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The Effectiveness of Educational Interventions to Enhance the Adoption of Fee-Based Arsenic Testing in Bangladesh: A Cluster Randomized Controlled Trial

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Abstract. Arsenic (As) testing could help 22 million people, using drinking water sources that exceed the Bangladesh As standard, to identify safe sources. A cluster randomized controlled trial was conducted to evaluate the effectiveness of household education and local media in the increasing demand for fee-based As testing. Randomly selected households (N = 452) were divided into three interventions implemented by community workers: 1) fee-based As testing with household education (HE); 2) fee-based As testing with household education and a local media campaign (HELM); and 3) fee-based As testing alone (Control). The fee for the As test was US$ 0.28, higher than the cost of the test (US$ 0.16). Of households with untested wells, 93% in both intervention groups HE and HELM purchased an As test, whereas only 53% in the control group. In conclusion, fee-based As testing with household education is effective in the increasing demand for As testing in rural Bangladesh.

INTRODUCTION

More than 20 million people in Bangladesh consume groundwater containing elevated levels of naturally occurring arsenic (As) that exceeds the Bangladesh standard for As in drinking water of 50 µg/L.[1] Exposure to inorganic As is associated with cancers of the skin, bladder, and lung,[2] reduced cognitive and motor function in children,[3] and skin lesions.[4] Attempts to reduce As exposure in this population have proven challenging. Less than half of the estimated population of 28–35 million initially exposed to unsafe levels of As have gained access to As-safe water since 2000. The most common As mitigation option (29%) used by this population was well switching, which involves a household using an As-unsafe well switching to an As-safe well located in their village. However, a prerequisite for well switching is knowledge of the As concentration of well water, which is not available unless As testing has been conducted.

Nearly a decade since the last government sponsored nationwide As testing campaign, the main source of As testing for most of Bangladesh, the proportion of untested wells in the country is increasing at an alarming rate. A 2009 United Nations Children's Fund (UNICEF) report found that nearly half of the households surveyed reported that their drinking water was untested for As,[1] increasing from 38% in 2006.[5] This is likely caused by the continued installation of wells since the early 2000s testing campaign.[6] Many households are unknowingly exposed to elevated levels of As in their drinking water because they lack access to As testing services in their communities.

Previous studies have shown that As testing coupled with health education and reminders increases the proportion of the population that switches to As-safe drinking water sources.[7–9] In Araihazar, Bangladesh, it was found that the majority of households using As-unsafe wells that received water As testing coupled with As education and the targeted installation of wells report switching to As-safe sources.[7,8] However, well testing in Bangladesh is usually project based, without efforts to design or implement sustainable testing mechanisms. A fee-based As testing approach, in turn, is likely to be more sustainable through a private-public partnership. It can also be cost-effective if integrated into the existing community health worker program of the government. It is not known, however, whether households with potentially As-contaminated wells will pay for testing services. Possibly, households' demand for fee-based As testing may increase with education and local media. This study is therefore aimed at comparing households' demand for fee-based testing when being offered the testing service alone, with education, or with education and local media interventions combined. It was hypothesized that community workers offering fee-based As testing *with As education* are more effective than those offering fee-based As testing alone in encouraging households to purchase an As test for their primary drinking water source. Furthermore, it was hypothesized that household-level As education in *combination with a local media campaign for As* further increases the proportion of households that use fee-based As testing. Knowledge of As in drinking water and health effects and self-reported switching to an As-safe drinking water source were also examined as secondary outcomes.

METHODS

Setting. This study was conducted in Shibalaya, Manikganj district of Bangladesh between April and August 2011. This area was selected because it contains a wide range of As concentrations, and because of the presence of the Christian Commission for Development Bangladesh (CCDB), a non-governmental organization that assisted with the implementation of this intervention. The CCDB presently works in 36 upazilas (sub-districts) in 15 districts of Bangladesh on poverty reduction.

Study design. A cluster randomized controlled trial was conducted with 452 randomly selected households living in three geographically separate clusters of three villages each (Figure 1). All groups were offered fee-based As testing services by a trained community worker, this individual will be referred to as an "As tester." Clusters were assigned to the

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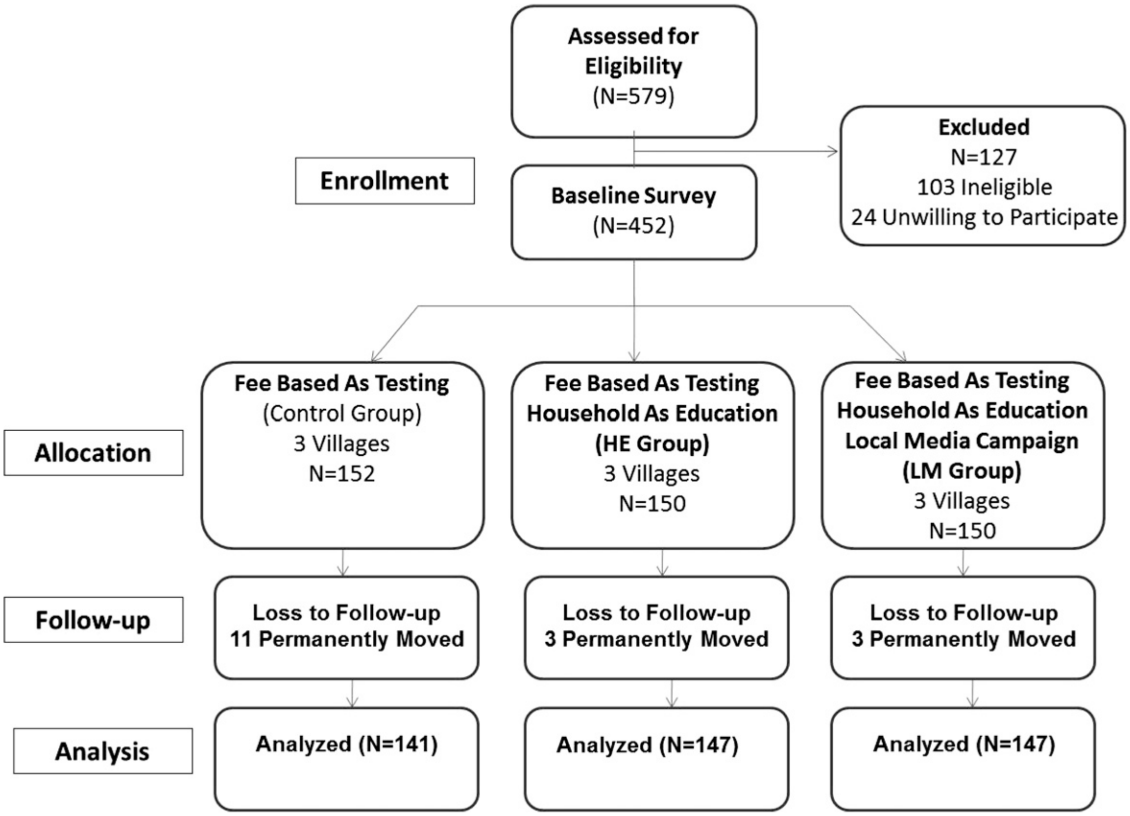

FIGURE 1. Consort diagram.

following three intervention groups: 1) fee-based As testing with household-level education (HE), 2) fee-based As testing with household-level education and a local media campaign (HELM), and 3) fee-based As testing alone (Control). Fifty respondents were randomly selected from each village (Figure 1). Arsenic testers used a structured script to offer As testing services and disseminate household-level As education to respondents according to their assigned intervention group. All intervention groups had equal access to As testing services. This script was in a manual that included a reference section containing information on the implications of chronic As exposure on human health. If respondents had additional questions after their household visit, the As tester referred to this reference section. We attempted to match villages on the proportion of unsafe wells based on a village wide household drinking water survey we conducted. Villages were randomly assigned by the study project coordinator to each intervention group at baseline using the random number generator in SAS 9.2 (SAS Institute, Inc., Cary, NC). Study households in each village were randomly selected in the same manner based on a census that was developed from the household drinking water survey. Each respondent was interviewed at baseline (April 2011) and at follow-up (August 2011). These surveys were conducted by trained professional interviewers from Dhaka, the capital of Bangladesh.

Eligibility criteria. To be eligible for inclusion, a village had to have 1) between 30% and 60% As unsafe wells, defined by the Bangladesh As standard of 50 μg/L; this was assessed through a village wide household drinking water survey; and 2) at least 50 households that had one person who meet the study eligibility criteria.

To be eligible, the respondents had to be 1) the person in the household responsible for primary drinking water collection; 2) using an untested or unsafe well; and 3) be 18 years of age or older. Individuals were excluded if 1) they had an As filter; 2) obtained water from an As treatment plant; or 3) did not have a primary well they used to collect the majority of their household's drinking water. The respondent did not have to be using a well that they owned.

The eligibility criteria for the community As testers were as follows: 1) can read and write; 2) can correctly use the As field testing kit, and disseminate As education after receiving training (assessed by mock visits); 3) be 18 years of age or older; and 4) can work for 20 hours per week.

Outcome measures. *Primary outcome: Purchase of water As test.* The primary outcome variable was the proportion of study respondents with untested wells at baseline that purchased an As test for their primary drinking water source by the time of the follow-up survey. This information was obtained from records kept by As testers and confirmed by the respondent who reported purchase of an As test.

Secondary outcomes. Self-reported well switching by the time of the follow-up survey, *knowledge of As at follow-up versus baseline*, and sociodemographic variables.

Knowledge of As quiz. The study respondent's knowledge of As was obtained by an 18 item quiz administered at baseline and at follow-up. Respondents were asked questions on the following: the source of As-contaminated water, safe uses of As-contaminated water, and the meaning of a red or green marked tubewell relative to As. Respondents were also asked if arsenicosis was contagious, and if As could be removed by boiling water. The following medical conditions were read and the respondent was asked if these could be caused by As: cholera, cancer, diarrhea, vomiting, and skin lesions. A quiz score was calculated for each respondent based on the cumulative score from all 18 quiz items. One point was given for a correct item, and zero points for an incorrect item. No partial credit was provided. Possible quiz scores ranged between 0 and 18.

Fee-based As testing. All households (N = 452) residing in the nine study villages were offered As testing services on-site for 20 Bangladeshi Taka (BDT) (0.28 US$) using the Econo-Quick As test kit (Industrial Test Systems, Inc., Rockhill, SC, Part No. 481298). The actual cost of the test is US$ 0.16 (US$ 47.64 for 300 tests). The community workers who performed the tests received 2 days of training on how to measure the As content of well water using the Econo-Quick As test kit. This kit uses a series of reagents added to a 50 mL reaction bottle containing the collected water sample. This reaction produces arsine gas if As is present. The arsine gas developed by the addition of these reagents is then trapped on a reaction strip that contains mercuric bromide. The color of the reaction strip is then compared with the reference scale given by the manufacturer. This kit uses a 10-minute reaction period, and measures As concentrations in water between 0 and 1,000 μg/L at a scale of 10, 25, 50, 100, 200, 300, 500, 1,000 μg/L. The kit includes an option to add a sulfur interference step. This was not done because sulfide levels in Bangladesh are generally too low to cause sulfur interference.[10] The Econo-Quick kit was found to perform well in a previous evaluation conducted in Bangladesh. It correctly determined the status of 89% and 92% out of 123 wells relative to the WHO As guideline (10 μg/L) and the Bangladesh As standard (50 μg/L), respectively, when compared with laboratory results using inductively coupled plasma mass spectrometry.[11] After testing, a green (safe) placard was attached to wells found to be below 50 μg/L As and a red (unsafe) placard for those above. If a study respondent's primary drinking water source was found to be unsafe relative to As, assistance to locate a nearby As safe drinking water source was provided.

Household-level As education. Arsenic testers in the HE and HELM intervention arms of the study disseminated household-level As education after receiving 1 week of intensive training. The As testers visited each study household in their assigned village to conduct a 25-minute As educational session *using a structured script and flash cards containing photos* over a 2-month duration. All individuals present at the time when the educational session was conducted were invited to attend. Sessions were designed to be interactive. Participants were asked questions and encouraged to contribute to the discussion. At the conclusion of the session the audience was asked to pledge their commitment to drink As-safe water and share As-safe wells with others. The As education sessions focused on disseminating the following nine key educational messages using photos:

1) If we drink As-contaminated water for a long period of time, we can develop non-itchy black or white spots on the chest, or roughness and spots on the palms and sole. This is called arsenicosis.
2) Arsenic can cause ill health in our children and may affect their intelligence.
3) Pregnant women should not drink or cook with As-contaminated water because it can affect the health of their unborn child later in life.
4) Arsenicosis does not occur by sleeping with a skin-diseased person. It is not a communicable disease.
5) Arsenic cannot be removed by boiling water.
6) We should not drink or cook with water from a red-marked tubewell because they are contaminated with As.
7) We should use water from tubewells marked green for drinking and cooking purposes.
8) Rainwater can be used as a source of As-safe drinking water. Pond, Canal, and River can also be used for As-safe water; however, it must be boiled before used for drinking.
9) Our commitment is that we should drink As-free water and encourage all to drink As-free water (Pledge).

Local media campaign. The local media campaign consisted of two promoters, separate from the As testers disseminating household-level As education, delivering health communication messages using a micro-rickshaw (a rickshaw with microphone equipment), and community sessions with theater performances and community level As education. Each village was visited by the promoters 3 days per week for a 6-week duration during the period of time the household-level As education was also being disseminated by the As testers. While riding through villages, the promoters provided messages regarding the sources of As, arsenicosis, As-safe water options, and the availability of As testing services. They further conducted community sessions twice daily. Each session was 1.5 hours in length, and setup in a meeting spot in each village (e.g., school, market). A display depicting risk perception information was set at these meeting places to encourage people to come to the sessions. During the community sessions theater performances were held employing role playing. The promoter and rickshaw driver performed skits where they enacted seeking As-safe drinking water sources and refusing to drink As contaminated water. This was followed by a 20-minute educational session on the health implications of As exposure, and As mitigation options. At the end of the community session, villagers were asked to commit to only drink water from As-safe tubewells. All those who attended the session received a poster, which provided information on the meaning of a red and green tubewell and safe uses of As-contaminated water. Flyers were also distributed that included contact information to obtain As testing services in the village.

Cost analysis of interventions. The wage of the community worker and material costs (i.e., flash cards, posters, rickshaw rental) per household amounted to ~US$ 1.41 for the control group, US $ 1.99 for the HE group, and US$ 4.35 for the HELM group.

Statistical methods. All of our power calculations were derived using Optimal Design Software (WT Grant Foundation, New York, NY). We were not able to locate any previous literature on the uptake of this type of fee-based testing program, thus we made an approximation for our power calculation based on our own pilot data. We assumed for the control arm a lower bound of 30%, and an upper bound of 50% for purchasing an As test. Given this sample size, we had 80% power to detect a 22% change between the control and intervention arms (40–62%, respectively) in the proportion of study respondents that purchased an As test for their primary drinking water source between the control and intervention groups with a type 1 error of 0.05.

The assumptions used for the power calculation for our secondary outcome of self-reported well switching was based

TABLE 1
Study arm characteristics at baseline*

Characteristics	Control group (N = 141)	HE group (N = 147)	HELM group (N = 147)	P value
Age (yrs) (mean ± SD [range])	37.3 ± 11.1 (20–65)	35.6 ± 12.2 (18–90)	37.8 ± 11.8 (18–70)	0.24
Female (%)	100	100	100	
Religion (%)				
Muslim	96	99	92	0.01
Hindu	4	1	8	
Respondent can read and write (%)	40	50	56	0.02
Knowledge of As Quiz score at Baseline mean ± SD (range)	9.5 ± 2.1 (5–15)	9.4 ± 2.1 (1–14)	9.8 ± 2.1 (5–16)	0.3
Radio ownership (%)	40	27	35	0.36
Television ownership (%)	65	73	74	0.16
Land ownership (%)				
No land ownership	9	8	3	0.002
Less than 1 acre	81	67	72	
Greater or equal to 1 acre	9	25	25	
Number of individuals living in household (mean ± SD [range])	5.1 ± 2.4 (2–18)	4.5 ± 2.0 (1–15)	4.7 ± 1.9 (1–13)	0.029
Number of children living in household (mean ± SD [range])	1.6 ± 1.2 (0–7)	1.2 ± 1.1 (0–5)	1.2 ± 1.1 (0–5)	0.002
Monthly income	6776 ± 4695 (0–30,000)	6637 ± 5220 (9–45,000)	6909 ± 5208 (0–26,000)	0.72
Household have electricity (%)	30	59	71	0.02
Proportion of unsafe wells in respondent's village (%)	25 ± 4.9 (20–30)	29 ± 10.3 (15–39)	76.4 ± 8.0 (65–83)	< 0.0001
Arsenic concentration (by Econo-Quick Kit)	35 ± 40 (0–200)	43 ± 43 (0–150)	134 ± 116 (0–500)	< 0.0001

*P values were calculated using a χ^2 test for categorical variables and analysis of variance (ANOVA) for continuous variables.

on a previous study conducted in Araihazar, Bangladesh.[8] We assumed that the proportion of well switching would be 30% in the control arm and 60% in the intervention arms, and that 50% of wells tested would be unsafe relative to As, based on our household drinking water survey. A lower bound of 15% and upper bound of 50% for well switching was used from findings in Schoenfeld and others.[12] On the basis of this calculation, we would only have a power of 58% with a type 1 error of 0.05, and thus we lacked sufficient power to detect a significant difference for this outcome.

Categorical variables were analyzed using a chi-square test and continuous variables were calculated using ANOVA. All analyses were performed using SAS, version 9.2 (SAS Institute Inc.).

Ethical approval. The study protocol was approved by the Columbia University and the Bangladesh Medical Research Council. Informed consent was obtained from all study respondents.

RESULTS

Dropout and baseline characteristics. During our baseline survey, 579 respondents were screened for eligibility. Of these respondents, 103 (17%) were ineligible for the following reasons: 57% were excluded because they were using a tubewell safe for As; 19% were unavailable to participate; 13% of households used an As filter for their drinking water source; 10% of households did not have one drinking water source from which they collected the majority of their drinking water; 8% were under 18 years of age; and 6% were not the person in their household responsible for primary drinking water collection. Some respondents had more than one reason for ineligibility. In addition, 24 (4%) of individuals screened were unwilling to participate. Seventeen (4%) of respondents were lost at follow-up.

The distribution of age, baseline knowledge of As, radio ownership, television ownership, and household income did not differ significantly between the study groups. However, there were significant differences observed between literacy, land ownership, and the proportion of unsafe wells in the village between the study groups. The villages of the HELM group had a higher proportion of unsafe wells present than the other study groups (Table 1).

Intervention outcomes. The vast majority (93%) of households using untested wells at baseline in both the intervention groups purchased an As test and had their wells tested through the fee-based As testing services offered by the community worker, compared with 53% for the control group (Table 2).

Thirty-nine percent of households with unsafe wells switched to safe wells in the HELM group compared with 26% and 32% in the HE and control groups, respectively. The majority of these households reported switching because their previous tubewell was unsafe for As (84%) (Table 2). The most common reasons for *not* switching was the distance of the tubewell was too far (46%), and the family owned its own tubewell and did not wish to impose on others (50%).

The knowledge of As quiz scores was significantly higher at follow-up, compared with baseline, for all groups (Table 2). In addition, the knowledge of As quiz scores in the HELM group was significantly higher than that of the control group at follow-up.

DISCUSSION

This study represents the first cluster randomized controlled trial evaluating the effectiveness of education and local media to increase the demand for fee-based As testing in Bangladesh. Testing for As by the government of Bangladesh and subsequent efforts by government and non-governmental

TABLE 2
Outcome variables by intervention group*

Characteristics	Control group (N = 141)	HE group (N = 147)	HELM group (N = 147)	P value
Was your baseline well tested for arsenic by your Arsenic Tester (among untested well users)? (%)				
Yes	53	93	93	< 0.001
Respondent follow-up Arsenic Knowledge Quiz score (mean ± SD [range])	12.9 ± 2.0 (6–16)	13.3 ± 2.0 (6–16)	13.8 ± 1.9 (6–17)	0.0010
Switching Status (among unsafe well users) (%)				
Switched	26	32	39	0.04
Reason for switching among unsafe well users (%)				
Previous tubewell was unsafe for arsenic	70	88	94	0.04
Previous tubewell broken	10	8	2	
Too many people using previous tubewell	0	0	0	
Dug a new tubewell	10	4	0	
Did not like the taste of previous tubewell	0	0	0	
Did not like the color of previous tubewell	0	0	0	
None of these	10	0	4	
Reason for not switching among unsafe well users (%)				
Distance of the safe tubewell was too far	48	47	43	0.17
Family owns its own tubewell and does not wish to impose on others	44	51	56	
Arsenic safe well had too many users	0	0	0	
Safe well owner near home does not want to share	4	0	0	
Physical Limitation	3	0	0	
Alternative well had bad taste	0	0	0	
Alternative well had unusual color	0	1	0	
None of these	0	1	1	

* P-values were calculated using a chi-square test for categorical variables and using ANOVA for continuous variables.
HE = household education; HELM = household education and a local media campaign.

organizations have largely been one-off and at no cost to households.[13,14] In addition, when such programs end, there are often no mechanisms remaining for further testing. More sustainable approaches for As testing are urgently needed that do not require extensive donor funding and have continuity over time to allow households to identify As-safe drinking water sources as newly installed wells arise.

As testing findings. The findings of this study indicate that the vast majority of households with untested wells in both the HE and HELM intervention groups paid for As testing (93%). Education increased the households' demand for well testing by 40% compared with offering well testing alone. This shows that the household level of As education—with or without local media—was very effective in encouraging households to purchase an As test. Perhaps more encouraging is that more than half of the households purchased well tests after being offered As testing services alone, suggesting that the households' demand for As testing is high and that they are willing to pay for this service.

Well switching findings. No significant differences were observed in well switching between the interventions groups, although switching rates were 7% higher in the HELM group in comparison with the control group. These effects are small compared with previous studies.[8,15] Possible reasons include the short duration of our intervention period, and that the percentage of As-unsafe wells in the HELM group were 76% (Table 1), leaving villagers with fewer As-safe wells to switch to.

As knowledge findings. A surprising finding was the significant increase in the knowledge of As across all study arms, even in the control group where no As education was provided. This result suggests that the fee-based As testing program itself can lead to an increased interest in the health implications of As and mitigation options. This may have led the control group to seek outside sources of As information beyond what was provided in our study. The knowledge of As at follow-up was significantly higher in the HELM group in comparison with the control group. This result further emphasizes the importance of reinforcement in increasing knowledge of As in the population.

Implications and limitations. The findings of this study show that fee-based As testing in combination with household-level As education and local media interventions can be effectively used to improve As testing coverage. However, it is important to recognize that if the tubewell a household is using is found to be unsafe for As they likely must still be motivated to switch to an alternative drinking water source. Previous studies have found that reinforcement over time is important in encouraging households to switch to As-safe drinking water sources.[8,9] Furthermore, social and physical (distance) constraints have been found to be important barriers to well switching.[16,17] Thus, future studies should investigate if a longer health communication is more effective in increasing the proportion of households with unsafe wells that switch.

This study has several important limitations. First, as previously mentioned the focus of our study was only on the use of fee-based As testing, because of budgetary constraints we lacked the resources to increase our sample size and extend our study duration. We also lacked a fourth intervention arm in which we could have evaluated the impact of the local media campaign on use of the fee-based As testing program without the presence of household-level As education. The proportion of households that used the fee-based As testing program was the same and very high (93%) for the household education and local media/household education intervention groups, therefore the impact of the local media campaign is unclear. Furthermore, we had only one household visit per study respondent, although the literature suggests that reinforcement is important in facilitating well switching.[9,16]

In addition, the geographic areas selected for this study were matched on the proportion of unsafe wells based on a village wide household drinking water survey conducted before the baseline survey. However, many wells at baseline were untested. When we went back to test these wells a higher proportion were unsafe in the HELM group versus the control group and the HE group. It is possible that the much higher proportion of unsafe wells found in the HELM group affected the households' decision to purchase an As test for their tubewells in a way we are unable to account for in our model. It could have also affected the well switching rate. Future studies should have a larger sample size, which would reduce the likelihood of such large discrepancies in the proportion of unsafe wells between study arms.

There was also heterogeneity in the distribution of electricity in the study area. This is likely more a reflection of physical barriers such as rivers then socioeconomic ones. For other socioeconomic variables such as radio and television ownership and monthly income no significant differences were observed between study groups.

Unfortunately, in this study we lacked the financial resources to verify field As test kit findings with laboratory methods using inductive couple mass spectrometry (ICP-MS). We recently published a paper in Environmental Science & Technology where we found that 92% of Econo-Quick As test kit results were correct relative to the Bangladesh As standard of 50 μg/L when compared with ICP-MS results as the gold standard.[11] This evaluation was conducted in the same study area as the present study. In resource limited settings, such as Bangladesh, laboratory testing is not a feasible tool for providing As surveillance. These low-cost rapid test kits provide for many household the only means for assessing the As content of tubewells.

CONCLUSIONS

Collectively, these findings point to the feasibility of incorporating fee-based As testing in safe water programs in rural Bangladesh and possibly other South and Southeastern Asian countries where groundwater As affects the health of 100 million people. Furthermore, the results of the cost analysis indicate that the actual cost per household to implement the household education intervention is minimal, < 2 US$ per household. A worthy next step is the integration of fee-based As testing services into safe water and health programs at the community level and to explore private–public partnership for sustainable access to testing services. This is likely to bring down the required cost of the intervention even further. One step in this direction is UNICEF Bangladesh's recent decision to include promoting fee-based As testing into its safe drinking water programming.

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