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Spatial Distribution of Bacteriologically Safe and Unsafe Sachet Water in Sokoto Metropolis

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Abstract
Sachet water emerged as an alternative to the seeming inadequate water in Nigeria, and if improved upon, would offer a low cost alternative water provision from private participation that could help in the drive towards achieving the target of the Sustainable Development Goals (SDGs) marked for 2030. However the mass rush of several entrepreneurs into water packaging in Nigeria seems to have compromised quality standards of that industry. Recently, the Standard Organization of Nigeria asserts that a large percentage of the sachet water brands produced in the country is unsafe for drinking. This paper assessed the microbial quality of sachet water produced in Sokoto Metropolis. 109 water packaging enterprises were surveyed and 83 of them were selected for analysis using Yemen's formula for sample determination. Multiple tube technique was used for the microbial analysis; Editing tool of the Arc GIS 9.3 were used to determine the spatial distribution; and The Spearman Rank Correlation Coefficient were used for Hypothesis testing. it was found that 38.6% of the water sachets are not safe for consumption. The following bacteria: Bacillus spp, Citrobacter spp, E.Coli, Entrobacter spp, Entrococcus spp, Klebsiella spp, Proteus, Providencia spp, Pseudomonas spp, Salmonella spp, Salmonella typhii, Shigiella spp, Staphylococcus Spp, Staphylococcus Aureus and Streptococcus spp were also isolated. it was also found that both safe and unsafe sachet water brands were unevenly distributed all over the study area, where only 1.79% quality of Sachet water is controlled by the geographical location of the brand. Finally, four remedial measures were recommended.
Key words: Sachet water, Water quality, Bacteriological sefety, Sachet water Brand.

INTRODUCTION
Pipe borne water in Nigeria is persistently inadequate in terms of quantity and quality. However alternative has been found in packaged water commonly sold in sachets, which if improved upon, would offer a low cost, readily available alternative water provision from private participation that could help in the drive towards achieving the target of the Millennium Development Goals (MDGs) (Dada, 2009). However, the recent involvement of several entrepreneurs into the business has brought a lot of concern to most stakeholders in the sector. Recently, the Standard Organization of Nigeria (SON) declared that most of the companies producing sachet water satisfy only three out of fifty parameters used in ascertaining the

quality of water (Nigerian Tribune, 2012). This is in addition to the numerous researches that found sachet water in different places across the country wanting in terms of quality standard.

The quality of water is a measure of its physical, chemical and microbial characteristics; but by far, the most serious public health risk associated with drinking water is microbial contamination (UNICEF, 2008). Microbial contamination of drinking water causes diseases such as typhoid, cholera, infectious hepatitis, dysentery, etc (WHO, 2006).

Numerous researches have been carried out on the bacteriological quality of sachet water across Nigeria. But the previous researches fail to examine the spatial location of the sachet water companies in question. To address these short comings, this research examines the spatial pattern of the sachet water brands used for the study.

MATERIALS AND METHODS

Sampling procedures

According to NAFDAC source (2012) there were 147 sachet water brands in Sokoto State out of which 130 were located within Sokoto metropolis. A reconnaissance survey was conducted to all the companies, through which the list was updated to 109 brands.

Yemen's formula for sample size determination was used to select 86 brands out of the 109 Sachet water brands. Thus: $n = \frac{N}{1 + N\,(e)^2}$ where N = Population size; e = 0.05.

However during the sample collection, two out of eighty six samples to be collected were closed for the day, while one insisted that he will not sell his water to the researcher. Therefore a total of 83 samples were collected instead of the proposed 86.

The Sachet water samples were purchased from producers (Ajayi and Adesida, 2009; Ezeugwunne *et al*, 2009 and Oyedeji *et al*, 2010) and transported to laboratory in insulated containers with ice packs within 8 - 24 hour (Okioga, 2007 and Edema et al, 2011). Meanwhile the samples were coded and labeled for easy identification.

Laboratory analysis

Most-Probable-Number Technique was used for the microbial analysis (Ramon *et al*., 1981; Tebbutt, 1998; Omezuruike *et al*, 2008; Addo *et al*, 2009; Oyedeji *et al*, 2010; Kalpana *et al*, 2011; Waziri, 2012, Muazu *et al*, 2012 and Adegoke *et al*, 2012). In this method, coliforms were detected in three stages, which include Presumptive test, Confirm test and Completed test (Fawola and Oso, 1995); and expressed as MPN per 100 ml of water (Johnson and Case, 2010).

Originally, only positive Presumptive result would be submitted to the Confirmed stage (Fawola and Oso, 1995; and Johnson and Case, 2010). But in this research, both positive and negative presumptive test were submitted to Confirmed stage. Thus, Most-Probable-Number Technique was modified (Ramon *et al*, 1981) in order to extend the detection beyond coliform bacteria. This is in response to the limitation of coliforms as indicator of overall bacteriological contamination (WHO, 2006). All the media used were weighed out and prepared according to the manufacture's specification

Map production

Editing tool of the Arc GIS software 9.3 was used to produce a map showing the spatial distribution of safe and unsafe sachet water brands in the study area. The map was produced using the coordinates collected using GPS during the reconnaissance survey.

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RESULTS AND DISCUSSION

In this study, only 16 samples (19.3%) showed positive presumptive test. The remaining 67 samples (80.7%) showed negative presumptive test (Table 1). However, only 15 samples (18.1%) show evidence of coliforms growth after completed test. On the other hand, only 6 samples (7.2%) showed no bacterial growth from the sub cultured media (Table 1).

Table 1 Gram reaction, morphological and bio-chemical characteristic of Isolates

Freq	Gram staining		Bio-chemical Identification													Isolates
	Gram R	Morph.	Cat	Coag	H_2S	Gas	Lac	Sug	Glu	Mr	Vp	Citra	Indole	MSA	Urease	
10	+ve	Rod			-	-	+	+	+							Bacillus spp
5	-ve	Rod			+	+	+	+	+	+	-	+	-		-	Citrobacter spp
4	-ve	Rod			-	+	+	+	+	+	-	-	+		-	E. coli
4	-ve	Rod			-	+	+	+	+	-	+	+	-		-	Entrobacter spp
1	+ve	Cocci	-	-											+	Entrococcus spp
2	-ve	Rod			-	-	+	+	+	+	+	+	-		+	Klebsiella spp
8	-ve	Rod			+	+	-	-	+	+	-	+	-		+	Proteus spp
2	-ve	Rod			+	-	-	-	+	+	-	+	+		-	Providencia spp
3	-ve	Rod			-	-	-	-	-	-	-	-	+		+	Pseudamonas spp
1	-ve	Rod			+	-	-	+	+	+	-	+	-		-	Salmonella spp
5	-ve	Rod			+	-	-	-	+	+	-	-	-		-	Salmonella typhii
5	-ve	Rod			-	-	-	-	+	+	-	-	-		-	Shigiella spp
14	+ve	Cocci	+	+										+		Staph. aureus
8	+ve	Cocci	+	+										-		Staphylococcus spp
5	+ve	Cocci	-	-												Strephtococcus spp
6									No growth							

Key: E. coli - Escherichia coli Spp. – Specie -ve – Negetive +ve – Positive

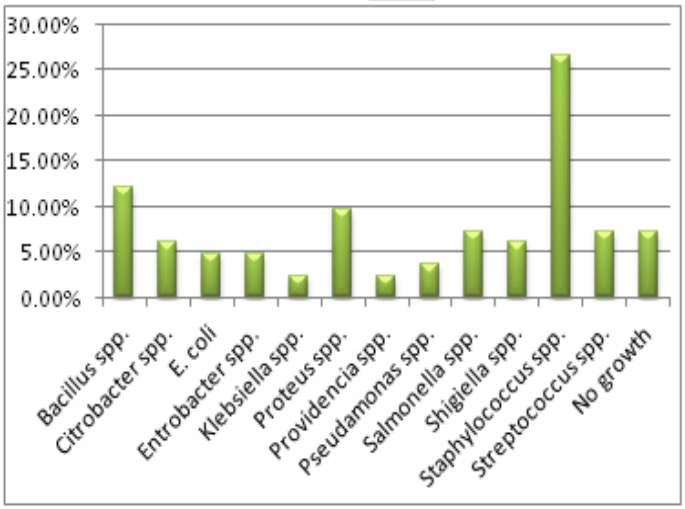

Figure 1 Isolates from Sachet Water Samples

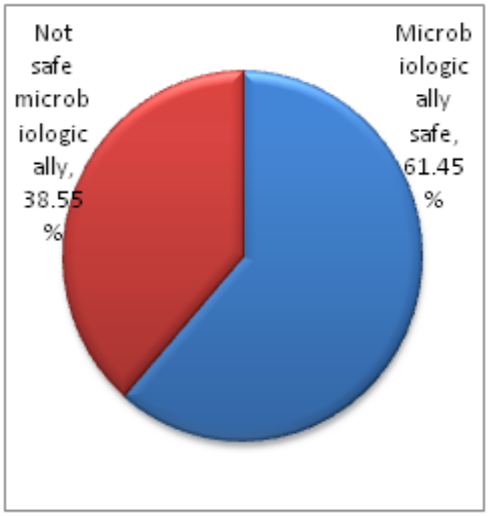

Figure 2 Sachet Water Safety

Isolates among the coliforms detected group include *Etcherichia* (4.8%), *Citrobacter spp* (6.0%), *Klebsiella* (2.4%) and *Entrobacter spp* (4.8%) (Table 1 and Figure 1), For more than 100 years, the microbial safety of drinking water has primarily been determined by testing for bacterial 'indicators' of fecal pollution (EPA, 2006), Therefore the samples detected with coliforms cannot be safe by all standards. However Coliforms are relatively sensitive to disinfection; hence their presence in drinking water can be an indication of inadequate disinfection.

It has been reported that, *E.coli* can cause serious diseases, such as Urinary tract infections, bacteraemia, meningitis, and in rare cases, an acute diarrhea (WHO, 2006), and it is considered the most specific indicator of fecal pollution (NHMRC, 2003; WHO, 2006 and UNICEF, 2008). Therefore the presence of *E. coli* in 4.8% of the sachet water samples indicate fecal pollution and is used to indicate that pathogenic bacteria, viruses and protozoa may also be present.

Bacilus spp. was detected from 12.1% of the samples (Table 1 and Figure 1). *Bacilus spp* are exceptionally resistant to unfavorable conditions (WHO, 2006). Hence they can only be an indication of inadequate filtration, but may not indicate inadequate disinfection. Except for *B.cereus* and *B.anthracis* which caused bacteraemia and anthtrax respectively, most of the *bacilus spp* are harmless; and they are often detected in drinking water supplies, even the supplies that are treated and disinfected by acceptable procedures (WHO, 2006). However, according to WHO (2006), drinking water has not been identified as a source of infection of pathogenic *Bacilus spp.* Thus the samples detected with the *Bacilus spp* may not be declared unsafe for drinking.

Proteus spp. was isolated in 9.6% (Table 1 and Figure 1). The genus *Proteus* consist of five species – *P.mirabilis P. Penneri, P.vugaries, P.myxofaciens* and *P.hauseri,* which are widespread in the environment and make up part of the normal flora of the human gastrointestinal tract (Mohr *et al*, 2000). *Proteus* was ranked the third as cause of uncomplicated cystitis, Pyelonephritis and Postatits infections. *P.mirabilis* has been implicated in bacteremia, neonatal meningoencephalitis, empyema, and osteomyelitis infections. *P.penneri* on the other hand, may play a role in diarrheol diseases and are believed to be the leading cause of kidney stone formation (Muller, 1986 and Griffith *et al*, 1976). However all these infections were nosocomial (Stamm, 1999), and are not acquired through drinking water.

Providencia was isolated in 2.4% of the samples. Like the *Proteus*, it also consists of five species, which include *P.alcalifaciens, P.heimbachae, P.rettgeri P.rustigianii* and *P.stuartii* (Mohr *et al*, 2000 and Myonsun *et al*, 2005). They are commonly found in soil, water and sewage (Mohr *et al*, 2000). Relevance of *Providencia* to human diseases was still not clear (Albert *et al*, 1992); but Myonsun *et al* (2005) identify *Providencia spp* as cause of diarrhoea and vomiting. However, the exposure according to them occurred through food, not water.

Pseudomonas spp were detected in only 3.6% of the samples. However, out of the numerous species under the genus *Pseudomonas*, only *P. aeruginosa* is medically important in drinking water quality analysis. It is associated with water-born outbreak in recreational water (Aysel *et al*, 2012); but apart from individual with some predisposing factors (burn and surgical wounds, physically damaged eye, profound neutropenia and cystic fibrosis), healthy persons are usually infractory to infection with P. aeruginosa through drinking water (Hardalo and Edberg, 1997). Therefor according to WHO (2006), ingestion of drinking water containing *P.aeruginosa* is not important source of infection; but is associated with complaints about taste, odor and turbidity in packaged water. However, It is not only un practical to eliminate *P. aeruginosa* from our drinking water, but attempts to do so would produce disinfection byproducts more hazardous than the species itself (Hardalo and Edberg, 1997). Thus, its presnce in drinking water can not be an indication of in adequet disinfection.

Salmonella spp. was isolated from 7.2% of the samples, with 83.3% of the genus being *S.typhi. Salmonella* infections are associated with consumption of contaminated groundwater, surface water or food, and the infections typically cause gestroenteris, bacteraemia or septicaemia, typoid fever and enteric fever (Arnold *et al*, 1985; WHO, 2006 and UNICEF, 2008). However typoid fever is associated with *S.typhi*, which make of 88.3% of the *Salmonella spp* detected (Table 1). Typhoid fever affects about 17 million people each year, causing some 600,000 deaths (UNICEF, 2008). The pathogens typically gains

entry into water system through fecal contamination from sewage discharge (WHO, 2006). It is relatively sensitive to disinfection; therefore its present in drinking water is an indication of inadequate disinfection.
Shigella spp. was isolated from 6.0% of the samples. Shigellosi epidemics can be caused by contaminated drinking water (Arnold *et al*, 1985), and all species can cause severe intestinal diseases, including bacillary dysentery, in which over two million infections occur each year, resulting in about 600,000 death, predominantly in developing countries (WHO, 2006). However, according to Kotloff and Winickoff (1999) there are estimated 165 million cases of *Shigella* infection each year, resulting in some 1.1 million deaths, mostly children under five. *Shigella spp* are enteric pathogens that can be transported by fecal-oral route through contaminated water, but the organisms are not particularly stable in water environment. Therefore their presence in drinking water indicates a recent fecal pollution of human origin (WHO, 2006).
Staphylococcus spp. was isolated in 26.5% of the samples, in which 63.6% were *S. aureus* (Table 1). *Staphylococcus spp* contains at least 15 different species most of which are harmless, but others like *S. aureus*, *S. pidemidis* and *S. saprophytic*, are associated with disease in human. Associated diseases include septicaemia, endocarditis, osteomyelitis, pneumonia etc. (WHO, 2006). They are occasionally detected in the gastrointestinal track and can be release into water through sewage contamination or by human contact into the water environment. However there is no evidence of transmission through the consumption of such water (WHO, 2006). Therefore detection of *Staphylococcus spp* in drinking water may not be a matter of serious concern. Better still, detection of such a non-spore-forming organism can be an indication of inadequate disinfection.
Streptococcus spp is isolated from 7.2% of the samples. They are Gram positive aerobic and facultatively anaerobic cocci of fecal and non fecal origin, that belongs to the family *Deinococcaceae* (Kour, 2006 and WHO, 2006). The habitat of *fecal Streptococcus* is mostly, the intestine of human and animals. However some sub-species has been found associated with vegetation, insects, and certain types of soils. Thus the usage of *Streptococcus* as indicator of fecal contamination in water analysis is only effective in conjunction with data for other coliforms species. Better still, presence of *Streptococcus spp* in drinking water can be an indication of very recent contamination; this is because *fecal Streptococcus* has short survival times outside their natural habitat.
Enterococcus spp, which is sub-group under *fecal Streptococcus* (EPA, 2006), was isolated in 1.2% of the samples (Table 1 and Figure 1). This sub-group was separated from the rest of *fecal Streptococcus* because they are relatively specific for fecal pollution; and that they tend to survive longer in water environment than the rest of *Streptococci*, and even *E.coli*. In addition they are comparatively resistant to chlorination (WHO, 2006). Thus the merit of *Entrococcus* as alternative indicator of fecal pollution has been acknowledged (NHMRC, 2003). Since *Streptococcus* and more specifically the *Entrococcus* indicate fecal pollution, the samples detected with these species cannot be safe for drinking.
From Figure 2, it is concluded that 38.5% of Sachet water brands produced in Sokoto metropolis are not safe for drinking microbiologically. This could have resulted from two factors: possible sewage contamination through base flow, leaching/infiltration from the surface (Cheremisinoff, 1998 and Oparaocha *et al*, 2010) in to the water used for the Sachet water production, and more importantly the inadequate treatment by the sachet water companies. According to Onemano and Otum (2003), some sachet water companies in Nigeria only do some minor treatment for water from springs, open wells and deep boreholes. However as far as the scope of this research is concerned, the remaining 61.5% are microbiologically safe for consumption (Figure 2 and Table 1).
Previous studies in Nigeria reported elevated levels of microbial contamination among Sachet waters produced in different locations; viz: Onweluzo and Akuagbazie (2010), Nsukka town; Oyedeji *et al*

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(2010), Ibadan metropolis and Ile-Ife city; Chinelo *et al* (2011), Owerri metropolis; Edema *et al* (2011), South-western Nigeria; Kalpana *et al* (2011), Kebbi state; Adegoke *et al* (2012), Aba; Anuonye *et al* (2012), Minna metropolis; Martin *et al* (2012), Enugu state; Muazu *et al* (2012), Maiduguri metropolis; and Waziri (2012) in Damaturu. However Adekunle *et al* (2004) reported about 94% Coliforms free in the municipal area of Ibadan city. Similarly, Oparaocha *et al* (2010) and Taiwo *et al* (2012) reported 100% Coliforms free in FUT, Owerri and Abeokuta metropolis respectively.

Spatial pattern of sachet water safety in Sokoto metropolis

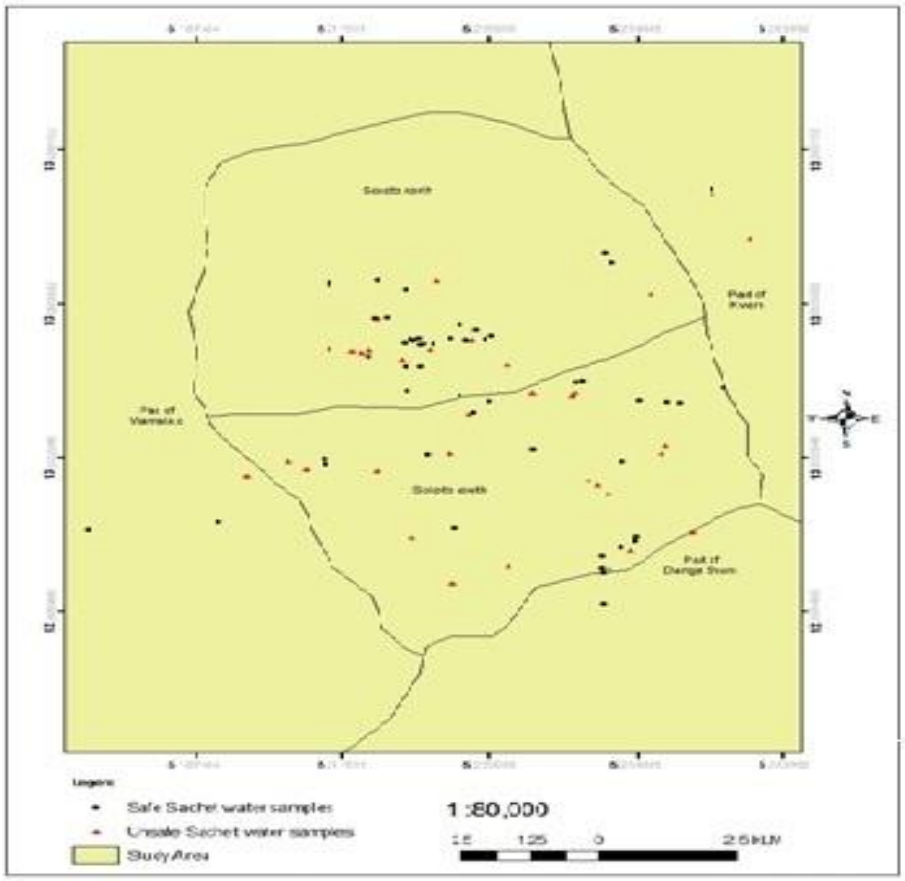

Figure 3 Spatial distribution of safe and unsafe Sachet water brands/samples in Sokoto metropolis

Figure 3 indicates that both the safe and unsafe brands are distributed all over the study area, where in many areas the safe and non-safe brands were located close to one another. Moreover the spearman Rank Correlation Coefficient fail to reveal a statistically significant correlation between Sachet water safety and Geographical location of the sachet water brands in the study area: r = 0.134, r^2 = 1.79%, p = 0.229, alpha = 0.05 (Table 2). This indicates that only 1.79% quality of Sachet water in the area is controlled by the Geographical Location of the brand. It is therefore expected that the treatment processes carried out during the production, and the integrity of the micro environment in which a perticular brand is produced contribute significantly to the safety or potability of sachet water than sorrounding environment.

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Table 2 Relationship between Sachet Water safety and Geographical locations of brands

Correlations			Sachet water Safety	Geographical location of the brand
Spearman's rho	Sachet water Safety	Correlation Coefficient	1.000	.134
		Sig. (2-tailed)	.	.229
		N	83	83
	Geographical location of the brand	Correlation Coefficient	.134	1.000
		Sig. (2-tailed)	.229	.
		N	83	83

CONCLUSION

Having analyzed the data obtained from laboratory analysis it is concluded that 38.6% of sachet water in the study area were not safe for drinking, and that Both safe and unsafe sachet water brands are unevenly distributed all over the study area, where only 1.79% quality of Sachet water is controlled by the Geographical Location.

RECOMMENDATIONS

- Water sources used for sachet water production need to be fully protected from sewage contamination.
- Effective filtration must be ensured, through the use of appropriate filters, regular back-wash of the filters and due replacement of expired ones.
- Adequate chlorination needed to be ensured so as to provide free chlorine residuals that could prevent microbial re-growth.
- The qualities of the environment in which sachet water are produced in the study area needs to be improved.
- Lastly strict adherence to water policy should be ensured.

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