as various chemicals such as fluoride, nitrates, cyanide, arsenic, mercury, lead are noted to have harmful effects of both regional and global public health importance [22-24]. Many individuals and communities are exposed to high levels of chemical pollutants through drinking water due to improper management of wastewater from agricultural, industrial and other sources [25]. Excessive or prolonged exposure to drinking water containing naturally-occurring chemicals like lead, arsenic and fluoride leads to diseases such as cancer, teeth and skeletal damage and even death. The series of lead poisoning related deaths in Zamfara State in northern Nigeria in 2010 is an example [17]. The long incubation periods of these diseases may often result in their being overlooked, resulting in devastating consequences.

Furthermore, there is mounting evidence to indicate that water-packaging materials made from polyethylene terephthalate may leach substances such as endocrine disrupting chemicals and antimony, a contaminant that has acute and chronic health effects [26,27]. Sub-Saharan Africa did not meet the Millennium Development Goals (MDGs) target for drinking water, which was to halve the proportion of the population without sustainable access to safe drinking water by 2015. Consequently, nearly half of the 663 million people worldwide using unimproved drinking water sources live in the region [22].

3.2 Packaged Water Industry in Nigeria: Growth and Regulations

Nigeria, with an estimated population of over 180 million people is a big market for sachet and bottled/packaged water manufacturers. Prior to the 1990s, the phrase ‘sachet water’ or ‘bottled water’ was virtually unknown in Nigeria. With population growth, there arose an increased demand on the piped water supply making it a scarce commodity and thus creating room for the proliferation of water vendors [28,29]. These vendors sourced government water and water from other ground sources, performed minor

treatments to make it more physically appealing, and then chilled and sold it to the public at a high price in hand filled, hand tied polyethene bags, otherwise called 'iced water' [28]. The polyethene bags were usually blown open by mouth, and after pouring-in some water, sealed off by tying a knot at one end by hand which make them unhygienic. Due to perhaps an increase in demand, or a sudden realization of the obvious sanitary risks, the late 1990s witnessed a gradual decline in iced water production. This gave way to the present factory-filled polyethene sachets /pouches (popularly called 'pure water') and bottled water consumed mostly by the lower and middle socio-economic classes and the high and middle socio-economic classes respectively [30,31].

The National Agency for Food and Drug Administration and Control (NAFDAC), an agency of the Federal Ministry of Health, came into play in the early 2000s and was saddled with the responsibility of ensuring that all packaged water complies with the Nigerian Standard for Drinking Water Quality (NSDWQ). To ensure adherence to international best practices, NAFDAC's regulation for bottled and sachet water in Nigeria meets the standards established by the WHO as adopted and adapted by the Standards Organization of Nigeria (SON). The SON plays a complementary role to NAFDAC by ensuring that all packaged water is of the highest quality and complies with the Nigerian Industrial Standard for potable water, especially with the physical, inorganic chemical and microbiological requirements as elaborated in the NIS 306:2008. The NIS 306:2008 is a standard developed for packaged water in Nigeria in order to ensure that all packaged water (excluding mineral water) available to consumers is free from substances that are hazardous to health. The NIS 306:2008 is the second edition of the standard and draws on information from national, international and the WHO guidelines. It covers the quality aspects (physical, organic and inorganic chemical, toxic chemical, microbiological, and disinfectants and their by-products) as well as the packaging, transport, distribution, storage, sampling, and test requirements for packaged water in Nigeria [11]. Despite laudable achievements in the regulation of packaged water, NAFDAC faces challenges such as few regional laboratories, huge financial costs involved in the frequent monitoring of microbial levels in these packages and poor institutional capacity. Consequently, NAFDAC uses a reactive approach - compliance monitoring - in regulation, destroying large quantities of packaged water found to be unsafe. The approach has been criticized as not being sufficient to safeguard the health of consumers [32,33].

3.3 Physical, Chemical, and Microbiological Requirements for Packaged Water in Nigeria

Ensuring the physical, chemical, and microbiological quality of packaged water renders it potable and thus safe for human consumption. According to the NIS 306:2008, the physical and chemical characteristics of packaged drinking water must also not exceed the maximum permitted levels stipulated.

Table 1 shows the physical properties of packaged drinking water according to the NIS standard. It allows for a maximum of 3TCU and 5NTU for colour and turbidity respectively and an unobjectionable taste and odour.

Table 1. Physical/ organoleptic characteristics of packaged water based on NIS standard

Parameter	Tolerance
Colour	3 True colour units
Taste	Unobjectionable
Odour	Unobjectionable
Temperature	Ambient
Turbidity	5 Nephelometric turbidity units

In Table 2, the inorganic constituents of water presented, according to the maximum allowable limits. The maximum limits for fluoride, nitrate, and pH are 1 mg/l, 10 mg/l, and 8.5 respectively. Organic contaminants include polynuclear aromatic hydrocarbons, such as 3, 4-benzpyrene, 11, 12- benzfluoranthene. Individual measurements for these chemicals should not exceed 0.0002 mg/L [11].

The maximum levels for toxic chemicals allowed in packaged drinking water in Nigeria shown in Table 3. Due to the toxic nature of these substances only very little amounts are allowed. Lead, Cyanide and Arsenic, which are of public health importance in the African region, have a maximum limit of 0.01 mg/l [24]. Disinfectants and their by-products such as free residual chlorine, 2- chlorophenol, 2,4-dichlorophenol, 2,4- trichlorophenol and trihalomethane have their maximum permitted levels set at 0.2 mg/L, 0.01 mg/L, 0.04 mg/L, 0.3 mg/L and 0.1 mg/L respectively. Other contaminants stipulated in the

standard are pesticides, mineral oil, ammonia, phenol, detergents (lauryl sulphate) and radionuclides; these have their respective limits set at 0.005 mg/L, 0.01 mg/L, 0.05 mg/L, 0.001 mg/L, 0.01 mg/L and 0.1 mg/L [11].

Table 2. Inorganic chemical constituents of packaged water showing the maximum allowable limits

Parameter	Maximum permitted level mm (mg/L)
Chloride	100 mg/L
Fluoride	1.0 mg/L
Copper	1.0 mg/L
Iron	0.3 mg/L
Nitrate	10 mg/L
Nitrite	0.1 mg/L
Manganese	0.05 mg/L
Magnesium	2.0 mg/L
Zinc	5.0 mg/L
Total dissolved solids	500 mg/L
pH	6.5-8.5
Hardness (as $CaCO_3$)	100 mg/L
Hydrogen sulphide	0.01 mg/L
Sulphate	100 mg/L
Conductivity	1000 us/cm

Table 3. Maximum permitted level (mg/L) of toxic chemical substances in packaged water

Substances	Maximum permitted level (mg/L)
Lead	0.01
Cyanide (as CN)	0.01
Cadmium	0.003
Arsenic	0.01
Barium	0.05
Mercury	0.00

Table 4. Microbiological requirements of packaged water as stipulated in the Nigerian drinking water standard

Microorganism	Permitted level
Clostridium perfringens	Nil
Chromobacterium violaceum	Nil
Escherichia coli	Nil
Faecal Streptococci	Nil
Klebsiella aerogenes	Nil
Staphylococcus aureus	Nil
Yeast/Mould	Nil

Table 4 above shows the microbiological requirements for packaged drinking water as stipulated in the Nigerian drinking water standard. Neither faecal coliform bacteria nor fungi are allowable in drinking water.

3.4 Global Perspective of Packaged Water

Data from studies in different parts of the world seem to indicate that most packaged water have good physical characteristics, but variable chemical and microbiological characteristics [34-36]. This may be because consumers readily detect anomalies in the physical properties such as the colour, taste, or smell of water than those related to the chemical or microbial properties, with consequent decrease in patronage [29]. In a study carried out in Texas, United States, to assess the physical, chemical, and microbial properties of bottled water, most of the chemicals analysed in the 35 samples used for the study were well below their recommended limits for drinking water and 11% (4 samples) were contaminated with bacteria [37]. A similar result was obtained in Saudi Arabia where the results of chemical contents of bottled water brands were within permissible limits save for the levels of fluoride and bromate [38,39]. Studies carried out on bottled water samples in Sri Lanka, Bangladesh, Fiji and Hungary have reported the presence of heterotrophic bacteria and faecal indicator bacteria such as *E. coli* exceeding the guidelines for drinking water [39-42]. Although heterotrophic bacterial counts reportedly do not pose a threat to health, their presence serve as an indicator of the cleanliness and integrity of water distribution systems. Evidence also suggests that there is a possibility of microbial growth when conditions are suitable [32].

3.5 Assessment of Packaged Water in Sub-Saharan Africa

Published studies across Africa have reported similar pattern of contamination, albeit with reports of higher levels of microbial contamination. In a study carried out in Ethiopia, the physical and chemical parameters of bottled water were within recommended limits [43]. The analysis of the physicochemical properties of 14 bottled water brands in Egypt showed that while the physical parameters were within recommended limits, the lead levels were out of range for all the brands while some brands had cadmium and nickel concentrations higher than the Egyptian drinking water standards [44]. Many studies to assess the microbiological composition of packaged water in Africa have yielded disheartening results. Several pathogenic

bacteria, including *Clostridium, Bacillus, Klebsiella, and Staphylococcus* have been isolated from packaged water [45-47]. The use of sachet water, seen by consumers as a safer and more readily available alternative to tap water seems to have compounded the situation, since its microbial quality decline considerably as it goes down the distribution chain especially when improperly handled by vendors [48]. A study in Tanzania revealed the presence of heterotrophic and faecal bacteria in bottled water [49]. In two similar studies conducted in Ghana to evaluate the microbial quality of packaged water, bottled water was found to be more satisfactory than sachet water, as several protozoa and bacteria including faecal coliforms were present in the latter than in the former [46,50]. However, in Accra Ghana, Stoler et al. [51] did not find faecal contaminants in 60 sachet water samples analysed. Another study in Ethiopia analysed 108 bottled drinking water samples and concluded that 7.4% of the bottled water sold in the study areas were unfit for human consumption based on the level of microbial contamination [43].

3.6 Overview of Packaged Water and Public Health Implications in Nigeria

In Nigeria, studies have determined that most packaged water generally have good physical characteristics, although objectionable taste has been documented [52-55]. Various harmful chemicals and pathogenic organisms abound. Orisakwe and colleagues assessed samples of sachet water sold in Eastern Nigeria for heavy metals. They discovered that 12% of the samples had lead levels above the maximum permissible limits; cadmium levels in 19.5% of the samples exceeded same limits [56]. Another study to determine the quality of packaged drinking water sold in Ibadan, Nigeria showed that the pH, aluminium, fluoride, and cyanide content of 30% of the 118-packaged water samples analysed were not within permissible limits. However, bottled water had better microbial quality than its sachet and iced water counterparts from which pathogenic bacteria like *Klebsiella sp., Streptococcus faecalis* and *Pseudomonas aeruginosa* were isolated [57].

Muazu et al. [52] evaluated the microbiological quality of sachet water vended in Maiduguri, Nigeria and found out that despite the good physical quality, 19 out of the 20 brands sampled contained *Salmonella spp, Pseudomonas spp,* or coliforms including *E. coli*. Out of 15 brands of commercially available bottled water analyzed by Igbeneghu and Lamikanra in Ile-Ife, southwestern Nigeria, only 4 brands met the recommended criterion of zero coliforms per 100 ml of water [57]. Olaoye and Onilude analysed the microbiological properties of 92 sachet water samples from western Nigeria and found out that some of the samples were of poor quality, as they contained several pathogenic organisms. The study detected *E. coli* in 2.2% of the samples [45]. Another study carried out in south-west Nigeria by Edema, Atayese and Bankole on the bacteriological quality of commercial sachet drinking water at points-of-sale revealed that *Salmonella spp* and/or *E coli* contaminated 94 samples out of 108 samples analysed [58]. Onweluzo and Akugbazie analyzed 11 sachet and 6 bottled water brands sold in Nsukka, Enugu State Nigeria and discovered that while the physical and chemical quality were within WHO/NAFDAC recommended limits, only two bottled water brands met the zero criterion recommended by the WHO. Other brands of sachet and bottled water had varying levels of total coliforms, with some of the highest levels of 14/ml and 29/ml seen in 1 bottled and 1 sachet brand respectively [36]. In a study to determine the prevalence of bacteria in 90 sachet water samples from 6 brands produced and sold in Nnewi, Anambra State Nigeria none of the samples met the WHO recommended standard of zero coliforms per 100 mls of water. *E. coli* was the most prevalent organism isolated in the samples studied. This finding is consistent with several studies carried out across Nigeria indicating the presence of varying degree of water contaminants and pathogens in packaged drinking water [59-71]. The importance of ensuring the availability and accessibility of safe drinking water to man cannot be over-emphasized as it is critical to his health and well-being. While most studies show that packaged water generally have good physical qualities, they have poor chemical and microbial qualities. Although sachet water has recently been included as an improved drinking water source in the post-2015 era, [72] concerted effort is needed to ensure the delivery of safe water to the population. Studies carried out on packaged satched and bottled drinking water in Owerri [73], Ibadan and Ile-Ife cities in South Western Nigeria [74] all indicated poor quality. This was consistent with those carried out in Zaria in Kaduna State, Northern Nigeria [75], Abeokuta in Ogun State in southwest Nigeria [76], Abuja [77], and Bauchi State in the north central [78] that all indicated varying levels of contamination.

4. CONCLUSION AND RECOMMENDATIONS

The government has the responsibility of providing her citizenry with adequate potable, piped water supply. While this may not eliminate the use of packaged water, it will enable lower income earners to have access to potable water without losing a sizable portion of their income in the process. The government should encourage her drinking-water regulating agencies to perform their oversight duties effectively. These agencies should improve on the current monitoring system for packaged water, to ensure that water production companies adhere to the stipulated standards. Provision of more regional laboratories for water quality monitoring and employment of adequate workforce is invaluable. A formidable disease surveillance system by the Federal Ministry of Health is essential for prevention and control of potential and actual epidemic occurrences. A strict surveillance system, monitoring, and evaluation with strict regulatory surveillance in line with global best practices will help to stem the tide.

CONSENT

It is not applicable.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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