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Sachet Water Quality and Brand Reputation in Two Low-Income Urban Communities in Greater Accra, Ghana

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Abstract. Sachet water has become an important primary source of drinking water in western Africa, but little is known about bacteriologic quality and improvements to quality control given the recent, rapid evolution of this industry. This report examines basic bacteriologic indicators for 60 sachet water samples from two very low-income communities in Accra, Ghana, and explores the relationship between local perceptions of brand quality and bacteriologic quality after controlling for characteristics of the vending environment. No fecal contamination was detected in any sample, and 82% of total heterotrophic bacteria counts were below the recommended limit for packaged water. Sachets from brands with a positive reputation for quality were 90% less likely to present any level of total heterotrophic bacteria after controlling for confounding factors. These results contrast with much of the recent sachet water quality literature and may indicate substantial progress in sachet water regulation and quality control.

INTRODUCTION

Sachet water or pure water, 500-mL heat-sealed plastic sleeves of drinking water, has become an immensely popular form of packaged drinking water in the face of urban drinking water shortages in western Africa.[1,2] The sachet water industry achieved rapid growth in the mid-2000s beginning in Nigeria and Ghana, and continues to fill gaps in consumer demand, particularly in areas with limited piped water services.[3] The urban poor remain especially vulnerable to variability in drinking water supplies,[4,5] and sachet water has not alleviated these concerns despite evidence of increased reliance on sachets by poorer communities.[6] Despite significant tradeoffs such as social justice concerns over pricing and the sustainability of plastic waste generation,[7] the industry has improved access to drinking water in urban Ghana, and sachets may even confer a health benefit if consumed in lieu of poorly-stored household water.[8] In the 2010 Ghana census, 28% of households across the Accra metropolitan area reported using sachet water, a rare product just a decade prior, as the primary drinking water source.

The ubiquity of sachet water in Ghana is undeniable, yet little is known about its bacteriologic and chemical quality. Several studies have reported poor bacteriologic or physiochemical quality of sachet water in Ghana over the past decade,[9–19] although a recent review of this literature through 2010 found that most sachet quality studies have suffered design flaws such as tiny samples sizes or egregiously non-random sampling.[3] The sachet water industry has also undergone significant transformation since the late 2000s because many cottage-industry players have been replaced by large corporate-type producers who are importing heavy industrial machinery to filter and process sachet and bottled water. Consistent quality control of sachet water has so far been unattainable in Nigeria, but in Ghana, the comparatively smaller and more concentrated urban market has enabled the Ghana Standards Authority to register most sachet producers and enforce standards over the past few years. Our field work now suggests that brand awareness among consumers is on the increase and that the conscious patronage of brands exhibiting better taste and no particles constitutes substantial market-based pressures for quality control by producers. Low-quality sachet brands may only persist in poor neighborhoods with severe drinking water shortages (i.e. among consumers with fewer choices).

Despite this progress in the sachet industry, the preponderance of studies with flawed designs and over-reaching generalizations about sachet water quality threaten to build a consensus that all sachet water is of dubious quality even when sachets remain a heterogeneous product in a rapidly evolving industry. No definitive study of sachet water has been conducted in any nation, and water access for a significant number of urban poor would be severely marginalized if the government banned sachets as part of a larger ban on plastic bags, a proposal that resurfaces annually in Ghanaian policy circles concerned with waste management, and has precedent in sub-Saharan Africa.[20]

This study builds on previous work by analyzing the relationship between local perceptions of sachet brands, additional sachet characteristics, and basic bacteriologic indicators for 60 sachet water samples in two low-income communities in the Greater Accra Region. This study might be the first to incorporate brand awareness and inventory point-of-sale characteristics, such as type of vendor or storage conditions, into an evaluation of sachet water quality. We hypothesize that “the consumer is always right”: brands perceived more favorably will exhibit lower degrees of bacteriologic contamination after controlling for potentially confounding factors. We conclude by discussing additional open issues regarding sachet water quality and implications for regulators.

MATERIALS AND METHODS

Study area. Old Fadama and Old Tulaku are both very-low-income urban communities in the Greater Accra Region (Figure 1) and would be considered slums by most housing and municipal service criteria. They share many demographic similarities; because of the high degree of sachet water use and generally low levels of education and disposable income, these

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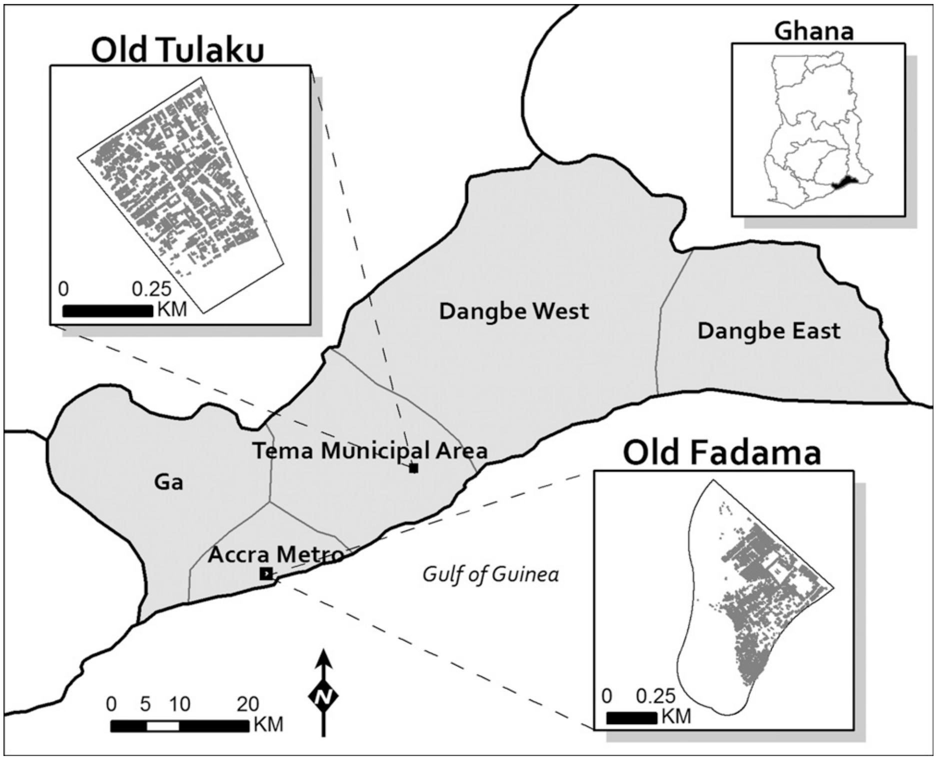

FIGURE 1. Greater Accra Region (shaded) of Ghana, its 2000 census districts, locations of the two study communities (Old Fadama and Old Tulaku), and corresponding 2006 buildings layer from Ghana Lands Commission.

communities are particularly vulnerable to the presence of low-quality sachet water in the local market.

Old Fadama began as a temporary lodging site in the 1980–1990s for internally displaced persons as a result of ethnic clashes in the northern parts of the country.[21] Its population is believed to exceed 80,000 given a combined estimate of actual permanent residents, and temporary and fluid populations,[22] and is regarded as the largest urban slum in Ghana. Residents do not have legal tenure to the land they inhabit because that space has not been planned for residential purposes,[23] and housing is generally built from sub-standard materials. There is no governmental oversight of the provision of social services, and water and sanitation options in Old Fadama are particularly dire. The neighborhood is bounded on the west by the Korle Lagoon, large canals to the south and east, and the Agbogbloshie market to the north.

Much less has been written about Old Tulaku, a community spanning approximately half the geographic area of Old Fadama. A fringe community in the fast-growing Ashaiman Municipality, which has an estimated population of 190,972,[24] Old Tulaku was not planned as a residential zone; thus, residents do not have legal tenure to the lands they occupy. The annual population growth rate of the municipality is approximately 4.6%, which is about 2% points higher than the national average, primarily because of migration and birth rates.[25] Old Tulaku contains approximately 250–300 housing structures, which are typically wooden shacks with sporadic shallow, hand-dug drains, and many residences have electricity. The community receives relatively stable municipal water service, though rarely piped into homes. The community is bounded on the west by the Ashaiman Road (also known as the Ashaiman-Tema Highway), to the north by Ashaiman-Lashibi Road, to the east by an unpaved lane (the second lane east of, and parallel to, Ashaiman Road), and to the south by the Ashaiman-Tema Highway toll booth road.

Study sample. Old Fadama and Old Tulaku were selected for this study from expert knowledge of local drinking water options, and after previous focus groups in these communities revealed high use of sachet water and strong brand awareness. Eight age- and sex-stratified focus groups in these communities, conducted in June 2013, disclosed consistent perceptions of quality among various brands of sachet water. Using these focus groups transcripts, we were able to dichotomize the reputation of all sachet water brands available in these communities into good or poor. The distinction was often priced into the market because poor brands were often sold at a discounted price of 3 sachets for 20 pesewas (3-for-20) instead of the usual 10 pesewas each, thus lowering the perceived quality of these brands to consumers.

Thirty samples of sachet water were purchased in each neighborhood, each from a unique vendor, and split evenly between perceived good and poor brands. Because sampling occurred in June, the height of the rainy season in Accra, fewer sachet water vendors were present relative to drier months, and thus our sample necessitated some brand duplication. In our sample, the brands classified as good were (in alphabetical order) Everpure (3), Ice Cool (1), Ice Pak (16), Mobile (2), Special Ice (6), and Standard Water (2); those classified as poor were Aqua Pure (1), Aqua Star (2), Aqua Taste (2), Capital O2 (1), Clear Taste (1), Cony's Pak (2), Deona (3), Ice Light (1), Nak (2), Nhyira (1), Queens (1), Royal Nsu Pa (4), Super Global (5), Valley (3), and Zam Aqua (1). The sample was not intended to be a representative sample of all sachet water or of any particular brand, but

Table 1
Potential confounders of sachet water quality, Accea, Ghana

Characteristic	Link to water quality
Neighborhood	Low-quality product could be steered into certain neighborhoods
Brand	Could signal differential quality control
Price	Could signal differential quality control
Vendor type	Could indicate variable care in storage, freshness of inventory
Sun exposure	Ultraviolet light could inhibit bacterial growth
Chilled	Could inhibit bacterial growth
Vendor as wholesaler	Could indicate freshness of inventory
Days sachet in stock by vendor	Could indicate freshness of inventory
Cheap plastic wrapper	Could signal differential quality control
Visible particles	Could signal differential quality control

rather a representative snapshot of the sachet water options available to consumers of these communities on a typical weekday in the rainy season.

To better understand factors that could influence sachet water quality, we inventoried several characteristics about the sachet itself and the conditions under which it was sold. In addition to the neighborhood, brand, and brand reputation, we recorded the price (10 pesewas versus 3-for-20 pesewas), vendor type (stores, stalls/kiosks, mobile/walking), whether sachets were stored in the sun, whether sachets were chilled for purchase, whether the vendor served as a wholesaler, the number of days that the vendor was in possession of the sachets (since purchase from their wholesaler/distributor), whether the sachet was packaged in lower-grade plastic, and presence of visible particles. The rationale for how each of these independent measures could influence sachet water quality is shown in Table 1.

Test media and indicators. All samples were purchased before noon and transported to the Council for Scientific and Industrial Research Water Research Institute laboratory for processing in Accra during the afternoon that same day. Using American Public Health Association standards, we analyzed sachets for total coliforms (TC), fecal coliforms (FC), and *Escherichia coli* (EC), all in colony-forming units (CFU) per 100 mL by using the membrane filtration method, and for total heterotrophic bacteria (THB) in CFU/mL by using the pour plate method.[26] These four common indicators (TC, FC, EC, and THB) constitute our dependent measures. Ghana Standards Authority sets local water quality standards[27] and for packaged water requires limits of 0 units for TC, FC, and EC, and an international consensus limit of 500 CFU/mL for THB.[28]

Culture media (M-FC agar [HiMedia, Mumbai, India] and Harlequin *E. coli*/Coliform medium [Lab M, Heywood, United Kingdom]) were prepared according to the manufacturer's instructions, sterilized at 121°C for 15 minutes, and dispensed into sterile petri plates. The membrane filtration manifold support was sterilized by flaming with a gas lighter for five seconds. A sterile 0.45-μm membrane filter was placed on the base of the membrane filtration manifold by using sterile forceps, and a sterile funnel was placed on the filter base and locked in place. The sachet was shaken vigorously and a corner was wiped with clean tissue soaked with 70% ethanol. The sterile corner of the sachet was cut by using sterile scissors (sterilized by dipping the scissors in 96% ethanol and flamed with a Bunsen burner). A total of 100 mL of the sachet water was poured into the sterile funnel and filtered with the aid of a vacuum pump. The funnel was removed and, using sterile forceps, we removed the membrane filter and placed it on the selected medium in petri plates. The petri plates were inverted and incubated at 44°C ± 0.5°C for 24 hours for FC and 37°C ± 0.5°C for 24 hours for TC and EC. After incubation, colonies were counted by using a colony counter. Blue colonies were recorded as fecal coliforms on M-FC agar. Dark blue to violet colonies were recorded as *E. coli,* and all pink, salmon red, and dark blue to violet colonies were recorded as total coliforms on Harlequin *E. coli*/Coliform medium.

Samples were analyzed for THB by using the pour plate method. Duplicate dilutions of 0.1 mL and 1 mL of each sample were plated on nutrient agar and incubated at 37°C for 48 hours. Nutrient agar was prepared according to manufacturer's instructions and sterilized at 121°C for 15 minutes. All colonies were counted and an average of duplicate samples was recorded as THB counts/mL (CFU/mL) for the sample.

Statistical analysis. We used Pearson's chi-square and analysis of variance *F* tests to compare nominal and continuous measures, respectively, between the two neighborhoods (30 samples per group), and between pooled good and poor brand reputations (30 samples per group). We did not test for differences across the four combinations of neighborhood and reputation because we did not make the *a priori* assumption that sachet characteristics among all four groups should necessarily be alike. Multivariable logistic regression was used to assess predictors of the bacteriologic indicators; we attempted to fit multilevel logistic regression models to control for sample location but our sample size produced unstable variance estimates. All quantitative analyses were conducted by SPSS version 21 software (IBM, Armonk, NY). This study was approved by the Institutional Review Board at the University of Miami and with independent oversight from Ghana Urban Water Ltd. in Accra. Ghana Urban Water Ltd. played no other role in this study.

RESULTS

Sachet quality by neighborhood and brand reputation. We summarize descriptive information for the 60 sachet water samples, stratified by neighborhood location and by brand reputation (Table 2). There were only a few statistically significant differences between the sub-samples of 30 sachets from each neighborhood. Sachets from Old Fadama were much more likely to have been purchased by a mobile vendor than a store or stall ($\chi^2 = 15.94$, $P < 0.001$), probably because of the much larger geographic area of the neighborhood compared with Old Tulaku. These mobile vendors are typically women carrying sachets in large bowls on their heads, and thus in Old Fadama sachets sampled were also more likely to be stored in the sun than in Old Tulaku ($\chi^2 = 7.18$, $P = 0.007$). In Old Tulaku, compared with Old Fadama, sachet brands with a poor reputation were more likely to be sold at a discounted price ($\chi^2 = 5.96$, $P = 0.015$), and vendors were in possession of their inventory for twice the number of days (4.2 versus 2.1 days; $F = 3.21$, $P = 0.078$). There were no statistically significant differences between communities for chilling

TABLE 2
Descriptive statistics for 60 sachet water samples, stratified by purchase location and brand reputation, greater Accra, Ghana*

Characteristic	Old Fadama		Old Tulaku		Significance
	Good	Poor	Good	Poor	
Nominal measures: count (%)					
Discounted price					†**
No	15 (25)	12 (20)	15 (25)	4 (7)	
Yes	0 (0)	3 (5)	0 (0)	11 (18)	
Vendor type					§¶
Store	0 (0)	2 (3)	5 (8)	4 (7)	
Stall	4 (7)	7 (12)	7 (12)	11 (18)	
Mobile	11 (18)	6 (10)	3 (5)	0 (0)	
Stored in sun					#
No	6 (10)	8 (13)	11 (18)	13 (22)	
Yes	9 (15)	7 (12)	4 (7)	2 (3)	
Chilled for purchase					‡
No	1 (2)	4 (7)	1 (2)	4 (7)	
Yes	14 (23)	11 (18)	14 (23)	11 (18)	
Vendor is a wholesaler					
No	15 (25)	12 (20)	14 (23)	14 (23)	
Yes	0 (0)	3 (5)	1 (2)	1 (2)	
Cheap plastic wrapper					‡
No	15 (25)	12 (20)	15 (25)	13 (22)	
Yes	0 (0)	3 (5)	0 (0)	2 (3)	
Continuous measures: mean (SD)					
Days in stock	2.3 (3.6)	1.9 (1.3)	2.7 (2.7)	5.7 (7.6)	††
Total coliforms	0 (0)	0 (0)	0 (0)	28.7 (50.6)	‡**
Fecal coliforms	0 (0)	0 (0)	0 (0)	0 (0)	
Escherichia coli	0 (0)	0 (0)	0 (0)	0 (0)	
Total heterotrophic bacteria	201.9 (484.5)	255.1 (502.8)	106.6 (359.0)	589.4 (813.5)	§

*Statistical significance was determined by using Pearson's chi-square test for nominal measures and analysis of variance for continuous measures.
† $P < 0.001$ for differences across pooled quality reputation (good vs. poor).
‡ $P < 0.05$.
§ $P < 0.10$.
¶ $P < 0.001$ for differences across location (Old Fadama vs. Old Tulaku).
# $P < 0.01$.
** $P < 0.05$.
†† $P < 0.10$.

the sachets, wholesaling, or quality of plastic. None of the 60 sachets sampled contained visible particles upon inspection at the point of purchase.

When pooling the 30 sachets in each brand reputation category (good versus poor), we again observed statistically significant differences in discounted price, because none of the good brands were discounted ($\chi^2 = 18.26$, $P < 0.001$). Brands with good reputations were also more frequently chilled ($\chi^2 = 4.32$, $P = 0.038$), never packaged in cheap-feeling plastic wrappers ($\chi^2 = 5.46$, $P = 0.020$), and purchased from mobile vendors ($\chi^2 = 4.98$, $P = 0.083$).

Bacteriologic indicators. Seven sachet water samples (11.6%) exhibited positive TC counts ranging from 12 to 186 CFU/100 mL (mean = 61 CFU/100 mL) and all came from poor brands in Old Tulaku. Thirty-six samples (60%) exhibited positive THB plate counts ranging from 1 to 2,900 CFU/mL (mean = 480 CFU/mL), although only 11 samples (18%) exceeded the acceptability threshold of 500 CFU/mL. There were no statistically significant differences in THB between study communities. None of the 60 samples were positive for FC or EC. Because the sub-sample of poor brands in Old Tulaku (n = 15) was too small for regression modeling of the seven samples that exhibited positive TC counts, and because we observed no fecal contamination that required further explanation, we took a closer look at factors associated with the presence of heterotrophic bacteria.

Predictors of heterotrophic bacteria. No significant predictors emerged for the 11 samples with THB > 500 CFU/mL. A multivariable logistic regression model of select covariates and the presence of any heterotrophic bacteria is shown in Table 3. We hypothesize that brand reputation would be associated with THB presence, and iteratively add covariates to the model until we reach the most parsimonious model that minimizes –2LogL. Neighborhood was not statistically significantly associated with THB presence (odds ratio [OR] for Old Tulaku = 1.74, 95% confidence interval [CI] = 0.21–14.69, $P = 0.609$), but sachet brands perceived to have a good reputation were approximately 90% less likely to display THB presence after adjusting for covariates (OR = 0.09, 95% CI = 0.01–0.62, $P = 0.014$). Vendor type was significant overall ($P = 0.007$), although mobile vendors were only marginally associated with THB presence (OR = 9.83, 95% CI = 0.86–112.40, $P = 0.066$). Sachets chilled for purchase also approached statistical significance in reducing the adjusted odds for THB presence (OR = 0.19, 95% CI = 0.03–1.49, $P = 0.115$) because chilling would generally be expected to slow bacterial regrowth within the sachet. The interaction of neighborhood and brand reputation was not significant, but the presence of this term in the model strengthens the association between brand reputation and THB presence. Model diagnostics include –2LogL = 60.90 and Nagelkerke pseudo-$R^2 = 0.38$.

DISCUSSION

This study examined basic bacteriologic indicators for 60 sachet water samples from two very low-income communities and inventory characteristics hypothesized to influence

TABLE 3

Multivariable logistic regression model of the relationship between select sachet water characteristics (n = 60) and any presence of heterotrophic bacteria (THB > 0 CFU/mL)*

Characteristic	*B*	SE	OR	95% CI	*P*
Constant	2.24	2.59	9.43	–	0.386
Neighborhood is Old Tulaku	0.56	1.09	1.74	0.21–14.69	0.609
Good brand reputation	–2.37	0.96	0.09	0.01–0.62	0.014
Neighborhood × brand reputation interaction					0.256
Old Fadama × good (reference)	–	–	–	–	
Old Fadama × poor	–1.55	1.36	0.21	0.02–3.07	0.256
Old Tulaku × good†	–	–	–	–	
Old Tulaku × poor†	–	–	–	–	
Vendor type					0.007
Store (reference)	–	–	–	–	
Stall	–0.70	0.96	0.50	0.08–3.27	0.467
Mobile	2.29	1.24	9.83	0.86–112.40	0.066
Chilled for purchase	–1.65	1.05	0.19	0.03–1.49	0.115
–2LL = 60.90; Nagelkerke R^2 = 0.38					

*THB = total heterotrophic bacteria; CFU = colony-forming unit; OR = odds ratio; CI = confidence interval.
†Not estimated because of collinearity.

the heterogeneity of sachet quality on the Ghanaian market. Using results from focus groups in our study communities, we categorized all brand perceptions in these communities into good or poor, and explored the relationship between brand perception and bacteriologic quality while controlling for multiple characteristics of the vending environment. No fecal contamination was detected, and only 11.6% of samples exhibited TC counts > 0. Varying levels of THB were present in 60% of samples, although the average THB count was below the recommended threshold of 500 CFU/mL and only 18% of all samples exceeded this level. These THB counts stand in stark contrast with those from a recent study in Accra, which reported that 87% of 60 sachet samples had THB > 500 CFU/mL and more than one-third of the samples were "too numerous to count."[18]

The presence of any THB was most strongly associated with being from a brand popularly perceived to be of poor quality, thus supporting the core hypothesis of this study. Chilled sachets were somewhat less likely to have any THB, which seems intuitive given that colder temperatures inhibit bacterial regrowth. Sachets sold by a mobile vendor were somewhat more likely to have any THB, a result that lacks a simple explanation given that mobile vendors carry sachet water on head-mounted bowls in direct sunlight (ultraviolet light [UV] suppresses bacterial growth), and that most mobile vendors acquire their sachet water stock the same day that they vend it. It is plausible that the young girls who typically hawk sachet water are sold older stock by wholesalers, but we did not test this hypothesis. To put these results in greater context, our two study communities are very well-known, poor neighborhoods that rely extensively on sachet water and thus are markets that would seem susceptible to savvy sachet producers trying to unload sub-standard product. It is not empirically known if low-income areas disproportionately serve as markets for poor brands, but our work offers no evidence that this necessarily implies a public health hazard.

Although this report might be the first paper to look at the relationship between sachet brands and quality, it is not the first paper to portray sachet water as a safe product in Ghana. A 2010 study found no TC, FC, or EC among 60 sachet water samples gathered near Koforidua, approximately 80 km north of Accra.[29] A 2004 study in six coastal districts of the Central Region of Ghana found that household use of bottled and sachet water (analyzed as a single category) was protective against finding EC in household drinking water relative to all other sources.[30] These results diverge from most of the sachet quality literature and underscore the variation in sachet water quality that we are attempting to sort out. As stated earlier, our sample should not be generalized to all sachet water, nor to the specific brands named, but rather is representative of consumer options on a random day in the rainy season. We hope to replicate this study in the driest months to check for seasonal demand effects on the bacteriologic profile of sachet water in local markets.

The bacteriologic indicators assessed in this study limit what we can infer about the safety of these particular sachet water samples. The fact that we did not detect fecal contamination in any sample from these very low-income communities is reassuring because Accra already battles sporadic cholera outbreaks caused by occasional breaches (often related to illegal connections) in its municipal water network. The absence of fecal contamination reaffirms recent progress by the Ghana Standards Authority and sachet industry to improve quality control, although more comprehensive studies, particularly those that culture specific organisms of public health importance, are needed to confirm the breadth of this progress. In lieu of fecal contamination, we modeled the effects of brand reputation and other sachet characteristics on THB. Heterotrophic plate counts detect a wide spectrum of organisms targeted by water disinfection processes, but these are only a small proportion of all organisms present in drinking water. THB is not a reliable indicator of pathogens, but can be a useful proxy for the effectiveness of water treatment.[31] Although THB remains a commonly used indicator for drinking water management, is not itself necessarily even a health hazard.[32] The higher THB counts in the poor reputation brands may be treatment-related, storage-related, or both.

The effects of storage-related factors on sachet quality remain understudied and largely unknown. The life cycle of sachet water tends not to exceed more than a few months (generally during rainy periods). Thus, the effect of sunlight may be more important given that sachets often spend much of their life cycle under the equatorial sun (e.g., on the back of a flatbed delivery truck or on a street vendor's head). Although UV light exposure may hypothetically inhibit pathogen growth/survival in sachets, there remains no known literature on the effects of plastic leachates, such as bisphenol-A or phthalates. The research gap on plastic leachates is largely attributable to resource and technology constraints in western Africa, but these UV tradeoffs are nonetheless an avenue for future study.

Sachet water continues to improve drinking water access in cities in western Africa and has become a particularly important source of water in Accra. The sachet industry is still maturing in Ghana and may someday achieve levels of quality control and product homogeneity seen in the bottled water industry, despite lingering concerns over plastic waste management. In the meantime, additional studies are needed to understand the variation in sachet water quality attributable to branding, storage, and the vending environment. If sachet water is adopted *en masse* by neighboring countries, as seen in Ghana, it would behoove water policy makers to learn from the experience in Ghana and promote the best possible drinking water quality for all.

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