

Contamination of Sachet Water Produced Within a Fast Developing Riverine Area of Lagos State, Nigeria

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ABSTRACT

Objectives: This study was conducted to determine the presence of contaminants and heavy metals in sachet drinking water samples, bought from ten different sachet water manufacturers in the rapidly developing riverine area of Ibeju-Lekki local government area, of Lagos State, Nigeria.

Methodology: Four pieces of ten different sachet water samples, from ten different manufacturers, located within the riverine area, of Ibeju-Lekki local government area, were purchased from the open market. The physical and chemical examination, of the sachet water samples were done using Standard Method, APHA (2005). The following minerals and heavy metals were analysed; Arsenic (As), Cadmium (Cd), Calcium (Ca), Chloride (Cl), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Magnesium (Mg), Manganese (Mn), and Zinc (Zn) using Atomic absorption spectrophotometry.

Result: Our findings showed that all sachet water samples fell below recommendation of World Health Organisation, (W.H.O.) Although, the physical and chemical analysis were 100 % within WHO recommendations, a further analysis of the mineral composition, showed elevated levels of arsenic, lead and manganese.

Conclusion: Sachet water is highly acceptable and accessible in our community, with a high rate of consumption. Therefore, it will be advisable for regulatory agencies to enforce 100 % compliance with labelling and proper treatment to avoid both acute and chronic heavy metal toxicity from its consumption.

Keywords: Contamination, Sachet water, Riverine area, Ibeju-Lekki, Industrial pollution.

INTRODUCTION

Ibeju Lekki local government area (LGA) is a riverine area in Lagos State and was created in 1990. Its population was 117,793 in 2006 according to the 2006 population census and a projected population of 162,200 was estimated for 2016. (National population census 2006).

Before its creation, the LGA was within the old Epe local government area, as a backwater suburb to the Epe central and north. However, after the creation of the local government, the area has witnessed an upsurge in the rate of development as evidenced by the presence of economic and infrastructure development. The area has demonstrated a continuous increase in commercial and industrial activities in recent years and it's fast becoming a business hub with many businesses and industries springing up.

Sachet water production is a thriving business in Lagos state and this local government is not an exemption. Bore-hole water or groundwater, is the usual

source of potable water, for most communities within the state. The search for affordable and accessible potable water, resulted to the emergence of sachet water[2]. The packaging of sachet water (packaged groundwater), popularly known as "pure water" has become a safe, accessible and affordable potable water, and also a booming business for in the country[3]. Establishing a sachet water industry is cheap, and the materials are sourced locally. Sachet water accessibility and affordability has made it a low cost alternative drinking water for rural and semi urban settings[4]. Before the emergence of sachet water, there were hand filled and hand tied transparent polythene bag packaged water. This was cheaper than sachet water but less hygienic[5]. Over time sachet water became popular and freely consumed by the both the rich and the poor[6].

Previously published studies have suggested that sachet water may be a vehicle of transmission of enteric pathogens and this has raised health concerns as well

as questions around its purity[7,8,9].

Furthermore, recent reports have suggested the presence of contaminants such as heavy metals and trace elements in underground water[10,11]. These contaminants when in high concentration are toxic to the human body, and has been reported to be responsible for diseases and illness such as gastroenteritis, vomiting, diarrhoea, dehydration, fever, and methemoglobinemia[12]. Continuous long-term contact with some heavy metals or their compounds may cause cancer[13].

With the rapid industrial development in Ibeju Lekki area, the area is at high risk of chemicals and toxic runoff from industries into the groundwater. These factories also emit toxic substances into the air and effluents into the soil. These pollutants and effluents from factories find their way into underground water and subsequently alter the physical, chemical and biological composition of underground water[14]. The effluents and pollutants from these factories contain heavy metals which can accumulate in underground water. If the underground water is not well treated and it is used in the production of sachet water, the heavy metals will find their way into sachet water and will subsequently be consumed in sachet water. Prolong consumption of heavy metals can lead to heavy metal toxicity, which can damage organs and result into altered mental and central nervous function, reduced energy levels, and damage to blood components. Accumulation of heavy metals in the body is dangerous, because of the damage done at cellular level, which will eventually affect vital organs like the lungs, kidneys and the liver. The damage caused at cellular level can result into many diseases. This cellular damage occurs due to production of free radicals[15]. Like most developing settlements in Lagos, Ibeju-Lekki has a burden of poor potable water, hereby leaving many within the community to depend on underground water for domestic and economic activities.

We therefore, decided to studied the physical, chemical and mineral composition of sachet water produced within Ibeju Lekki LGA of Lagos State.

METHODS

Sample collection

Ten (10) sachet water samples, from different manufacturers within the riverine area of Ibeju Lekki area of Lagos state, were randomly purchased from the open market. Only sachet water samples whose factories/production were situated in Ibeju Lekki area of Lagos state were used for this study. Four pieces of each brand were purchased, clearly marked and transported to the Lagos State Drug Quality Control Laboratory, Lasuth Complex, Ikeja, Lagos State for

analysis.

Physical and Chemical examination of sachet water

The packaged water sachet surfaces were cleaned and cut with a sterilized scissor. 250mls was measured and poured into a clean sterile sample bottles. The physical examination was carried out on the 250mls poured into the clean sterile sample bottles. The ten sachet water samples were analysed for pH, colour, turbidity, temperature, total dissolved solids (TDS), total suspended solids (TSS) and conductivity.

The temperature was measured in degrees Celsius ($^{\circ}\text{C}$), using Standard Method 2550 B (APHA 2005). The Colour was determined with ultra violet (U.V.) Spectrophotometric Method according to Standard Method 2120 C (HACH LANGE DR 5000, USA.) expressed in hazen units (HU), (APHA 2005). The turbidity was determined with Nephelometric Method, as outlined in the Standard Method 2130 B: using a turbidimeter (HACH 2100P, USA) and expressed in Nephelometric Turbidity Units (APHA 2005). Conductivity was determined with a conductivity meter (JENWAY 4510, U.K) and expressed in micro-Siemens per centimeter ($\mu\text{s}/\text{cm}$), (APHA 2005). Total dissolved solids (TDS) and total suspended solids (TSS) were determined according to Standard Methods used in the examination of water and wastewater and the values were expressed in mg/L (APHA2005).

Alkalinity was determined using Titration Method and expressed in mg/L, as stated in Standard Method 2320 B (APHA 2005). Chloride was determined using Argentometric Method and expressed in mg/L according to Standard Method 4500-Cl-B (APHA 2005). Total hardness and calcium hardness were analysed according to Standard Method described by (APHA2005).

Minerals and heavy metals determination in sachet water

The following minerals and heavy metals; Arsenic (As), Cadmium (Cd), Calcium (Ca), Chloride (Cl), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Magnesium (Mg), Manganese (Mn), and Zinc (Zn) were determined for each water sample using Atomic absorption spectrophotometry (Buck Scientific, VPG 210) procedure as reported[17, 18].

Statistical analysis

Data were analysed using Graph Pad Prism, version 6.0. Data were presented as mean \pm standard deviations. The significant difference between the experimental mean and WHO standard values was put at significance $p < 0.05$.

RESULTS

Table 1: Labelled Information on Sachet

Sample	NAFDAC Number	Batch Number	Product Name	Production Address	Manufactured date	Expiry date
Requirements	+	+	+	+	+	+
A	+	-	+	+	-	-
B	+	-	+	+	-	-
C	+	-	+	+	-	-
D	+	-	+	+	-	-
E	+	-	+	+	-	-
F	+	-	+	+	-	-
G	+	-	+	+	-	-
H	+	-	+	+	-	-
I	+	-	+	+	-	-
J	+	-	+	+	-	-

Table i. The table shows the information present and missing on sachet water packaged and sold at Eti-Osa Local government area. (+) = present while (-) = missing. From the table above, we observed that none of the sachet water samples exhibited 100% compliance with basic required information such as product name, production address, manufactured and expiry dates, batch number and NAFDAC number

Table 2: Physical Analysis of Water Samples from Sachet

Sample	Colour (TCU)	Temperature (°C)	Turbidity (NTU)	Conductivity (µs/cm)	TSS (mg/L)	TDS (mg/L)	Appearance	Odour	Taste
WHO Standard	0-15	Ambient	0-5	0-1000	-	1000	Clear	Unobjectionable	Unobjectionable
A	0.00	30.4±1.02	0.65±0.02	27.2±2.22	0.00	23.11±0.23	Clear	Unobjectionable	Unobjectionable
B	0.00	30.5±0.01	0.96±0.01	22.3±1.02	0.00	73.10±0.12	Clear	Unobjectionable	Unobjectionable
C	0.00	30.5±0.21	1.94±0.04	31.4±0.21	0.00	93.32±0.24	Clear	Unobjectionable	Unobjectionable
D	0.00	30.8±0.03	0.79±0.01	7.25±1.04	0.00	83.14±0.03	Clear	Unobjectionable	Unobjectionable
E	0.00	30.5±1.01	1.19±0.02	9.21±2.03	0.00	53.48±0.21	Clear	Unobjectionable	Unobjectionable
F	0.00	30.4±0.13	0.75±0.01	23.2±1.01	0.00	43.10±0.04	Clear	Unobjectionable	Unobjectionable
G	0.00	30.8±1.03	0.96±0.02	27.3±1.24	0.00	94.22±0.22	Clear	Unobjectionable	Unobjectionable
H	0.00	30.5±0.12	1.84±0.04	31.8±2.20	0.00	55.02±0.41	Clear	Unobjectionable	Unobjectionable
I	0.00	30.4±0.02	0.89±0.03	9.15±2.02	0.00	72.66±0.24	Clear	Unobjectionable	Unobjectionable
J	0.00	30.5±0.01	1.17±0.02	11.2±1.21	0.00	81.02±0.18	Clear	Unobjectionable	Unobjectionable

Table ii. The table shows results of physical analysis of sachet water samples from Eti-Osa Local government area. Data are presented as mean ± standard deviation where n = 4. TSS = Total Suspended Solids and TDS = Total Dissolved Solids. TCU = true colour unit, NTU = Nephelometric Turbidity Unit. From the above table all the ten samples were colourless, odourless and tasteless. The turbidity for the ten samples ranged between 0.65-1.94 NTU which were within the specification. All values obtained for TDS were within WHO recommendation.

Table 3: Chemical Analysis of Water Samples from Sachet

Samples	pH	Alkalinity (mg/L)	Total Hardness
WHO Standard	6.5-8.50	≤500	≤150
A	7.05±0.03	30.12±2.03	60.06±4.03
B	7.02±1.01	98.76±4.01	60.08±3.04
C	7.06±0.08	48.50±3.04	62.08±1.12
D	7.10±1.03	72.40±5.03	12.01±0.03
E	7.13±0.02	65.02±3.01	16.02±2.08
F	7.15±1.02	60.01±1.02	58.06±4.03
G	7.04±0.08	42.02±4.01	60.04±3.31
H	7.06±1.10	82.02±2.05	64.08±4.01
I	7.08±0.03	66.03±1.04	12.20±0.03
J	7.14±0.04	52.12±2.20	26.02±2.13

Table iii. The table shows results of chemical analysis of sachet water samples from Eti-Osa Local government area. Data are presented as mean ± standard deviation where n = 4. In the chemical analysis of samples, the pH, alkalinity (mg/L) and total hardness were measured. The results showed that all parameters studied were within the WHO recommended range.

Table 4: Mineral Composition of Samples from Sachet Water

Sample	Arsenic (As)	Cadmium (Cd)	Calcium (Ca)	Chloride (Cl)	Chromium (Cr)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Magnesium (Mg)	Manganese (Mn)	Zinc (Zn)
WHO Standard	0.01	0.003	150	200	0.05	1.0	0.3	0.01	20	0.2	3.0
A	0.00	ND	24.02	49.64	0.00	0.29	0.04	0.006	8.5	0.31*	1.04
B	0.03*	0.00	24.01	35.46	0.01	0.02	0.02	0.017*	8.75	1.40*	1.90
C	0.00	ND	4.80	21.07	0.00	0.09	0.03	0.015*	1.75	2.30*	1.40
D	ND	0.002	24.82	35.46	0.02	0.10	0.03	0.011*	9.05	8.00*	1.80
E	0.01	0.001	6.414	0.02	ND	0.30	0.03	0.009	2.34	1.10*	2.50
F	ND	ND	24.02	35.70	ND	0.27	0.04	0.006	8.5	0.20	1.84
G	0.00	0.00	26.01	22.07	0.00	0.02	0.02	0.017*	8.75	0.31	1.96
H	0.02*	ND	4.85	32.44	0.01	0.08	0.03	0.021*	1.75	2.42*	1.60
I	0.00	0.002	24.52	44.02	0.00	0.10	0.03	0.014*	9.05	3.34*	1.92
J	0.03*	0.001	6.80	37.50	0.02	0.31	0.06	0.009	2.34	5.08*	2.50

Table iv. The is a display of the mineral composition analysis of the sachet analysed. The samples showed significant deviation, from the WHO recommended limits of mineral composition for potable water. In more than 50% of the samples studied, we found lead and manganese to be highly elevated.

DISCUSSION

We observed from our study that all sachet water samples had 0 % compliance with regards to display of manufacture date, expiry date, and batch number (Table 1). However, there was 100 % compliance with regards to display of batch number, NAFDAC registration number, product name and product address. These findings were similar to that of Omalu ICJ *et al.*, 2010 [19].

Labelling of sachet water with manufacturing and expiry date is very important because, it has been reported that long time storage degrades water quality and this could have health implications[20]. Also of importance was the batch number labelling. This is vital as there may be a need to trace or recall products from the market when there are concerns on the quality of the product[21]. This poor labelling attitude may be due to lack of knowledge of this basic requirement on the part of the manufacturers or a deliberate act to make it impossible to recall and trace sachet water from the open market back to the manufacturers in the event of health concerns.

Table 2 showed the results of physical analysis of the 10 sachet water samples studied. All 10 samples were colourless, odourless with no taste. The temperature of all samples were between 30.4±0.13°C and 30.8±1.03°C, with an average temperature of 30.4°C. This was within the WHO recommendation of ambient temperature, as these temperatures data were about the room temperature where samples were stored. The turbidity of all samples were low and within WHO range (0-5 NTU). The results gotten for Total suspended solids (TSS) were also impressive, as all samples had no suspended solids. However, our analysis discovered dissolved solids i.e the combined sum of all ion particles < 2 microns (0.0002cm) in all samples, but these values were low when compared to WHO recommendation of 1000 mg/L. The mean TDS was 65 mg/L. This probably explains why the water was tasteless, as high level of TDS affects the taste of water, giving it an alkaline taste[22].

The conductivity data from the 10 samples

studied were between 7.25±1.04 µs/cm and 31.8±2.20 µs/cm with a mean value of 20.0 µs/cm. These values were within the WHO range, of 0-1000 µs/cm for safe water and also suggestive that all sachet water analysed contained few dissolved ions. Our conclusive findings on the physical analysis of the 10 samples studied was suggestive of no contamination from any organic substance from the soil, or any constituents of streams, lakes or sea. These findings were similar to the findings of Danso Boateng E and Frimpong IK[23].

Table 3 shows the chemical analysis of sachet water studied. The pH of the sachet water studied were between 7.02±1.01 - 7.15±1.02 and a mean pH of 7.07, which was within the WHO recommended range of 6.5-8.50. The pH values obtained confirmed that the water samples were not acidic rather slightly alkaline and as such can be considered safe, as pH values within WHO recommendation are considered soft water and does not pose a health hazard. The alkalinity values were also all within the WHO recommendation of 0-500 mg/L, with the lowest value as 30.12±2.03 mg/L and the highest value was 98.76±4.01 mg/L. Chemical analysis data from our studied samples showed that all 10 samples, were soft water not acidic with low range of total hardness level. A previous study in the northern part of Nigeria, reported similar findings[24].

Table 4 is the summary of the minerals and heavy metals analysed in the sachet water samples studied. Calcium (Ca), Chloride (Cl), Copper (Cu), and Magnesium (Mg) were all within WHO recommended range. These macro minerals (calcium and magnesium), and micro minerals play vital roles in the immunity of the body[25], while the deficiency of Magnesium, can result to cardiac and neurological dysfunction[26]. Chloride is an abundant biological anion that is pivotal in regulation of ion channels in the human body, it also plays the role of counter-ion in anion-exchange mechanisms in cellular transport systems. This substantiate the important of chloride in mechanisms that regulates cell volume and pH. Therefore, the presence of these macro and micro minerals in sachet water could serve as safe dietary

source when water is drunk and the probability of toxicity will be rare, because they are within recommended range. Cadmium and Zinc are metals found in the soil and both belong to group 12 of the periodic table. They are both essential cofactors for enzymatic reactions in the body. Zinc is a cofactor for many enzymatic reaction (metalloenzymes), while Cadmium a naturally occurring element is also a catalytic metal for cadmium- carbonic anhydrase enzyme. Cambilistic enzyme such as Cadmium-specific carbonic anhydrase 1 use either Zn or Cd for its catalytic reaction[27]. Both Cadmium and Zinc were within the recommended limits in all the sachet water studied and therefore rules out the possibility of toxicity on consumption.

The element Arsenic can be found in its pure form or in combination with other metals or sulphur, therefore its toxicity may occur along side with other element toxicity. 30% of the samples analysed had Arsenic levels exceeding the recommended WHO limit. Therefore, prolonged consumption of arsenic-contaminated water can result to arsenic poisoning, and present with symptoms such as skin pigmentation, vomiting, abdominal discomfort and bloody diarrhoea[28]. Other medical conditions reported from arsenic poisoning are Raynaud's phenomenon, acrocyanosis, toxic delirium and encephalopathy and more severe diseases such as Blackfoot disease was reported in Taiwan[29].

Naturally occurring Chromium can be found in soil and it exist in various oxidative state ranging from chromium (II) to chromium (VI). However, elemental chromium known as chromium (0) does not occur naturally so also chromium (VI) rarely occurs in nature but can originate from anthropogenic sources.

It has been reported that ingestion of chromium (VI) can induce tumour in the digestive tract[30]. All sachet water samples analysed had chromium, copper and iron levels within the acceptable WHO limits. While those of lead and magnesium were outside the upper limit of WHO recommendation. 60 % of the samples had Lead values over the upper limit while 80 % of the samples studied had Manganese values over the upper limit of WHO recommendation. Past study has shown that exposure to high lead levels resulted in renal tubular damage with associated glycosuria and aminoaciduria[31]. Furthermore, Lead toxicity has also been reported to reduce immune response[32]. The trace element Manganese (Mn) is a trace element needed for development and body functioning of the human body. It also regulates many enzymes throughout the body, but in excess can be toxic. In early manganese toxicity symptoms such as aggressiveness, and irritability may be present and with prolonged toxicity, manganism a neurological disorder develops[33]. This disorder is characterised by difficulty in walking, spasms of facial muscles and tremors. All sachet water samples analysed except one showed deranged mineral composition which could be of considerable health concern if consumed over a prolonged period of time.

CONCLUSION

The physical, chemical and mineral composition of the ten sachet water samples produced and bought from the open market at Ibeju Lekki LGA were analysed. Our study showed that sachet water produced in the riverine area of Ibeju Lekki LGA, did not exhibit 100 % compliance with basic required information such as product name, production address, manufactured and expiry dates, batch number and NAFDAC number. Although, the physical and chemical analysis were 100 % within WHO recommendations, however a further analysis of the mineral composition showed elevated levels of arsenic, lead and manganese.

In view of the acceptability of sachet water in our community and its consumption by many it will be advisable for regulatory agencies to enforce 100 % compliance with labelling and proper treatment to avoid both acute and chronic heavy metal toxicity from its consumption.

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