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CONTAMINATION OF COMMERCIALLY PACKAGED SACHET WATER AND THE PUBLIC HEALTH IMPLICATIONS: AN OVERVIEW

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ABSTRACT

Quality water should be colourless, tasteless, odourless and free from faecal contamination. This study investigates the level of contamination of commercially vended packaged water and their public health implications. Published baseline information and data were used in the study. Using different isolation techniques, coliform bacteria of up to 100% and faecal contamination of up to 40% were reported. The consumption of contaminated commercially packaged water by the public has led to different disease conditions and death of millions of people all over the world. This calls for strict adherence to good management practices (GMP) by producers of packaged water, improved monitoring and enforcement of guidelines of production by regulatory bodies according to World Health Organization (WHO) standards, increased public awareness and sensitivity to the presence and dangers of consuming such water and creating easy, always potent reporting channels through which disease cases and suspected contaminated water manufacturers could be reported to the authority so as to prevent infection from consumption of such packaged water, diseases and deaths.

Keywords: Contamination, sachet water, public health implications

INTRODUCTION

This paper sets out to use published baseline information to investigate contamination and levels of contamination of packaged water, the implication to public health as well as seek and suggest ways in which such produced water could be more wholesome and fit for consumption.

Production, sales and consumption of packaged water is growing rapidly in most countries of the world especially in developing countries (Oyedeji *et al.*, 2010; Mgbakor *et al.*, 2011; Gangil *et al.*, 2013). Many scientists all over the world have carried out researches on the microbial analysis of commercially vended packaged water using different laboratory techniques and reporting varying percentages of microbial isolation (Warburton *et al.*, 1992; Bharath *et al.*, 2003; Oladapo *et al.*, 2009; Prasanna and Reddy, 2009; Kuitcha *et al.*, 2010; Oludairo *et al.*, 2013). There are tremendous public health hazards associated with the consumption of microbial contaminated packaged water; these include diseases and deaths (Oladapo *et al.*, 2009).

Water is a vital substance for the survival of all lives (Thliza *et al.*, 2015). It is absolutely necessary for most life driven processes (Aroh *et al.*, 2013). It is one of the indispensable resources needed for the continued existence of all living things including man (Gangil *et al.*, 2013). It is also one of the most important and most abundant compound on earth, vital to any organism's survival (Onilude *et al.*, 2013). Water is one of the most important needs of all forms of life and is unavoidable in man's daily life, constituting a sizeable percentage of man's daily food intake because human bodies do not have reserve supply (Anyamene and Ojiagu, 2014). It is also an essential requirement of life for drinking, domestic, industrial and agricultural uses (Isikwue and Chikezie, 2014). Quality water is colorless, tasteless, odourless, as well as free from faecal contamination (Opara and Nnodim, 2014).

Water is an essential part of human nutrition and is required for maintenance of personal hygiene, food production and prevention of diseases (Thliza *et al.*, 2015) It is the most abundant substance in nature and occupies about 70% of the earth's crust (Anyamene and Ojiagu, 2014; Thliza *et al.*, 2015). Due to its natural abundance and also because the protoplasm of many living cells contain about 80% water and most biochemical reactions which occur in the metabolism and growth of living cells involves water medium it is considered a universal solvent (Nwosu and Ogueke, 2004; Okechukwu and Chikezie, 2014). Water is a biological medium which exists as solid, liquid and gas (Thliza *et al.*, 2015).

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CHALLENGE OF SAFE WATER SUPPLY

A reliable supply of clean wholesome water is highly essential in a bid to promote healthy living among the inhabitants of defined geological region in addition to being key to sustainable development, health, food production and poverty reduction (Balogun *et al.*, 2014). In many developing countries however, availability of quality water has become a crucial and urgent problem and has become a matter of concern to families and communities (Maduka *et al.*, 2014).

It is estimated that 1.2 billion people around the world or one fifth of world's population lack access to safe water either because of unavailability or inadequacy (Oyelude and Ahenkorah, 2011; Akinde *et al.*, 2011; Adebayo *et al.*, 2012). This could probably be due to increase in human and animal population (Meduka *et al.*, 2014; Adegoke *et al.*, 2012) or because potable water now attracts increased rates and fees which many cannot afford due to poverty (Oyelude and Ahenkorah, 2011; Adewoye *et al.*, 2013; Balogun *et al.*, 2014) or because of rapid industrialization, urbanization and new uses of treated water (Mojekeh and Eze, 2011; Gangil *et al.*, 2013). Many therefore result to taking unsafe water which places them at risk of different diseases resulting in public health challenges (Maduka *et al.*, 2014).

POTABLE WATER

Potable water is that which one will not mind to put in his pot, water that is safe for cooking and drinking, containing less than 1000 ml per liter dissolved solids, does not contain chemical substances and microorganisms in amounts that could cause hazard to health. It should be clear, without disagreeable taste, color or odor therefore fit for human and animal consumption. It is water that has been treated, cleaned or filtered to meet established drinking standards (Aroh *et al.*, 2013; Isikwue and Chikezie, 2014). It can be sourced from surface water such as river, streams or the ground water such as spring, well and borehole (Aroh *et al.*, 2013).Water quality is the physical, chemical, radiological and biological characteristics of water in relation to the requirements of human and animal need (Johnson *et al.*, 1997; Diersing, 2009; Danso-Boateng and Frimpong, 2013).

Agencies that regulate water qualities worldwide rely on the World Health Organization (WHO) standards and guidelines for drinking water quality (WHO, 1993, 1996, 2001 and 2002). So as to ensure the highest quality of potable water in order to safe guard public health (Anunobi *et al.*, 2006; Isikwue and Chikezie, 2014).

Table 1. Physico-chemical characteristics of potable water maximum permitted level (mg/l)

Parameter	Packaged	Unpackaged
Colour	3.0 TCU	15.0 TCU
Taste	Unobjectionable	Unobjectionable
Odour	Unobjectionable	Unobjectionable
Temperature	Ambient	Ambient
Turbidity	5.0 NTU	5.0 NTU
pH	6.5-8.5	7.0-8.0
conductivity	1000µs/cm	1000µs/cm
Chloride	100	250
Fluoride	1.0	1.0
Copper	1.0	1.0
Iron	0.03	0.05
Nitrate	10	10
Nitrite	0.02	0.02
Manganese	0.05	0.1
Magnesium	0.20	0.20
Zinc	5.0	5.0
Total dissolved solids	500	500
Hardness (as CaCO3)	100	150
Hydrogen sulphide	0.01	0.01
Sulphate	100	100

TCU = true colour unit, NTU = Nephelometric turbidity unit (USESA, 2012)

These potable water guidelines form the basis for judgment of acceptability of water. The recommended physico-chemical and biological characteristics are shown in the Tables 1 and 2. Potable water must be free of microbial indicators of fecal contamination and coliform count per 100ml of drinking water must be zero (WHO, 1984, 1997; Pierre, 1999).

Table 2. Microbial limits in potable water (SON, 2007; CSF, 2014).

Microbiological characteristic parameter	Maximum Permitted Levels
Total Coliform Count	10 (Cfu/ml)
Faecal Coliform Count	0 (Cfu/100ml)

SATCHET WATER

Access to safe drinking water is important to health and development (Adetunde *et al.*, 2014), but because of its inadequacy and government's inability to provide enough, a number of small scale water producing industries are packaging and marketing factory filled sachet drinking water (Thliza *et al.*, 2015). These are small nylon sachets containing 0.5L of water which are electrically heated and sealed at both ends (Adegoke *et al.*, 2012). The sale and consumption of packaged water continue to grow astronomically and rapidly in most countries of the world (Mgbakor *et al.*, 2011; Oyedeji *et al.*, 2010; Gangil *et al.*, 2013).

The quest for cheap and readily available source of potable water has led to the emergence of sachet water (Anyamene and Ojiagu, 2014) which is a locally sourced low cost alternative drinking water scheme providing sustainable access to safe water in rural and semi urban settings of developing nations (USEPA, 2012; Balogun *et al.*, 2014). This is thought to be cheaper and more affordable than bottled water and also safer, more hygienic and better than hand filled, hand tied packaged polythene bag water initially popularly sold (Oyedeji *et al.*, 2010; Akinde *et al.*, 2011). Consequently sachet water has gradually become the most consumed liquid for both the rich and poor (Akinde *et al.*, 2011).

Current trends however unfortunately suggest that sachet water could be a route of transmission of enteric pathogens which raises issues of the problem of its purity and health concern (Oladapo *et al.*, 2009; Mgbakor *et al.*, 2011; Akinde *et al.*, 2011; Isikwue and Chikezie, 2014).

PACKAGED WATER CONTAMINATION

Packaged water, no matter their sources, are susceptible to microbial, toxic organic and inorganic contamination (Anyamene and Ojiagu, 2014; Sudhakar and Manatha, 2004; Gangil *et al.*, 2013). The presence of coliforms in potable water is used as indicator of water contamination (Opara and Nnodim, 2014).

Coliform bacteria describe a group of enteric bacteria that include *E. coli*, *Klebsiella* and *Enterobacter* species. They are rod shaped, gram negative organisms which ferment lactose with the production of acid and gas when incubated at 37ºC for 48 hours. They are broad class bacteria that live in the digestive tract of humans and animals (Opara and Nnodim 2014). Although coliforms are generally not harmful, they indicate the presence of pathogenic bacteria, viruses and protozoa (Anyamene and Ojiagu, 2014; Goel, 2006).

Escherichia coli is used as indicator of possible recent sewage/ faecal contamination (Anyamene and Ojiagu, 2014; Onuh and Isaac, 2009; Opara and Nnodim, 2004) because this is one of the first bacteria present in water when contamination occurs and will present in larger quantities than some other pathogenic microbes. Other microbial indicators of possible faecal, soil and natural water contaminations are faecal *Enterococci* especially *Enterobacter faecalis*, *Clostridium perfringens* spores, *Clostridium sporanges*, *Salmonella typhi*, *Shigella dysenteriae*, *Vibrio cholera*, *Pseudomonas aeruginosa*, *Klebsiella* spp. *Aeromonas* spp., *Mycobacterium* spp., *Alcaligens*, *Actinetobacter*, *Chromobacterium*, *Serratia spp*, *Flavobacterium spp.*, *Proteus* spp., *Bacillus subtilis*, *B. mycoides*, *Enterobacter cloaca*, *Enterobacter aeronenes*, *Nostocida fexibacter* and *Norcardia* spp. (WHO, 1993; Edema *et al.*, 2001; Tortora *et al.*, 2002; Oyedeji *et al.*, 2010; Khaniki *et al.*, 2010; Cleark, 2010; Oludairo *et al.*, 2013; Onilude *et al.*, 2013; Falegan *et al.*, 2014). These could cause different disease conditions and clinical signs such as giardiasis, cryptosporidiosis, gastroenteritis, diarrhea, typhoid fever, cholera, bacillary dysentery, hepatitis, shigellosis *etc.* (Akinde *et al.*, 2011; Thliza *et al.*, 2015; Oyedeji *et al.*, 2010; Isikwue and Chikezie, 2014; Aroh *et al.*, 2013; Hughes and Koplan, 2005). Water borne diseases are reported to account for 80% of illnesses in developing world, killing a child every 8 seconds. This is a global public health threat (Hughes and Koplan, 2005).

PREDISPOSING FACTORS TO PACKAGED WATER CONTAMINATION

Various factors predispose packaged water to contamination. These include contaminated sources of water ranging from rain water, shallow well water, rusty unwashed tanker to other contaminated sources (Dibua *et al.*, 2007). Some contaminants enter packaged water through seepage of sewage and rainfall runoffs into well water and exposed boreholes (Defives *et al.*, 1999; Adegoke *et al.*, 2012). Introduction of contamination during the process of production due to contaminated materials or external introduction of contamination from vending machines etc. (Omalu *et al.*, 2010). Prolonged storage of packaged water at favorable environmental conditions aiding total aerobic heterotrophic bacteria to grow to level that may be harmful to humans (Warburton *et al.*, 1992). The unhygienic conditions and filthy environments in which some of the water packaging companies operate especially in developing countries could introduce contamination to packaged water. These companies are mostly not registered and are engaged in sharp, questionable practices which are encouraged by the irregular and ineffective monitoring of authorities that enforce standard. They therefore, do not follow international quality standards nor appropriate methods of water treatment (Oyedeji *et al.*, 2010; Ofori, 2011; 2011; Mensah, 2011; Danso-Boateng and Frimpong, 2013; Falegan *et al.*, 2014; Isikwue and Chikezie, 2014). Improper handling by hawkers could be another reason why packaged water is contaminated (Adegoke *et al.*, 2012). Absence of sterilization procedures such as pasteurization and thermal sterilization for the treatment of packaged water also increase susceptibility to contamination (Anyamene and Ojiagu, 2014). Ignorance on the implication of carelessness in the production line by producers with sole aim of making profit thereby disregarding safety and quality in producing water for the public (Dodoo *et al.*, 2006; Onemaniand Otun, 2003; Ackah-Arthur *et al*., 2012). Use of non feed grade sachets for water production and the release of packaged water to the public without production and expiry date markings could also enhance sachet water contamination (Adewoye *et al.*, 2013).

TYPICAL PACKAGED WATER PRODUCTION PROCESS

Typical production process of packaged water (Adetunde *et al.*, 2014).

Source:
bore-hole / deep well water with submersible pumps
↓
Raw water tank storage (usually PVC)
↓
Industrial modules (consisting of sand bed filter and activated carbon
↓
Water tank (PVC)
↓
Micro-filters 1, 2, 3(5µm -2µm-0.5µm, respectively)
↓
UV sterilizer (attached to sachet water machine)
↓
Packaging (automatic filling machine and heat sealing of polythene sachets)
↓
Sachets stocked in bigger bags ready for distribution

There are various water treatment processes, the major procedures are aeration, coagulation, flocculation, sedimentation, slow sand filtration, rapid filtration and disinfection (Ibemesim, 2014). Small scale package water production factories usually employ boiling, sedimentation, coagulation and filtration. Water is brought to a good rolling boiling point for about 15-20 minutes to destroy microorganisms present, drive out dissolved gases and give a flat taste (Lorch, 1987). Multiple candle pressure filter which employ active carbon filter beds are commonly used in packaged water production to remove contaminants like sand, rust, metal, sediments, algal films and bacteria while sealing is done using heating sealing machines (Hunter and Burge, 1987; Ackah-Arthur *et al*., 2012).

CASE REPORTS OF CONTAMINATED PACKAGED WATER

In Boltaganga municipality, Ghana in 2012, using the multiple tube fermentation method, 264 water samples made up of 120 branded sachet water, 48 unbranded hand filled water and 96 bottled water were analyzed. Three out of every 4 sachet water and all the hand tied water were reported to be contaminated with coliform bacteria (Oyelude and Ahenkorah, 2012). In another study carried out in 2014 in the same municipality, using standard plate count and multiple tube fermentation method of isolation of microorganism out of 20 sachet water tested, at least 14 (70%) have different levels of heterotrophic bacteria ranging from 101-158 cfu/ml. These included *E. coli* and *Streptococci* (Adetunde *et al.*, 2014).

In a study in Jaipur city, India, 50% of the 20 sachets and bottled water were polluted. 100% had high coliform counts with 40% having the presence of *E. coli*. Ten fold dilution and pour technique were used (Gangil *et al.*, 2013; Parashar *et al*., 2003).

Seven sachet water samples supplied in and around Palavaran, India were subjected to microbial analysis, using the serial dilution and pour technique. Contamination was found in all the sampled water these include *Proteus mirabilis*, *Klebsiella pneumoniae*, *Pseudomonas vesicularis*, *Pseudomonas aeruginosa* (Banu and Menakuru, 2010). In Kalama region, Egypt 30% of the sachet water analyzed were contaminated with at least one coliform and pathogenic bacterium (Ennayat *et al.*, 1998). In Abuja, Nigeria, out of 100 brands of packaged water samples, using the multiple tube method, 40.04% *E. coli*, 10.36% *Streptococci faecalis*, 9.36% *Pseudomonas aeruginosa* and 39.64% *Klebsiella* spp. were isolated (Ibemesim, 2014).

In Port Harcourt, Rivers State, Nigeria, using the heterotrophic plate count and spread plate technique, 40% out of 10 brands of sachet water samples have faecal coliform count with *E. coli* been the predominant microorganism isolated (Akinde *et al.*, 2011).

Out of a sample size of 720 from 6 different brands of sachet water in Zaria, Kaduna State, Nigeria, Thliza *et al.* (2015) reported the isolation of bacterial species in 54, representing 7.5%. Multiple fermentation technique was used. *Staphylococcus aureus*, *E coli* and *Baccillus aureus* were predominantly isolated (Thliza *et al.*, 2015).

Mgbakor *et al.* (2011) using the serial dilution method, reported 73.3% and 66.6% of pathogenic growth respectively from two different batches of sachet water collected from Owerri, Imo State, Nigeria. Of the total of 120 samples, *Klebsiella pneumoniae* 29.2%, *Serratia* spp. 25%, *Proteus mirabilis* 25%, *Pseudomonas aeruginosa* 12%, *Chromobacterium* spp. were isolated (Mgbakor *et al.*, 2011). In another study in Owerri, Imo State, Nigeria, using multiple tube technique, contamination of some sachet and table water were reported. Organisms isolated were *E. coli*, *Streptococcus faecalis*, *Klebsiella pneumonia* and *Staphylococcus aureus* (Opara and Nnodim, 2014). Contamination of sachet water was also reported by Maduka *et al.* (2014). Microorganisms isolated included *E. coli* 42.43%, *Streptococcus faecalis* 24.24%, *Klebsiella pneumonia* 12.12% and *Staphylococcus aureus* 21.21%. The dilution and pour technique was used for isolation (Maduka *et al.*, 2014).

In Aba, Abia State, Nigeria, From 20 sachet water samples analyzed, using heterotrophic bacterial count and culture, 32% of the samples reportedly tested positive for *Staphylococcus* spp., 20% *Klebsiella* spp., 23% *Pseudomonas*, 15% *Proteus* and 10% *Enterobacter* (Adegoke *et al.*, 2012). Sachet water samples collected from 5 different manufacturers reportedly yielded *Pseudomonas aeruginosa* 37.5%, *Staphylococcus aureus* 20.8%, *Klebsiella* spp. 25.02%, *Proteus* spp. 16.68% in Ado Ekiti, Ekiti State, Nigeria. The serial dilution and pour plate technique methods were used (Falegan *et al.*, 2014). Also in another study carried out simultaneously in both Aba and Port Harcourt, Aroh *et al.* (2013) using the membrane filter procedure to analyze 80 sachets water reported coliform bacteria level of between 8.3% to 91.7%. *Staphylococcus* spp., *Enterobacter* spp., *Salmonella* spp., *Klebsiella* spp., *Shigella* spp., *E. coli*, *Citrobacter* spp., *Pseudomonas* spp., *Streptococcus* spp. and *Micrococcus* spp. were the common isolates (Aroh *et al.*, 2013).

Studies carried out in Akwa, Anambra State, Nigeria using 10 fold serial dilution and pour plate techniques, reported contamination of 8 of the 10 sachet water samples analyzed. Isolated microorganisms include *E. coli*, *Klebsiella* spp., *Pseudomonas* spp., *Bacillus* spp., *Proteus* spp. and *Staphylococus* spp. (Anyamene and Ojiagu, 2014).

In Ile-Ife, Osun State, Nigeria, Oyedeji *et al.* (2010) reported that all brands of sachet water (100%) analyzed had total coliform count with 20% positive for *E. coli* and *Enterococcos faecalis* present in 10% of the samples. Multiple tube fermentation and membrane filtration technique were used (Oyedeji *et al.*, 2010). Using the paqualab kit, all the 5 sachet water brands and government tap water were reported to have bacterial pollution in Bauchi, Nigeria (Isikwue and Chikezie, 2014).

In Oyo State, Nigeria, *E. coli* 13.3%, *Pseudomonas aeruginosa* 39.9%, *Enterobacter aerogenes* 53.3% were isolated from commercially sold sachet water. Serial dilution and pour technique was used (Onilude *et al.*, 2013). *E. coli*, *Klebsiella* spp., *Pseudomonas aeruginosa* and *Enterobacter* spp. were isolated from sachet water in Abeokuta, Ogun State, Nigeria. The serial dilution and pour technique were used (Balogun *et al.*, 2014).

In Ogbomoso, Oyo State, Nigeria, 30 sachet water samples were analyzed for microorganisms using serial dilution and pour technique. The isolated organisms were *Bacillus substilis*, *Bacillus alvei*, *Pseudomonas putida*, *Pseudomonas fluorescens*, *Bacillus cereus*, *Enterobacter aerogenes*, *Staphylococcus aereus*, *Streptococcus lactis*, *Micrococcus acidophilus*, *Pseudomonas aeruginosa* and *Proteus mirabilis* (Adewoye *et al.*, 2013).

However, of the 198 samples representing 22 brands of packaged water analyzed in Kumasi, Ghana, using standard coliform technique, no enterococci bacteria was isolated by Danso and Frimpong (Danso-Boateng and Frimpong, 2013).

PUBLIC HEALTH IMPLICATIONS OF MICROBIAL POLLUTION OF COMMERCIALLY SOLD PACKAGED WATER.

Water has always been associated with disease. The first reported case of polluted drinking water was that of Broad street water pump, London after which many other cases have been reported in different parts of the world (Gangil *et al.*, 2013). Conditions resulting from microbial contamination of drinking water is said to affect a large part of the world's population (Hughes and Koplan, 2005) and continue to be one of the major health problems globally (Boubetra *et al.*, 2011). It accounts for 80% of illnesses in developing world (Isirimah, 2003).

Microbial pollution of packaged water particularly in developing countries has grave implications on public health (Warren and Mark, 1998). It threatens the population's existence causing diseases such as cholera (Njoku and Osondu, 2007; Ackah-Arthur *et al*., 2012), gastroenteritis (Grabow, 1996), hepatitis, typhoid fever, shigellosis (Oguntoyinbo *et al.*, 1978; Gangarose *et al.*, 1980; Fraechem *et al.*, 1983; Jiburum and Mba, 2004; Kwakye *et al.*, 2007; Banu and Menakuru, 2010; Anyamene and Ojiagu, 2014) and giardiasis (Opara and Nnadim, 2014). It could also result in symptoms such as bacillary diarrhea (Mead *et al.*, 1999). WHO estimates that 88% of diarrhea cases is caused by unsafe water (CAWST, 2009; WHO, 2004). Mortalities due to water associated diseases and symptoms now exceeds 5 million people per year (Cabral, 2010).

Studies carried out on packaged water around the world revealed high level contamination of microorganisms which indicated that most of the brands were unfit for human consumption. They were found to be of doubtful quality and did not meet the WHO drinking water standards (Rutz, 1996). Consumption of these packaged water brands could result in public health hazard. This, therefore, requires concerted effort on the part of all stake holders to correct the anomaly.

Regulatory bodies should intensify effort at monitoring of packaged water manufacturers, periodic sanitary inspection of factories should be carried out. Emphasis should be placed on good management practices (GMP) by producers of packaged water especially in terms of location of the factories and maintaining high level of hygiene within the premises of production. Regulatory agencies should ensure the enforcement of water quality regulations. Manufacturers should be compelled to use standardized equipments and water treatment procedures. Test and analysis of packaged water products at different stages of production; preproduction, production and postproduction including periodic market sample testing should be carried out by regulatory authorities. Results of laboratory tests should be made available to packaged water producers to encourage them to improve on their production process. Hazard analysis and critical control point (HACCP) used in the food industry to prevent contamination could also be used in the water production industry. Manufacturers should be mandated to inscribe production and expiry dates on packaged water products, expiry date should not exceed 4 weeks from the date of production. This is because storage at room temperature over a long period of time has been reported to increase the total heterotrophic bacteria to levels that can be harmful to human health. Manufacturers should be made toeducate retailers on the proper handling of products to ensure product quality. There is need to create public awareness on the potential danger of consuming non certified, contaminated packaged water and the adverse effect of storage of products for long periods of time.

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