What Point-of-Use Water Treatment Products do Consumers Use and Value?
Evidence from a Randomized Controlled Trial among the Urban Poor in Bangladesh

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Abstract

Background: There is evidence that household point-of-use water treatment products can reduce the enormous burden of water-borne illness. Nevertheless, adoption among the global poor is very low, and little evidence exists on why.

Methods: We gave 600 households in poor communities in Dhaka, Bangladesh randomly-ordered two-month free trials of four water treatment products: dilute liquid chlorine (sodium hypochlorite solution, marketed locally as Water Guard), sodium dichloroisocyanurate tablets (branded as Aquatabs), a combined flocculant-disinfectant powdered mixture (the PUR Purifier of Water), and a silver-coated ceramic siphon filter. Consumers also received education on the dangers of untreated drinking water. We measured which products consumers used with self-reports, observation (for the filter), and chlorine tests (for the other products). We also measured drinking water’s contamination with E. coli (compared to 200 control households). After the trials we ran real-money auctions to measure willingness-to-pay for each product.

Findings: Households reported highest usage of the filter, although no product had even 30% usage. E. coli concentrations in stored drinking water were generally lowest when households had Water Guard. Households that self-reported product usage had large reductions in E. coli concentrations as compared to controls. Households’ willingness-to-pay for these products was quite low on average, although a modest share was willing to pay the actual or expected retail price for the low-cost chlorine-based products (Water Guard and Aquatabs).

Conclusion: These results demonstrate a modest potential market for low-cost water treatment products among low-income urban residents of Dhaka, Bangladesh. At the same time, low usage of all products when households have a free trial and multiple visits explaining the dangers of untreated water makes clear that important barriers exist beyond cost, information, and variation among these four product designs. Unless demand increases markedly, household water treatment is unlikely to reduce morbidity and mortality substantially in urban Bangladesh and similar populations in the immediate future.

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Introduction

A number of careful studies suggest that treating household drinking water at the point of use (POU) could prevent many of the infant and child deaths attributable to waterborne illness in developing countries (1-3). Nevertheless, household water treatment products such as chlorine or a water filter are very rarely used by the global poor (although boiling is common in a few nations (4)).

There is little evidence on what does (or could) induce poor consumers to purchase and use POU products. Thus, our knowledge of factors promoting and impeding adoption of POU products is based on anecdotal reporting of field activities, a “gray” literature of unpublished reports (5-9) and a published article that collates the scattered documentation of sustained product use from epidemiological studies (10-12). While each report adds value, there is room to improve our understanding of the preferences for and barriers impeding use of different POU products among poor consumers.

In this research we analyze how often poor consumers in Dhaka, Bangladesh use four POU products and measure their willingness-to-pay after they have experience with each product. Along with a companion study (13), this is one of the first attempts to generate rigorous evidence of how urban households choose and use POU products when multiple products are made available.

Methods and data

Ethics Statement

Participants were briefed as to the details of the study and afforded opportunity to ask questions and receive answers to those questions. Enumerators obtained informed written consent from each respondent prior to inclusion in the study. This study was reviewed and approved by the
Ethical Review Committee at ICDDR,B and the Committee for the Protection of Human Subjects at the University of California, Berkeley.

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. All authors had access to all the data in the study. DL and SL had final responsibility for the decision to submit for publication.

Products

This study examines usage of, preferences for, and willingness-to-pay for four point-of-use water treatment products. Three of the products, which we refer to as the “chemical products,” rely on chlorine for disinfection, including: 1) locally produced and marketed liquid sodium hypochlorite (branded as Water Guard by BioChemical), 2) sodium dichloroisocyanurate tablets (branded as Aquatabs by Medentech, Ltd.), and 3) a combined flocculant-disinfectant powdered mixture (branded as PUR® Purifier of Water by the Procter & Gamble Company). The fourth product is a siphon-driven porous ceramic filter (branded as the CrystalPur Filter by Enterprise Works/VITA) (Figure 1). Each product (or a close variant, in the case of the CrystalPur, for which this is the first field trial) dramatically reduces concentrations of pathogen indicators in drinking water (13-16). The CrystalPur filter is distinct from the more common gravity-driven filters because it utilizes a siphon-driven pressure gradient to draw water through the filter element. (The manufacturer of the product provided third-party laboratory results from Waterlaboratorium Noord (May 2008) indicating >5 log10 reduction of E. coli in two tested filters. We replicated similar E. coli reduction in our own laboratory tests.) Meanwhile, a recent meta-analysis of 31 POU product studies yields a pooled estimate of 42% (95% CI: 33-50%) reduction in diarrheal disease risk (17). A range of liquid and tablet chlorine products (under various brand names) were available locally at the time of our study.
We recommended each 10 liters be treated with 4 drops of Water Guard (a 5.25% concentration), one Aquatab, or one sachet of PUR. Users can add Aquatabs and Water Guard to the container they use to carry water from an outside tap to their home. In contrast, PUR requires a second vessel and a cloth to complete the treatment process. The recommended wait-time for treatment using the chemical products is 30 minutes.

The siphon filter can sit in the stored water container if users are willing to wait to draw water through the filter when they want to drink or use the filtered water. Alternatively (and more commonly in our setting) users can filter water from a transport container into a storage container. The filter has a production rate of up to 4 L/hr, declining to 1 L/hr as the water level in the vessel declines and as solids accumulates within the filter. Users have several means maintenance options to restore filter flow after it accumulates solids including cleaning the filter’s sleeve, backwashing, and scrubbing the ceramic surface with an abrasive.

The chlorine-based products all provide protection against recontamination until all the free chlorine has reacted with the walls of the storage vessel or with contaminants and metals in the water. If a substantial share of the chlorine reacted with ammonia in the source water, the resulting chloramines still provide some residual protection against recontamination even when the free chlorine is gone.

**Experimental Design**

We conducted this research in low-income neighborhoods in the densely-populated mixed-income community of Mirpur within Dhaka (see supplementary web appendix, Figure A1). At baseline we first selected several neighborhoods that survey staff knew to be relatively poor. The field team began at one end of each neighborhood and selected every fifth household. If there was a child under 5 years old, enumerators conducted interviews on basic assets, water supply,
water treatment, sanitation, and hygiene behaviors, and if not, they approached to the next closest household and repeated. The baseline sample consisted of 800 households.

After completing the baseline survey, enumerators explained the health risks of untreated local water. For example, enumerators explained, “Human feces can enter the water as a result of faulty pipes introducing contamination from the environment. This means that even before the water gets to your household, it can be contaminated. Also, water can become contaminated easily within the home, for instance by not keeping your drinking water storage containers clean and covered at all times or by dipping your hands into the container to draw water.”

Enumerators then provided detailed presentations of the four POU products in randomized order and asked households to rank their preferences and state their willingness-to-pay for each product.

After the baseline survey, 200 of the 800 households were randomly selected as controls. Their participation in the baseline ended at this point. For the 600 treatment households, enumerators then provided one of the four products for a two-month free trial. The order of the product trials was randomized.

During the two-month product trials a separate team of technicians visited both treatment and control households to collect stored drinking water samples and ask a few questions about water collection and treatment behaviors. These visits took place roughly one to four weeks after the baseline survey and introduction of the first product and 4 to 8 weeks after later survey rounds and product introductions.

At the end of each two-month trial period enumerators visited each treatment household for a follow-up survey to measure self-reported product usage and updated product preferences and stated willingness-to-pay. Each household was then assigned a new product in random order.
The cycle was repeated four times, so that over 8 months every treatment household had a two-month trial with each of the 4 products in random order.

Enumerators visited both treatment and control households at the final survey round to collect information on final product preferences and stated willingness-to-pay for each product.

During the final survey round we further measured willingness-to-pay using the Becker-DeGroot-Marschak auction (18). In this auction each household bids its own money for each product (as opposed to stated willingness-to-pay information collected in this and all earlier survey rounds). The household wins the auction (that is, purchases the product) if its bid is greater than a computer-generated price hidden in an envelope. If the household wins, they pay the price in the envelope, not their bid (which was always at least as high as the envelope’s price). Thus, the bid determines if the household wins the auction, but not how much they pay. This auction provides incentives for truthful disclosure of willingness-to-pay as long as participants understand the rules of the auction. (See the supplementary webappendix for a copy of our auction protocol and instructions.) Participants bid on all four products, although we explained that only one randomly-selected product (also hidden in the envelope) would actually be offered for sale to them.

**Water Quality Analysis**

We analyzed multiple measures of product usage. Most directly, we asked users to self-report product usage both at the water collection visit and at the survey. Because courtesy bias can lead to over-reported product usage (19), we also analyzed several objective indicators of product usage.

We measured the concentration of *E. coli* in water stored at the household. At the water collection visit we collected stored water samples in autoclaved bottles and used cold boxes to
transport the samples to the laboratory at ICDDR,B. We assessed the concentration of *E. coli* using the membrane filtration technique (20). In brief, an aliquot of 100 ml of water was filtered through 45-micron Millipore membrane filters. Filter papers were then placed on modified membrane-thermotolerant *E. coli* agar media and incubated at 35°C for two hours and then at 44.5°C for another 22 hours. Red or magenta colonies were counted.

We utilize three measures of *E. coli* to examine usage and efficacy: fractions of homes with *E.coli* concentrations less than one colony forming unit (CFU) per 100 mL (the WHO-recommended maximum for drinking water, which we also refer to as “no detectable *E. coli*”); fractions of homes with *E. coli* concentrations < 10 CFU/100 ml; and the distribution of *E. coli* concentrations (CFU/100 ml). Note that low *E. coli* concentrations (relative to controls) depends on both homeowners using the product and the microbiological effectiveness of the product.

Also, if the user self-reported use of a chemical product (Water Guard, Aquatabs or PUR) during the water collection visit, we tested for residual free chlorine using a color wheel colorimeter (HACH LANGE GmbH, USA). However, even if a household uses one of the chemical products we will not detect free residual chlorine if all the free chlorine has reacted with the storage container or contaminants in the water.

**Sample Size, Enrollment, and Attrition**

To detect differences in proportions of product usage of 10 percentage points with 80% power at 95% confidence required a sample size of approximately 100 treatment households per product-trial, for a total of 400 households. We sampled 150 treatment households per product-trial to account for any potential attrition. We also sampled 200 households in the control group.

The study began in January 2009 with 800 participating households and was completed in December 2009 with 755 participating households, resulting in 94% retention, with similar
proportions for treatments (95%) and controls (94%). We also collected water quality data but no exit survey for 7 treatment households (1.2%) and 5 control households (2.5%). The most common reason for a household to drop out of the study was outmigration from the community. Attrition does not appear related to a household’s first assigned products or other randomized treatment assignments. When we ran a probit regression predicting dropout as a function of all treatment assignments, the joint Chi-squared test was not statistically significant (p-value = 0.24).

Randomization appeared successful. The chi-squared test p-value was 0.67 in a probit regression that predicts treatment versus control as a function of baseline literacy, household size, native Urdu speaker, type of source water, and respondent age and gender. Results on the regressions predicting dropout and randomization are in the supplementary webappendix.

Data Analysis
Household survey results were recorded in hardcopy forms and double-entered into digital forms using Epi Info (Microsoft Corp., Redmond, WA). Digital data tables were then exported into Stata (StataCorp LP, College Station, TX). Laboratory results were recorded in hard copy and double entered.

All reported confidence intervals, regressions and statistical tests take into account the repeated nature of the sampling by using the sandwich estimator for standard errors using the “cluster” option in Stata. Full details on the statistical analysis are included in supplementary webappendix.

We often report tests of statistical significance for outcomes at households with one or two of the products versus those households when they had the other products. As there are multiple comparisons possible with four different products, the p-value of a single reported test can have
inflated power. To reduce accidental data mining, we do not report comparisons between individual products if results across the four products are not jointly statistically significant.

**The Setting**

Only one third of respondents had completed primary school and the majority of per capita household incomes were less than the global poverty line of $2 (in purchasing power parity) per day.

The study area is a crowded urban community, with almost all households sharing walls. Most residences have cement floors (82%), cement or tin walls (81%), and a corrugated iron roof (92%).

A substantial minority (45%) of our sample are Urdu-speaking Bihari. The Bihari are Muslims who left Bihar and nearby north Indian states for East Bengal (later East Pakistan) at the partition of British India. In part because most opposed the independence of Bangladesh from Pakistan and many await repatriation to Pakistan, most remain living in refugee-oriented neighborhoods.

At the baseline survey, 74% of treatment households and 76% of controls reported piped water as their main drinking water source (difference not statistically significant). Most of the others store piped water in a cistern for a household or group of houses.

Almost all water stored in the control households was contaminated with *E. coli*. Over all waves, 83% of water samples from control households had detectable *E. coli*, with 33% less than 10 CFU / 100 ml. (N = 720 observations on 200 households). The mean and median *E. coli* concentrations were 182 and 43.5 CFU / 100 ml, respectively.

No controls reported treating their current drinking water with any of the point-of-use products we tested. At the same time, at baseline, 43% of all respondents claimed they treated their drinking water (at least sometimes), with 78% of those mentioned boiling and 41% mentioning
filtering through a cloth (multiple response were allowed). Fewer than 2% of all respondents at baseline mentioned a POU product such as a filter or chlorine.

**Results**

**Usage and performance indicators, averaging over all products**

Table 1 and Figure 2 present several measures of usage and performance, averaging over all products and survey waves. At the water collection visits, 21% of treatment households report having treated their water in the past 24 hours (Table 1). For the survey (typically about two weeks after the water collection visit), we defined self-reported users as those who report some or all of their current stored drinking water is treated and that they used their POU product since yesterday. The share of self-reported users with this definition is 15%, a bit lower than the proportion at the water collection visit (with its slightly different question).

The proportion of households with either measure of self-reported usage is somewhat higher than our objective measures of product usage, yet all suggest improvements in water quality (Table 1, Figure 2). 8% of treatment households receiving a chemical product had free chlorine detected at the water visit. Across all products, 27% of treatment households exhibited no detectable *E. coli* in stored drinking water, as compared to 17% of controls (*P* < 0.01). There was a similar difference between the fractions of treatment and control households with *E. coli* concentrations < 10 CFU/100 ml (43% vs. 33%, *P*< 0.01). The mean *E. coli* concentration in stored drinking water among treatment households (154 CFU/100 mL; 95%CI 138-169) was just lower than that of control households, although this difference is only significant at the 10% level (182 CFU/100 mL; 95%CI 153-210; *P*=0.09)
Usage by product (Table 2)

Self-reported usage
Combining all study waves, households at the water collection visit were most likely to self-report using the filter (29%, 95% CI: 25-32%). The share reporting using Water Guard (24%, 95% CI: 20-27%) and Aquatabs (20%, 95% CI: 17-24%) were similar (and statistically indistinguishable) from each other, but were both statistically significantly lower than for the filter. PUR had the lowest share of self-reported usage at the water collection visit (10%, 95% CI: 8-13%, difference significant at P <0.01 on four-way adjusted Wald test).

Self-reported usage at the survey for the filter and Water Guard (21%; 95%CI: 17-24% and 19%; 95%CI: 15-22%) were statistically significantly higher than for Aquatabs (13%; 95%CI: 10-16%) which, in turn, was statistically significantly higher than for PUR (7%; 95%CI: 5-9%).

Chlorine tests
Among households assigned a chemical, those with Water Guard had a similar proportion of positive chlorine tests (11%) as households assigned Aquatabs (9.9%, difference not statistically significant). Both proportions were statistically significantly higher than for PUR (3.3%, P< 0.001).

Microbiological performance among all households receiving a product
Among our three objective measures of product performance and usage, it is only the share of households with no detectable $E. coli$ that has differences across all 4 products that is statistically significant and thus allows product-by-product comparisons. Of households assigned Water Guard, 31% had no detectable $E. coli$, 47% had < 10 CFU / 100 ml, and the mean $E. coli$ concentration was 139 CFU/100 mL. Households assigned Aquatabs had no detectable $E. coli$ 28% of the time (difference with Water Guard not significant), low $E. coli$ (<10 CFU/100 mL)
42% of the time, and a mean \( E. coli \) concentration of 151 CFU/100 mL. When households were assigned either Water Guard or Aquatabs they exhibited less microbiological contamination than when the same households were assigned PUR (24% no detectable \( E. coli \), 41% <10 CFU/100 ml, and 159 CFU/100 ml; \( P=0.03 \) on three-way test across chemicals for no detectable \( E. coli \)).

The story is more complex for the filter, which had slightly higher self-reported usage at the water collection visit (29%) than any other product. In contrast, only 24% of households assigned the filter had no detectable \( E. coli \), which was statistically significantly lower than for Water Guard (31%, \( P < 0.05 \)), marginally lower than the share for households assigned Aquatabs (28%, difference not statistically significant (\( P=0.14 \)), and about the same as the share for households assigned PUR (24%, difference with filter not statistically significant). Yet the mean \( E. coli \) concentrations in homes assigned a filter was 163 CFU/100 mL, statistically indistinguishable from that of the other products (PUR: 159 CFU/100 mL; Aquatabs: 151 CFU/100 mL; Water Guard: 139 CFU/100 mL; 4-way test of differences not statistically significant). Moreover, 42% of households assigned the filter had low \( E. coli \) (that is, < 10 CFU/100 mL), which was similar to the 41-47% of households assigned the other three products (p-value on test of all equal = 0.11).

**Microbiological performance among self-reported users**

The previous section analyzed microbiological outcomes for all households *assigned* a product, and therefore includes non-users of each product. The products appear substantially more effective when we focus on the non-random subset of households that reported they *used* each product (Table 3 and Figure 3).

On average, the \( E. coli \) contamination of those at the water collection visit who reported using the POU product in the past 24 hours is far below that of non-users or of controls. For example,
the mean *E. coli* concentration of stored water in homes of self-reported users is 76 CFU/100 mL (95%CI: 51-100), which is far below the mean of 174 CFU/100 mL (P<0.01; 95%CI: 156-192) for self-reported non-users and 182 CFU/100 mL for control households (P<0.01; 95%CI: 153-210).

Among the homes self-reporting usage of the chemical products, about 70% had no detectable *E. coli*, which was a higher share than the 45% of filter users without detectable *E. coli* (difference P < 0.01, see Table 3 and Fig. 3). A much lower 17% of controls had no detectable *E. coli*, which was similar to the share among self-reported non-users of each product (15-20%). The higher rates of detectable *E. coli* for self-reported non-users and for controls relative to self-reported users were statistically significant for all products. Differences between controls and non-users and among non-users of different products were not statistically significant.

Self-reported product usage resulted in a roughly 1.3 log_{10} reduction in *E. coli* concentration in stored water as compared to controls: average log_{10} *E. coli* was roughly 1.6 points lower for Water Guard, 1.4 points lower for Aquatabs, 1.2 points lower for PUR, and 0.9 points lower for the filter (with differences compared to controls all significant at the 1% level; we assign a log_{10} value of -1 to those observations with no detectable *E. coli* to retain them in the analysis). These water quality improvements are very similar when comparing self-reported users to controls or to self-reported non-users, respectively.

We detected chlorine residual in the stored water of 43% of self-reported users of the chemical products, and none of the 124 samples with positive chlorine results exhibited detectable *E. coli*. By contrast, those who self-reported usage but whose samples tested negative for chlorine exhibited *E. coli* > 1 CFU/100 mL 47% of the time, about two and a half times the proportion of controls (with similar proportions across the three chemical POU products).
The comparisons between users and non-users (among the treatment households) and between users and controls can be biased estimates of causal effects of product use if there is self-selection of who uses these products. For example, if users have less safe water, the causal effects will be larger than those seen in the comparisons in Table 2. In fact, the almost-identical mean *E. coli* concentrations for controls and for treatments who report they did not use a POU product suggests those with more (or less) contaminated water are not more likely to use a POU product. As an additional check, we use treatment status as an instrumental variable to estimate the effect of being assigned a safe-water POU product on the treated (21). Results were very similar to those shown in Table 2 (see webappendix).

**Willingness-to-pay**

Our auction measured the demand curve for each product; that is, the share of respondents willing to pay any given price (with their own money out of pocket). In Figure 4 we present these demand curves for treatment households after they had a two-month free trial with each product. The products auctioned included enough Water Guard for two weeks or longer, enough Aquatabs for 10 days, enough PUR for five days, and a filter that would typically last a year or two.

All products show high dispersion in willingness-to-pay. For example, each product received zero bids from over 40% of consumers. At the same time, a significant minority were willing to pay the expected retail price for Aquatabs and for Water Guard. Specifically, 47% bid 5 taka ($0.07) or more for a sleeve of Aquatabs (about 10 days’ supply) and 33% bid 8 taka ($0.12) or more for a bottle of Water Guard (which would last 2 weeks or longer).
Nearly 80% bid zero for 5 sachets of PUR, the highest share of zero bids of any product. Correspondingly, PUR would have zero demand at its typical retail price in other nations ($0.50 for 5 sachets).

Forty two percent of respondents bid zero for the filter, while 20% bid 200 taka ($2.90) or more. Only 1% (8 out of 755) bid 500 taka ($7.25), a reasonable estimate of the retail price of the filter.

**Discussion**

Our main results are as follows:

- Even with four bimonthly household visits explaining the health hazards of untreated drinking water, and free trial periods, even the most popular product (the filter) exhibited less than 30% usage.

- The siphon filter was generally self-reported to be used slightly more than Water Guard and Aquatabs, and all were used substantially more than PUR.

- All products were very effective at reducing *E. coli* concentrations when used, although self-reported users of the filter had somewhat higher rates of detectable *E. coli* than self-reported users of the chemical products.

- There was wide dispersion in willingness to pay for the products. For each product, more than 40% of consumers bid zero. At the same time, a third or more of consumers were willing to purchase Aquatabs and Water Guard at a price above the actual or expected retail cost.

Self-reported users of chemical products often (57% of the time) had no detectable chlorine, but even without detectable chlorine they were nearly three times more likely than controls to produce no detectable *E. coli* in stored water (47% vs 17%, respectively, Table 3). This suggests
that many self-reported users of chemicals without detectable chlorine in their stored water are truthfully reporting product use. (Comparisons of \textit{E. coli} between product users and non-users can be biased measures of product effectiveness if usage depends on \textit{E. coli} contamination or factors correlated with contamination. In our data self-reported non-users have rates of no detectable \textit{E. coli} between 15.2 and 19.6%, all very close to the 16.9% of controls with no detectable \textit{E. coli}. Thus, self-selection does not appear to be important.) There are several possible explanations for the 53% of self-reported users of chemicals who had no detectable free chlorine but had detectable \textit{E. coli}: imperfect recall or a courtesy bias leading to over-stated recent product use, incorrect product usage, or consumption of the free chlorine followed by water handling that leads to recontamination (22; 23).

Recontamination may also explain some of the filter users with detectable \textit{E. coli} in their stored water. In our laboratory results the filter was excellent at eliminating all detectable \textit{E. coli}, yet in the field over half of the samples of stored water from self-reported users of the filter had detectable \textit{E. coli} (as compared to 30% of self-reported chemical users having no detectable \textit{E. coli}, and none of the chemical users whose stored water contained measurable chlorine residual). Users of the chemical products may have had more success in maintaining water without detectable \textit{E. coli} because chlorine residual (and perhaps by-products of chlorine reactions such as chloramines) minimizes recontamination after treatment.

These results reinforce the familiar advice that safe storage is an important complement to point-of-use water treatment, particularly for POU products such as water filters that provide no lasting protection.

While the above discussion emphasizes comparisons across products, our most striking result is the low usage of even the most popular products. Most theories of health decision-making
identify consumers’ lack of information on the risks of untreated water coupled with product cost as key constraints on household water treatment (24-26). Our intervention addressed these barriers: Price was zero during the free product trials and there were multiple household visits providing information that untreated water is dangerous and these products can effectively reduce that danger.

On the one hand, our results suggest that with this level of education on safe water products these poor communities can support a larger-than-current private market in low-cost household water treatment products such as Water Guard and Aquatabs. (We note that in standard auctions bidders usually bid below their true willingness to pay so they retain some value if they win. This strategy is not in the participant’s self-interest in our auction design, but can occur if participants did not understand the rules of the auction, did not calculate all the implications of those rules, or if they did not trust the enumerator. Auction bids can also be below a household’s willingness to pay if the woman bidding does not control much of the household’s finances or if it takes a few days to gather cash for a relatively large purchase such as the water filter. At the same time, the auction bid can be above the sustained willingness to pay of participants who are trying to be polite to the enumerator - who has given them 8 months of free trials - or who intend to purchase once, but not regularly.)

On the other hand, we find low usage for these products even at zero price. Unless demand increases considerably, household water treatment is unlikely to reduce morbidity and mortality substantially in urban Bangladesh. Thus, those designing and distributing safe water products must better understand the preferences, choices, and aspirations of the at-risk populations.

It is plausible that effective marketing will need to go beyond standard messages about water and health (such as those we used). Product design that lowers the cost and promotes the habit
of water treatment is likely to be important (27). Additional tests of marketing messages that engage community pride, associate untreated drinking water with ingestion of human feces, build on norms that make consumers ashamed to be seen engaging in unsanitary activities, and build on religious injunctions related to purity are all important – as are extending all tests to multiple products and settings.

**Contributors**

All the authors contributed to the design of the study and reviewed drafts of the report. DL, JL, and JA led design of the study. JA led selection of products and DL and JL led design of the informational scripts. JL and MM led design of the survey, and MM led the design and testing of the auction. NN supervised the data collection and SI supervised the microbiological laboratory. LU and SL directed the ICDDDR,B team. JL led data analysis. DL wrote the first draft. DL and SL are guarantors for the report.

**Conflicts of interest**

This study was partially funded by the P&G Fund of the Greater Cincinnati Foundation, which is associated with the Procter & Gamble Company (the manufacturer of PUR).

**Acknowledgements**

We are grateful to Mohammad Abdul Kadir for initiating fieldwork on this complex study, Peter Martinsson for helping shape our initial questions, the field team Tahmina Parvin, Fatema Tuj-johra, Rita Begum, Halima Hawa, Kathika Rani Biswas, Abdul Karim, Shahnaj Aktar, supervised by Farzana Yeasmin, and lab personnel Md Shahneawz Khan and Partha Sarathi Gope. We appreciate comments from Daniele Lantagne.


Table 1: Indicators of POU product usage (averaged for all products). N is the number of household visits for the 600 treatment and 200 control households across four household visits (not including the baseline). Free chlorine was measured only among self-reported users of chemical products, but N in that column refers to number of households with chemical products at that survey round.

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<th>From Survey</th>
<th>From water collection visit</th>
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Table 2: Indicators of POU product usage, divided by product. N is the number of household visits for the 600 treatment and 200 control households across four household visits (not including the baseline). Free chlorine was measured only among self-reported users of chemical products, but N in that column refers to number of households with chemical products at that survey round.

<table>
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<th>Source of data</th>
<th>% self-report: “Treat your drinking water with [POU product]” and “How long ago did you treat?” ≤ 24 hours</th>
<th>% self-report: “At least some water treated” AND “Last used product” is “today” or “yesterday”</th>
<th>% of homes with detectable free chlorine (sample = households with chemicals)</th>
<th>E. coli in stored drinking water (CFU/100 mL)</th>
<th>% of homes with E. coli &lt; 1 CFU / 100 ml in stored water</th>
<th>% of homes with E. coli &lt; 10 CFU / 100 ml in stored water</th>
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<tr>
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<td>13</td>
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<td>1.6</td>
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<td>3.3</td>
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Table 3. Microbiological performance. Percentages of homes with non-detectable *E. coli* and mean *E. coli* concentrations in stored water. Data are from water collection visits.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>% <em>E. coli</em> &lt;1 CFU/100mL</th>
<th>Mean <em>E. coli</em> (CFU/100mL)</th>
<th>N</th>
<th>Self-report POU use within 24 hours?</th>
<th>Among self-reported users: chlorine detected?</th>
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<tbody>
<tr>
<td></td>
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<td>Total among households assigned chemicals</td>
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<td>183</td>
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<td>374</td>
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<td>Total among all treated households</td>
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<td>Controls</td>
<td>% <em>E. coli</em> &lt;1 CFU/100mL</td>
<td>17</td>
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<td>N</td>
<td>720</td>
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Figure 1. Tested POU products Aquatabs (A), the CrystalPur siphon filter (B), the PUR Purifier of Water flocculant/disinfectant mixture (C), and dilute hypochlorite solution branded as Water Guard (D).
Figure 2. Fractions of households with E. coli concentrations below <1 and <10 CFU/100 mL, respectively, in intervention households vs. control households, measured across four household visits (not including the baseline) for the 600 treatment and 200 control households. Error bars correspond to the standard error of mean.
Figure 3. Percent of households with stored water samples with no detectable *E. coli*, by assigned product and by self-reported usage in last 24 hours. Based in part on data in Table 3.
Figure 4. Demand curves for Aquatabs, Water Guard and PUR (upper graph) and the CrystalPur siphon filter (lower graph). Note: Sample is Treatment households at final survey (N=568). Demand measures the percent of respondents bidding at least that price for: 1 bottle of Water Guard (sufficient for 2 weeks or longer), a sleeve of Aquatabs (sufficient for roughly 10 days), 5 sachets of PUR (sufficient for roughly 5 days), or one filter. Respondents who won paid their own money.