A Cluster-Based Randomized Controlled Trial Promoting Community Participation in Arsenic Mitigation Efforts in Bangladesh

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Submitted in partial fulfillment of the
requirements for the degree
of Doctor of Philosophy
in the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY
2012

Abstract

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Abstract:

Millions of villagers in Bangladesh drink water which exceeds the Bangladesh arsenic (As) standard of 50 µg/L. Exposure to elevated levels of inorganic As (As) is associated with cancers of the skin, bladder, and lung, developmental effects, cardiovascular disease, skin lesions, and decreased children's intellectual functioning. Arsenic mitigation typically involves an outsider coming into a village to test the well water for As. After the results of the As test are provided this person typically leaves the village without providing the resources to address health concerns or give advice on mitigation options.

In this dissertation, in an effort to provide ongoing resources on the health implications of As and to reduce As exposure, we sought to evaluate community level intervention strategies that could be used for successful As mitigation in Bangladesh. In Singair, Bangladesh, we conducted a household drinking water survey of 6649 households. The results of our survey indicated that 80% of wells were untested for As. Furthermore, we demonstrated that testing all of these untested wells would increase the number of households that lived with fifty meters of an As safe drinking water source by nearly 2.5 fold.

In a cluster based randomized control trial (RCT) of 1000 households, we evaluated the effectiveness of having community members, compared to outside representatives, disseminate As education and conduct water As (WAs) testing. In 10 villages, a community member disseminated As education and provided WAs testing. In a second set of 10 villages an outside

representative performed these tasks.

Overall, fifty three percent of respondents with unsafe wells at baseline switched after receiving the As education and WAs testing intervention. There was no significant association observed between the type of As tester and well switching (Odds ratio (OR) =0.77; 95% confidence interval (CI) (0.37-1.61)). At follow-up, the average UAs concentrations for those with unsafe wells at baseline who switched to safe wells significantly decreased. In both intervention groups a significant increase in knowledge of As was observed at follow-up compared to baseline. The unavailability of As-safe drinking water sources in some villages was the most substantial barrier to well switching identified.

The Hach EZ As field test kit measurements conducted by the As testers were highly correlated with laboratory results. This finding indicates that the As testers were able to accurately measure the WAs concentration of wells. Furthermore in our pilot study, the performance of the Econo-Quick (EC) kit, a new field WAs testing kit, was comparable to that of the commonly used EZ kit and the Wagtech Arsenator kit. The EC kit has the advantage of a substantially shorter reaction time of only 12 minutes in comparison to the 40 minutes required by these other kits.

Through this dissertation, we have demonstrated that As education and WAs testing programs can be used as an effective method to reduce As exposure and increase As awareness in many As affected areas of Bangladesh. Furthermore, our findings indicated that many households are using tubewells that are untested for As therefore demonstrating the urgent need for access to water As testing services.

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Abbreviations

As	Arsenic
As^{+5}	Arsenate
As^{+3}	Arsenite
AMI	Acute Myocardial Infarction
AS3MT	Arsenic (+3 methylation state) methyltransferase
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BAs	Blood Arsenic
BMI	Body Mass Index
CCDB	Christian Commission for Development Bangladesh
CHW	Community Health Worker
CC16	Clara Cell Protein
CI	Confidence Interval
DPHE	Department of Public Health Engineering
DM	Diabetes Mellitus
DMA^V	Dimethylarsinic acid
EQ	Econo Quick Arsenic Test Kit
EPPM	Extended Parallel Process Model
FAQ	Frequently Asked Question
FEV(1)	Forced Expiratory Volume measured in 1 second
FVC	Forced Vital Capacity
GEE	Generalized Estimating Equation
GFAAS	Graphite Furnace Atomic Absorption Spectroscopy
HEALS	Health Effects of Arsenic Longitudinal Study
HE	Household Education
HR	Hazard Ratio
HR ICP-MS	High-Resolution Inductively-Coupled Plasma-Mass Spectrometry
ICP-MS	Inductively-Coupled Plasma-Mass Spectrometry
IM	Integrated Model
InAs	Inorganic Arsenic
LDEO	Lamont Doherty Earth Observatory
LM	Local Media
MMA^{III}	Monomethylarsonic Acid
Mn	Manganese
NGO	Non-governmental Organization
OR	Odds Ratio
PMI	Primary Methylation Index
RR	Risk Ratio/Relative Risk
SAH	S-adenosyl homocysteine
SAM	S-adenosylmethionine
SCT	Social Cognitive Theory
SE	Standard Error
SMI	Secondary Methylation Index
SMR	Standardized Mortality Ratio

TWA	Time-weighted Well As Concentration
UAs	Urinary Arsenic
UCr	Urinary Creatinine
UNICEF	United Nations Children's Fund
WISC	Wechsler Intelligence Scale for Children
WAs	Water Arsenic
WHO	World Health Organization

ACKNOWLEDGEMENTS

DEDICATION

My dissertation is dedicated my parents, Esther and Gregory George, for all their love and support. Through their sacrifices I have been able to pursue my intellectual aspirations. This research is also dedicated to Leroy George, my grandfather, and Leroy George Jr., my uncle, who have recently passed away.

1.1 Arsenic Problem in Bangladesh

Arsenic (As) can occur naturally in groundwater without an anthropogenic source of contamination. Groundwater pumped from approximately half of the roughly 10 million tubewells in Bangladesh do not meet the World Health Organization (WHO) guideline for As of 10 µg/L (1). Other countries around the world are also affected by elevated levels of As in drinking water such as Chile, Mexico, Mongolia, Nepal, Vietnam, India, Taiwan, China, and the United States (2). During the 1970s, the United Nations Children's Fund (UNICEF), in collaboration with the government of Bangladesh, encouraged a shift from using microbial-contaminated surface water to tubewells that tapped groundwater (3). Before the widespread use of tubewells, diarrheal and parasitic disease from microbial contamination of surface water was a major cause of childhood mortality (4). Tubewells were believed to represent a safe drinking water option relative to surface water that were easy to install, relatively cheap, and required low maintenance. Indeed, following the installation of tubewells in Bangladesh there was a decline in mortality from diarrheal diseases (5). This is consistent with other international studies that suggest that safe water supplies reduce the incidence of diarrheal diseases, and thereby mortality (5-7). However, by the early 1990s it was apparent that many of these tubewells tapped aquifers with elevated levels of naturally occurring As (8). Recent studies suggest that irrigating crops with groundwater with elevated As can reduce crop productivity and contribute to dietary exposure to As (9-13). A massive As testing campaign was initiated in 1999. By 2005, 1.4 million tubewells were found to have levels of As above the Bangladesh As standard of 50 µg/L; these tubewells were painted red. Another 3.5 million wells were found to be below the Bangladesh standard for As and painted green (1).

1.2 Study Purpose and Rationale

Arsenic mitigation typically involves an outsider coming into a village to test the well water for As. After the results of the As test are provided this person typically leaves the village without providing the resources to address health concerns or advice on mitigation options. This lack of follow-up at the local level, we hypothesize, may be an important factor limiting the impact of As mitigation in Bangladesh. We also hypothesize that lack of local expertise explains why the numerous wells that continue to be installed are typically untested for As.

The largest As testing program in Bangladesh was the World Bank sponsored Bangladesh As Mitigation Water Supply Project (BAMWSP) conducted between 2001 and 2004 (14). The project used non-governmental organization (NGO) workers from outside the village to test and label private tubewells for As concentrations in nearly half of the country's 10 million tubewells. BAMWSP staff labeled the spout of each well red if the As concentration was greater than 50 µg/L, the As standard in Bangladesh, and green if the As concentration in the well was less than 50 µg/L. The BAMWSP project did not offer follow-up to villagers after testing. Two years later, the impact of this work was evaluated by faculty at Columbia University in their study area of Araihazar, Bangladesh. It was found that 30% of unsafe well users in the area who received BAMWSP testing without further reinforcement switched to an alternative well (Figure 1) (15). In contrast, it was found that in areas where BAMWSP had conducted testing and Columbia University provided additional reinforcement through village and household level As education in combination with well testing/labeling and the targeted installation of deep tubewells, 58% of unsafe well users switched to alternative wells (16). These results suggest that reinforcement is an important factor in determining the proportion of unsafe well users that switch to alternative

water sources.

This dissertation tested the hypothesis that training someone within a village to routinely perform As testing and disseminate As education is more effective in terms of reducing exposure than sending a trained person from the outside to conduct these same tasks. We believe that the introduction of expertise on As into a village will improve responses to As education. If having community involvement in As testing indeed is proven to be more successful than using an outside tester, this model could provide a sustainable option for communities to monitor their As exposure, a strategy that could be used by government or non-governmental agencies to conduct future interventions

Government Water Arsenic Testing Only

Switched — 30%

Did Not Switch

Reinforcement by Village Health Workers ?

Columbia University Study Area

Switched — 58%

Did Not Switch
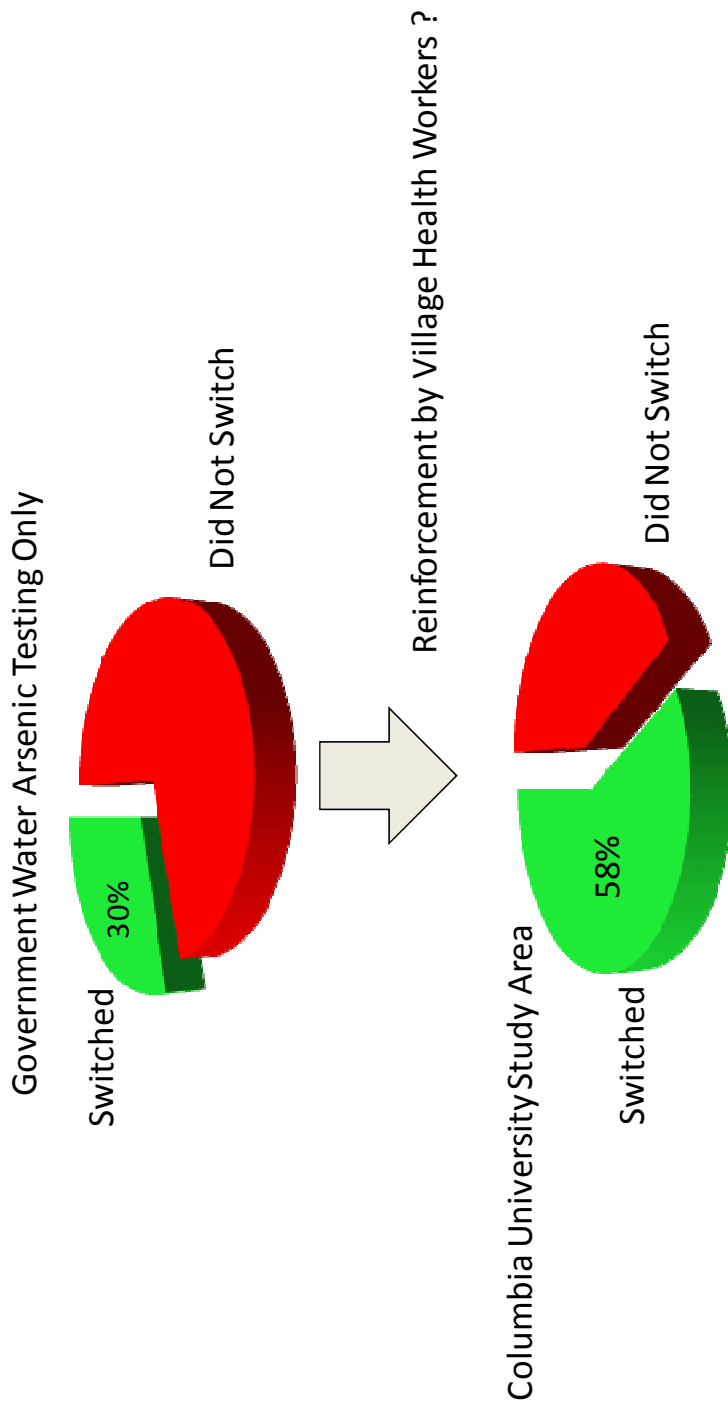
Figure 1. Well Switching in the Columbia University and BAMWSP Study Area. Demonstrates the contrast between the 30% of 2100 households that switched away from unsafe wells within an area of Bangladesh surveyed by a government program (BAMWSP) and 58% of 6512 households switching away from unsafe wells within Columbia's main study area of Araihazar.

Source: Opar A, Pfaff A, Seddique AA, Ahmed KM, Graziano JH, van Geen A. Responses of 6500 households to arsenic mitigation in Araihazar, Bangladesh. Health Place 2007;13(1):164; Chen Y, van Geen A, Graziano JH, Pfaff A, Madajewicz M, Parvez F, et al. Reduction in urinary arsenic levels in response to arsenic mitigation efforts in Araihazar, Bangladesh. Environ Health Perspect 2007;115(6):917-23.

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1.3 Specific Aims and Hypothesis

In an effort to reduce As exposure, we conducted a longitudinal intervention study of 1000 households in Singair, Bangladesh to evaluate the effectiveness of having village community members, compared to outside representatives, conduct water As (WAs) testing and disseminate As awareness education. This study was implemented to accomplish the following specific aims and hypotheses:

Hypothesis 1: Training someone within a village to routinely perform As testing and disseminate As education is more effective in terms of reducing As exposure than sending a trained person from the outside to conduct these same tasks.

Specific Aim 1.1: We will conduct a cluster based randomized controlled trial of 1000 households in Singair, Bangladesh. The study population of 20 villages will be divided into two groups: in the first group of 10 villages, an outside tester residing outside the study union will conduct WAs testing and provide As education. In the second group of 10 villages, a person residing in the study village will provide these same services.

Specific Aim 1.2: We will develop and implement a training program for 10 community members and 10 individuals outside the community on how to measure the As content of tubewells using As test kits, and to educate villagers about the consequences of continued As exposure as well as their mitigation options.

Specific Aim 1.3: We will determine whether having a person living in a village providing WAs testing and As education is more effective in terms of reducing As exposure then having a person from outside the village perform the same tasks. Two indices of effectiveness will be used: (a)

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well switching behavior, that is the proportion of households with unsafe wells that switch to an alternative well; and (b) a decline in Urinary As (UAs) exposure between baseline and follow-up at as the biological index of exposure.

Hypothesis 2: We will observe a higher follow-up knowledge of As quiz score in the local versus outside tester villages after controlling for baseline knowledge of As.

Specific Aim 2.1: We will use baseline and follow-up knowledge of As quiz scores of the 1000 study respondents to assess the effectiveness of the As testers to increase the As knowledge score of the study respondents.

Specific Aim 2.2: We will use baseline and follow-up As quiz scores of study respondents to assess the association between knowledge of As and As exposure. Two indices of exposure will be used: (a) the proportion of households with unsafe wells that switch to an alternative wells (b) a decline in UAs exposure between baseline and the follow as the biological index of exposure.

Hypothesis 3: The As tester training program will effectively train the As testers to measure the amount of As in the drinking water using an As field testing kit and to disseminate As education to study households.

Specific Aim 3.1: We will use the laboratory analysis of water samples collected from the primary drinking water sources of study households to determine (a) if field As test kit measurements significantly correlate with laboratory measurements (b) if the laboratory and field WAs results will be concordant in terms of predicting safe or unsafe wells relative to the Bangladesh As standard of 50 micrograms per liter.

Secondary Analyses

We will characterize the potential predictors of (a) well switching (b) follow-up UAs after controlling for baseline UAs and (c) follow-up knowledge of As quiz score after controlling for baseline knowledge of As. We will examine at the following potential predictors: proportion of unsafe wells in a village, sociodemographic characteristics, reinforcement provided by As tester, and educational level.

Chapter 2: Health Effects of As and Metabolism

2.1 Arsenic Metabolism

Inorganic As (InAs) is metabolized once it enters the body. Arsenate (As^{+5}) is first reduced to arsenite (As^{+3}) in a glutathione dependent reaction (Figure 2). In Bangladesh, the primary form of As in well water is As^{+3}, although some oxidation to As^{+5} may occur before the water is consumed in the household. Arsenite then goes through oxidative methylation with S-adenosyl methionine (SAM) as the methyl donor leading to the formation of monomethylarsonic acid (MMA^V) and S-adenosyl homocysteine (SAH). After this step MMA^V is reduced to MMA^{III}, followed by an oxidative methylation step that forms dimethylarsinic acid (DMA^V) and SAH. MMA^{III} and DMA^{III} are thought to be more toxic than the pentavalent or inorganic As forms (17-19). The ratios of MMA:InAs (primary methylation index (PMI)) and DMA:MMA (Secondary Methylation Index (SMI)) are indicators of the efficiency of the first and second steps of methylation (20). A decrease in the efficiency of the first step of As methylation has been associated with reduced plasma antioxidant capacity. This finding suggests a potential pathway by which As exposure could increase levels of reactive oxidants in the cell (21).

An increased proportion of MMA in urine has been associated with an increased risk of cancers of the lung (22), bladder (23-26), and skin (27-29), urothelial carcinoma (25, 26), skin lesions (30, 31), peripheral vascular disease (32), atherosclerosis (33), and hypertension (34). Genetic polymorphisms, folate status, total homocysteine, body mass index (BMI), and sex have been shown to be associated with As metabolism (17, 31, 35-53). Polymorphisms of the As^{+3} methyltransferase (AS3MT) gene that encodes a 43kDa protein that catalyzes the methylation of InAs has been demonstrated to affect As metabolism (41-54). A case control study in Mexico

found that an AS3MT polymorphism (genotype Met287Thr) significantly increased the odds of premalignant As induced skin lesions (Odd Ratio (OR)=4.28; 95% CI (1.0-18.5)) (51). In animal studies, AS3MT knockout mice had larger and more abundant granules in the bladder epithelium and a greater proportion of inorganic and monomethylated As in urine than wild type mice (54, 55).
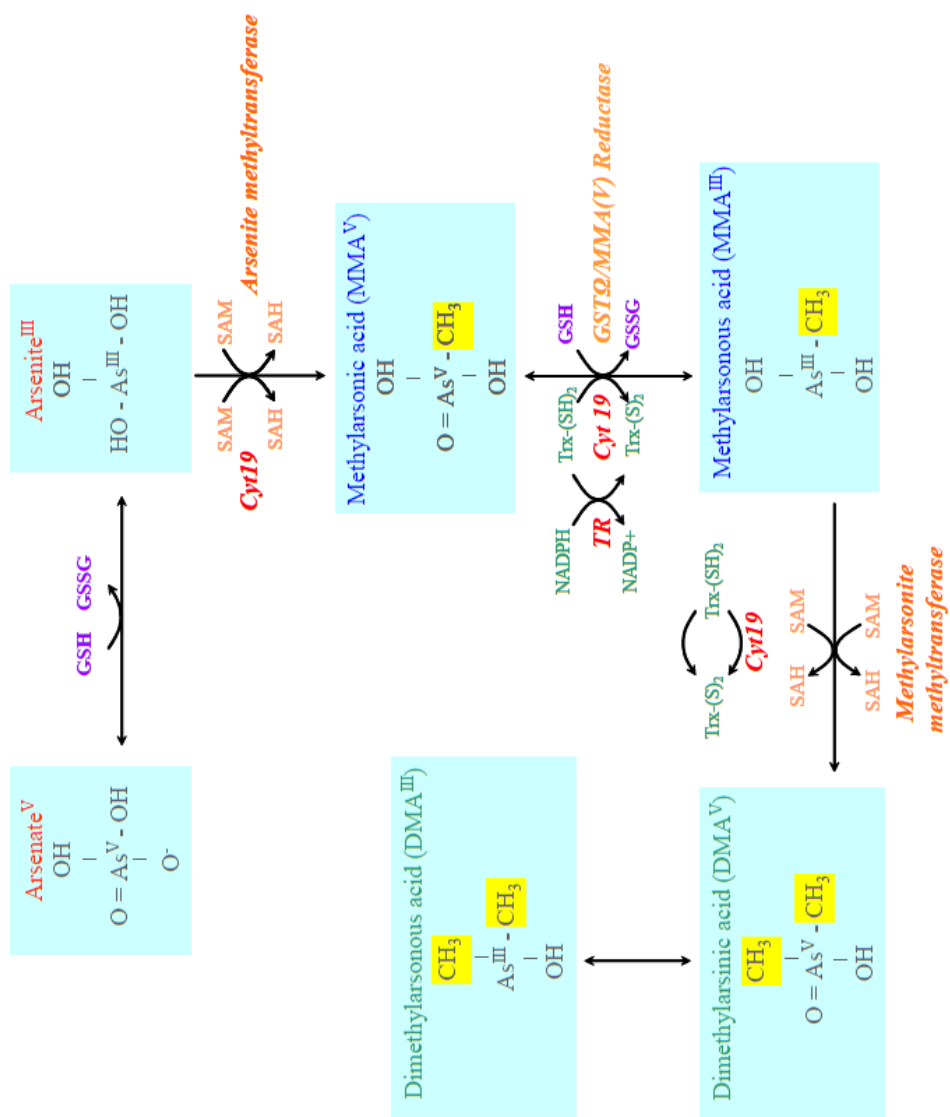
Figure 2. Arsenic Metabolic Pathway
Source: Gamble MV

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2.2 Biomarkers of As Exposure

Elimination of ingested As occurs predominately in the urine (56-58). Biomarkers of As exposure include concentrations of As in hair, toenails, blood and urine (59-70). Arsenic accumulates in hair and nails due to its affinity for sulfhydryl groups in keratin (60, 66, 71).

In a cross-sectional study in Australia, a significant correlation was found between WAs concentrations and toenail As (r=0.55, P<0.01) and hair As (r=0.49, P<0.01) concentrations (72). A study in West Bengal, India found significant correlations between WAs concentrations and fingernail InAs (III), MMA(V), DMA(III), DMA(V), and total nail As concentrations. There were also significant correlations found between WAs concentrations and hair MMA(V), DMA(III), DMA(V) concentrations (66). In a study conducted in a region of Chile that was highly exposed to As between 1958-1970, a decline in hair and nail clipping As concentrations was observed six years after the exposure ended (69), demonstrating that a reduction in WAs exposure can successfully reduce these biomarkers of As exposure.

Toenail and hair As concentrations are measures of past As exposure while urinary As (UAs) provides a measure of more recent exposure (71). Thus, in order to evaluate the short term changes in As exposure such as those that would occur over a short term intervention study, UAs would be the preferred biomarker of exposure. Furthermore, the majority of As absorbed is excreted into the urine, and UAs has the advantage of being relatively easy to collect (57).

UAs measurements have been found to be relatively stable over time (73-75). A recent study in Michigan of 131 participants, where As concentrations in drinking water ranged from 10 to 100 µg/L, found a significant correlation between the UAs concentrations in first morning void urine

and spot urine samples for the sum of As (III), As(V), MMA(V), and DMA(V) (r=0.80 P<0.001). Furthermore, there were also significant correlations between spot urine samples and first morning void urine for MMA (V) (r=0.083 P<0.0001) and DMA(V) (r=0.77 P<0.0001) (75). Therefore spot urine samples can be used to estimate short term As exposure. However, because of the presence of non-toxic arsenobetaine and arsenocholine from the consumption of seafood, speciation of inorganic and organic forms of UAs is ideal for the measurement of As exposure rather than total UAs (76). In Vietnam, a significant correlation was found between InAs intake from water and urine concentrations of InAs (r=0.41 P<0.001), total DMA (r=0.41 P<0.001), and total As (r=0.39 P<0.001) adjusted for creatinine. Arsenic concentrations in groundwater in the study area were <1.8 to 486 µg/L (65).

In a study conducted in Araihazar, Bangladesh, it was found that UAs concentrations were on average 3 times higher for individuals drinking from unsafe wells (>50 ug/L As) compared to those using safe wells (≤50 ug/L As). Furthermore for those individuals who switched from an unsafe to a safe well there was an overall average drop in UAs per gram creatinine of 46% over a two year period. Urinary As levels did not change appreciably for individuals who continued to rely on the same well for drinking water. The results of this study suggest that switching from an unsafe to a safe well can reduce UAs to a level that approaches those of residents who have been consistently relying on safe wells (16).

Collectively, these studies demonstrate that UAs can be used as a reliable biomarker of As exposure to determine changes attributable to well switching. However, there are some potential drawbacks to the use of UAs as a biomarker of As exposure. The scientific literature indicates that the body retains stores of As after the cessation of exposure; therefore, it is possible that As

can be excreted into urine over time even after the exposure has ended (16, 77, 78). Furthermore, UAs only provides a measure of excretion and does not provide a measure of the tissue burden of As (71). Recent data suggests that there may be a gender bias introduced when urine samples are normalized for creatinine to adjust for hydration status. It has been found in Bangladesh that urinary creatinine is significantly correlated with plasma folate concentrations particularly in males, due to their higher prevalence of folate deficiency (79). Age, ethnicity, and BMI are all significant predictors of urinary creatinine (UCr) (80).

Blood As (BAs) does not need to be normalized for dilution because blood concentrations are very tightly regulated. It also represents an internal dose of both past and current exposure. Blood As has the potential to serve as a biomarker of past exposure. An early study in Argentina found that BAs could only be detected at high As exposures (81). However, recently our group has developed a method to allow for continuous BAs measurement from 3 to 50 μg/L using inductively coupled plasma mass spectrometry (ICP-MS). Blood arsenic is eliminated using a 3-component exponential decay pattern. The first half life is 1-2 days, the second 9.5 days, and the final 38 days (58). Hall et al demonstrated that BAs is strongly correlated with both water and UAs adjusted for creatinine (r=.76 and r=.85 respectively). Furthermore, in a case-cohort study in Araihazar, Bangladesh a significant association was found between the highest two quintiles of BAs concentration and an increased risk of skin lesions (60).

There are two potential drawbacks to using BAs as a biomarker of As exposure in our study population in Bangladesh. The first is the short half life of organic and InAs species in blood (57). The second is that individuals in Bangladesh, because of their cultural perceptions of blood, often feel extremely uncomfortable giving venous blood samples. This causes particular

difficulty when research participants are invited to be involved in clinical trials where blood is collected at multiple time intervals over a period of months or years. To overcome this problem our research group has employed capillary blood sampling for the measurement of BAs. Collecting blood by fingerstick requires less blood then traditionally used venipuncture measurements. The precision of venous and capillary blood collection for measuring BAs were compared. Arsenic measured by venous and capillary sampling methods were highly correlated (r=0.97) with a mean difference between capillary and venous methods of 1 µg/L. These results demonstrated that capillary sampling is an acceptable alternative to venipuncture for measuring BAs concentrations.

2.3 Health Implications of As Exposure

Exposure to elevated levels of inorganic As is associated with increased risk for, lung cancer (82-87), bladder cancer (82, 83, 86, 88-90), kidney cancer (86, 91, 92), skin cancer (82, 86, 93), developmental effects (94, 95), cardiovascular disease (96, 97), neurological effects (98, 99), skin lesions (100, 101), respiratory effects (102, 103), all cause mortality (104), and less conclusively colon cancer (82), liver cancer mortality (105), and prostate cancer (106). Chronic As exposure is also associated with deficits in childhood cognitive and motor function (95, 107, 108). However there is conflicting scientific literature as to whether As is associated with diabetes (109, 110) and adverse pregnancy outcomes (111, 112). In following sections we look at each of these outcomes in greater detail.

2.3.1 Arsenic Induced Skin Lesions

Skin lesions are the most commonly associated clinical sign of toxicity from chronic As exposure (113). Arsenicosis has been defined as chronic subclinical or clinical toxicity due to high levels of As being present in the body. Clinical symptoms of arsenicosis can include: melanosis, spotted and diffuse keratosis on the palms and soles, and dorsal keratosis (114). In contrast to other diseases associated with As, arsenicosis has been reported to present after a short duration of exposure. Studies have reported arsenic induced skin lesion cases after six months of As exposure (114-117). K.C. Saha found As induced skin lesion from as early as 1980s in West Bengal, India (118, 119).

The Health Effects of As Longitudinal Study (HEALS) is an ongoing prospective cohort study in Araihazar, Bangladesh of 12,000 men and women ages 18-65 years old that began in 2000. The study area of the cohort contains a wide range of well WAs concentrations. Baseline health information was collected from study participants as well as whole blood, urine, well water samples, a semi-quantitative food frequency questionnaire to measure dietary intakes, and an extensive physical exam. The cohort is followed up in 2 year intervals. The primary objective of this cohort study is to investigate the health effects associated with chronic As exposure. The study area is located in Araihazar upazilla which is a subdistrict, one of 507 upazillas located in Bangladesh. Araihazar has an area of 183 square kilometers and is comprised of 12 unions (62).

Several studies have discovered a dose response relationship between As exposure and skin lesions (120-124). In the most recent evaluation by the Columbia University HEALS study, 10,182 adults free of skins lesions at baseline were followed between 2000 and 2009. The multivariate –adjusted hazards ratios (HR) for skins lesions were calculated comparing the

following ranges of WAs exposure: <10 (referent group), 10.1-50, 50.1-100, 100.1-200, and $\geq$200.1 μg/L. The HRs were 1.17 (95% CI: 0.92, 1.49), 1.69 (95% CI: 1.33, 2.14), 1.97 (95% CI: 1.58, 2.46), and 2.98 (95% CI: 2.40, 3.71), respectively (P(trend) = 0.0001) (120). This evaluation has the strength of prospectively evaluating a cohort over a 9 year period.

The risk of skin lesions from As exposure has been shown to be modifiable by factors such as exposure to sunlight, gender, age, socioeconomic status, folate and selenium status, smoking, BMI, and genetic polymorphisms related to As metabolism (28, 30, 115, 121, 125-130). Studies have suggested that eating a diet rich in vegetables may reduce As induced skin lesion risk (131). Significant synergistic effects have been observed between fertilizer use and WAs exposure and risk of skin lesions (132).

Our research group conducted a randomized double-blind placebo-controlled pilot trial of 121 men and women to evaluate the effects of vitamin E (alpha-tocopherol) and selenium (L-selenomethionine) on As induced skin lesion in Bangladesh. The study found that supplementation with vitamin E and selenium or either alone slightly improved skin lesion status, however this was not statistically significant (2). Currently our research group at the University of Chicago is conducting the Bangladesh Vitamin E and Selenium Trial (BEST) which is a 2 x 2 factorial clinical trial of the prevention of cancer and mortality among more than 7000 individuals with As induced skin lesions.

2.3.2 Arsenic and Cancer

A calculation of lifetime excess risks due to As in Bangladesh by our research group found that elevated As exposure from drinking water could be attributed to a doubling of lifetime mortality

risk from liver, bladder, and lung cancers (229.6 vs. 103.5 per 100,000 population) in Bangladesh (133). Furthermore, studies indicate that tobacco use can increase the risk of skin, lung, and bladder cancer from As exposure (84, 85, 89, 93).

In a case control study in northern Chile of 152 lung cancer cases and 419 controls, a significant dose response relationship was found between As in drinking water and lung cancer. The ORs for lung cancer were calculated comparing the following ranges of WAs exposure: <10 (referent group), 10-29, 30-49, 50-199, 200-400 µg/L. The ORs were 1.6 (95% CI: 0.5, 5.3), 3.9 (95% CI: 1.2, 12.3), 5.2 (95% CI: 2.3, 11.7), and 8.9 (95% CI: 4.0, 19.6), respectively (84). Further, an ecological study conducted in Chile found an increasing trend for lung cancer mortality with increasing As exposure (92).

In an ecological study in Argentina, As exposure was associated with increased risk of colon cancer in women, and lung and bladder cancer in both sexes (82). However, this result for colon cancer has not be replicated elsewhere. An ecological study conducted in Chile found an increasing trend for kidney cancer mortality with increasing As exposure (92). Ecological studies in both Argentina and Taiwan found a significant dose response relationship between bladder cancer mortality and increasing As exposure (86, 134). However these ecologic and retrospective case control studies have methodological limitations because of the absence of individual level exposure data.

In areas of Taiwan where households had switched to As safe municipal water supplies in 1970s from the As contaminated wells they had been using since the 1920s, an age-period cohort model was used to calculate cancer risk. A significant reduction in the relative risk of bladder cancer (RR: 20 (early cohort (birth year 1914-1943)) vs. 5 (late cohort (birth year 1944-1953)) and lung

cancer (RR: 8 (early cohort(1909-1928) vs. 1.5-2 (late cohort (birth year 1949-1953))) was observed between the early versus late birth cohorts (83). Despite the limitation of it being an ecologic study, thereby lacking individual level exposure data, these findings suggest that a reduction in As intake from contaminated well water can reduce the risk of As induced cancers.

Current research suggests that individual differences in As metabolism, may affect susceptibility to As induced cancers (22, 24, 26, 27). A case control study in Argentina of 45 lung cancer cases and 75 controls found that those with higher % MMA in urine (highest tertile) had a significantly higher lung cancer OR (OR 3.09 [95% CI: 1.08-8.81]) (22). Consistent with these findings, in a prospective cohort study in Taiwan it was found that elevated % MMA (>26.7%) in urine was associated with increased risk of skin cancer (OR=20.91 (95% CI 2.62-166.5) (27). Two case control studies in Tawian also found that individuals with low DMA have an increased risk of developing bladder and skin cancer (23, 135). Further, two prospective cohort studies in Taiwan have found a significant association between urothelia carcinoma and higher percentage MMA (25, 26). The majority of the studies investigating the role of As metabolism in cancer risk involve cases and controls. Future studies should focus on prospectively evaluating the impact of As metabolism on As induced cancers, and the role of genetic polymorphisms on arsenic methylation .

In Region II of northern Chile, a series of ground breaking studies were conducted where WAs concentrations of a municipal water supply were on average 860 µg/L between 1958-1970. In 1970 this was reduce to 40 µg/L with the installation of a water treatment plant (84). Because of this sudden reduction in As exposure this site provided a unique opportunity to evaluate the impact of early life high exposures to As (88). A ecologic study demonstrated that adults age 30-

39 years old who were born *just before* or *during* the high As exposure period had an significantly increased risk of kidney cancer mortality (RR=7.1 [3.1-14]) (91). A second ecological study in this region on early life exposure investigated the impact of high As exposure on childhood mortality. It was found that those individuals exposed to As as young children had a significantly higher risk of liver cancer mortality (RR=10.6 [2.9, 39.2]) (105). A third ecological study in Chile of a birth cohort born between 1950-1957, right *before* the high As exposure period, found an significant increase in the standardized mortality ratios (SMR) for lung cancer compared to the rest of Chile (SMR: 7.0 (95% CI: 5.4-8.9)). Further, for those born *during* the high exposure period (1958-1970) there was also a significantly higher SMR for lung cancer (SMR:6.1 (95% CI: 3.5-9.9) (87). These studies demonstrate the effect of prenatal and early life exposure to high concentrations of WAs on As induced cancers. Further, these studies have shown a long latency period for mortality from kidney, lung, and bladder cancers, even though As exposures had decreased more than 25 years previously (84, 91). A potential limitation of these studies is that they compare "older born to later born generations", therefore there is the possibility of an intergenerational effect, where younger populations are healthier in general because of factors such as improved nutrition.

Potential Mechanisms

A recent study has identified an As-induced tumor suppressorome comprised of 17 tumor suppressor genes known to be silenced in human cancers (136). Silencing of this tumor suppressorome may be a possible biological mechanism for arsenic induced cancers. Furthermore, increased free radical generation from arsenic exposure has been linked to cell signaling, apoptosis, and mutagenesis (137). A study by Wen et al. found that human small

airway epithelial cells exposed to arsenic had significantly higher apoptosis after being treated with Fas ligan and hydrogen peroxide, apoptosis inducing agents (138), and studies in mammalian cells have shown that arsenic exposure can increase 8-hydroxy-2V-deoxyguanosine (139). However, whether this free radical generation results in arsenic induced cancers remains inconclusive (140). Several studies suggest that arsenic could potentially induce p53 through an ATM-dependent pathway (141). While other studies have found that the promoter of p53 in arsenic exposed cells becomes hypermethylated resulting in decreased p53 expression, leaving cells venerable to uncontrolled proliferation, apoptosis, and genomic instability (142, 143). In contrast, a recent study found that arsenic exposure resulted in a increase of oncoprotein expression which correlated with a decrease in wild-type p53 expression and hyperhosphorylated retinoblastoma (144).

2.3.3 Arsenic and Childhood Intellectual and Motor Function

Numerous studies of children have reported an association between As exposure and decreased cognitive (94, 95, 107, 108, 145-149) and motor function (148, 150). In a 2004 cross-sectional study of 201 children ten years of age in Bangladesh by our research group, the association between As exposure and childhood intellectual function was investigated. Intellectual function was assessed using the Wechsler Intelligence Scale for children (WISC) version III. Those children with elevated As exposure (>50 µg/L) had significantly lower performance and full scale scores than the reference group (WAs <5.5 µg/L) (P<0.01) (108). In a 2007 cross-sectional study in Bangladesh of 301 children six years of age by our research group, the association between As exposure and childhood intellectual function was also investigated. Intellectual function was assessed using the Wechsler Preschool and Primary Scale of Intelligence version

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III. There was a significant association found between increased WAs exposure and performance raw score (Regression Coefficient (B): −0.48 (Standard Error (SE): 0.24) P<.05) and processing speed raw score (B: −0.54 (SE: 0.28) P<.05) (107).

In a recent cross-sectional study of 299 children 8-11 years of age, our research group investigated the possible synergistic impact of As and manganese (Mn) exposure on children's intellectual function. Participants were stratified by As and Mn exposure into the following four categories: (1) As >10 µg/L and Mn >500 µg/L; (2) As >10 µg/L and Mn $\leq$ 500 µg/L; (3) As $\leq$ 10 µg/L and Mn > 500 µg/L; and (4) As $\leq$ 10 µg/L and Mn $\leq$ 500. In the unadjusted analysis a significant inverse relationship was found between BAs and Mn and full scale IQ (WISC-IV scores) and several subscales. However after adjustment for maternal intelligence, maternal age, school months, head circumference and high plasma ferritin (>32.5), an inverse significant relationship was only found between BAs concentrations and verbal comprehension scores (B: −1.49 (SE: 0.71) p<0.05) , and blood Mn concentrations and working memory (B: −2.56 (SE: 1.22) p<0.05) and perceptual reasoning scores (B: −4.88 (SE: 2.34) p<0.05). There was no significant interaction found between Mn and As exposure (95). The most recent evaluation by our research group investigated the association between WAs and Mn exposure and motor function in the same group of children. A significant association was found between log transformed BAs concentrations and decreased total motor function composite score (β=-3.63; 95% CI: -6.72, -0.54), fine motor control (β= -1.68; 95% CI: -3.19, -0.18), and body coordination (β= -1.61; 95% CI: -2.72, -0.51). Manganese exposure was not found to be associated with motor function (150).

In Matlab, Bangladesh a study of 1799 infants was conducted to determine the effect of As

exposure during pregnancy on child development at 7 months using two problem solving tests, the motor scale of the Bayley Scales of Infant Development-II, and behavior ratings. There was no significant association found between UAs and any of the developmental outcomes (151). In a longitudinal cohort study of 2112 children in Matlab, Bangladesh, there was no association found between pre- or post-natal As exposure and child development using the Bayley Scales of Infant Development-II at 18 months (152). A limitation of both these studies was that all mothers were given folate supplementation during pregnancy which has been shown to reduce blood arsenic levels, and increase arsenic methylation (36). Furthermore, the later study had a considerable loss to follow-up, and the lost to follow-up children had lower birth-weights and head circumferences. Although the findings in these studies were null, it is possible that cognitive deficits from arsenic exposure will become apparent later in childhood.

In China, a cross-sectional study of 720 children between 8-12 years of age was conducted to investigate the impact of WAs and fluoride exposure on children's IQ and growth. Childhood IQ was measured using a modified version of the Combined Raven's test- The Rural in China. The mean IQ score for the highly As exposed area (190 ± 183 µg/L As) was significantly lower than in the control group (2 ± 3 µg/L As). The IQ scores were 95 ± 17 and 105 ± 15, respectively ($P<0.01$). A major limitation of this study however is the lack of individual level exposure data for all children enrolled in the study, village means were calculated based on a random subset of water and urine samples (147). However, these findings are consistent with third a cross-sectional study of 132 children 6 -10 years old in Mexico which found that increased UAs concentrations were associated with decreased Full IQ scores ($\beta=-5.72$, $P=0.003$) (153). In West Bengal, India, a cross-sectional study of 351 children between the ages of 5 -15 years old was conducted to investigate the association between water As exposure and intellectual function. Neuro-

developmental function was assessed using the WISC, a total sentence recall test, the Raven's

colored progressive matrices test, and a pegboard test. There was a significant association found

between increasing tertiles of UAs and a reduction in adjusted scores for the vocabulary test (0, -

0.14, -0.28; P for trend= 0.02), the object assembly test (0, -0.16, -0.24; P for trend = 0.03), and

the picture completion test (0, -0.15, -0.26; P for trend = 0.02). However no association was

observed between cumulative WAs exposure and intellectual function measured using the WISC

(146). In Taiwan, a cross-sectional study was conducted of 109 junior high students (~12-14

years of age) to investigate the impact of As exposure on cognitive function. Cognitive function

was assessed using the Neurobehavioral Evaluation System 2. Reduced pattern memory,

switching attention, symbol digit performance, and continuous performance test were

significantly associated with long-term cumulative As exposure adjusting for age and sex (p<.05)

(149).

In Mexico, a cross-sectional study of 607 children between the ages of 6-8 years old was

conducted to evaluate the impact of As exposure on cognitive function. The source of As was a

metallurgic smelter complex located 3.5 kilometers from their homes. Urinary As concentration

was found to be significantly associated with Visual-Spatial Abilities with Figure Design, the

Peabody Picture Vocabulary Test, the WISC-RM Digit Span subscale, and Letter Sequencing

test (P<0.05) . A potentially serious limitation of this study however was that urinary arsenic was

not adjusted for hydration status (148). Another cross-sectional study conducted in Mexico of 80

children, 6-9 years old, investigated the impact of chronic As and lead exposure from a smelter

and under nutrition on neuropsychological development in children. The WISC was used to

assess neuropsychological development. Urinary As concentrations were significantly associated

with decreased verbal IQ score (P<0.01) (94). A potential limitation of these smelter studies

however is that they involve both lead and arsenic exposure simultaneously therefore it is difficult to determine the impact of either alone. Finally, in Oklahoma, a pilot study was conducted of 32 children between the ages of 11-13 years old to investigate the impact of heavy metal exposure from a hazardous waste site on childhood intelligence scores. A significant inverse relationship was found between hair As levels and verbal IQ scores ($P\leq0.01$) (98). These findings collectively indicate that childhood As exposure can result in decreased cognitive and motor function.

Possible Mechanisms

A recent animal study found that As was present in all areas of the brain but accumulates the most in the pituitary gland (47). Arsenic is suspected to induce oxidative stress in the brain by increasing the formation of reactive oxygen species (154-157). Further, animals studies have indicated that As exposure can result in nitric oxide dysfunction affecting neurotransmission in the brain, and may be responsible for structural alterations in the brain such as faulty migration, delayed maturation, and alterations in nuclear area measurements of Purkinje cells that can affect early brain development. There was also evidence of effects on the hypothalamic-pituitary gonadal axis in male rates (47, 158, 159).

2.3.4 Arsenic and Respiratory Disease

Human studies find associations between chronic As exposure and reduced lung function (160-162), bronchiectasis (87, 102, 163, 164), and cough (69, 102, 163-167), and less conclusively pulmonary tuberculosis (168), acute respiratory infection (169). Arsenic has been shown to interfere with JAK-STAT, essential for mediating cytokine receptor signaling pathways and the

regulation of cell growth, by suppressing cytokine function and production (170).

In Matlab, Bangladesh, a cohort study (n=140) was conducted to determine the effects of *in-utero* As exposure on childhood immunity and acute respiratory infections in infants. Maternal UAs concentrations (collected at 6-10 and 30 weeks of gestation) were negatively associated with interleukin-7, lactoferrin, and child thymic index at 12 months, and positively associated with the number of days of acute lower respiratory infections at 6-12 months ($P<0.01$) (169). However, this study had a relatively small sample size. In another prospective cohort study (N=1552) in Matlab, Bangladesh, infants of mothers with UAs concentrations (collected at 8 and 30 weeks of gestation) in the highest quintile during gestation had significantly increased relative risk of lower respiratory tract infection (LRTI) (RR: 1.69 [95% CI: 1.36, 2.09]) and severe LRTI (RR: 1.54 [95% CI: 1.21, 1.97]) at 12 months compared to those in the lowest quintile (171). These results indicate an association between prenatal As exposure and immune response and respiratory infections in children, however the mechanism underlying these effects remain unclear. A potential limitation of these studies is that outcome classifications were based on mother's report of respiratory systems, and there was no measurement of the infant's exposure to arsenic.

In Chile, a cross-sectional study of 97 participants was conducted to evaluate the effects of early life As exposure (<10 years of age) on lung function. Early life As exposure was significantly associated with decreased lower forced expiratory volume measured in one second (FEV(1)), decreased forced vital capacity (FVC), and increased breathlessness ($P<0.05$). Furthermore a significant exposure response relationship was found between early life As exposure and FEV(1) and FVC (P for trend= 0.03) (160). This study was the first to demonstrate that arsenic exposure

40 years earlier could be linked to reduced lung function and increased respiratory symptoms. However, a potential limitation of this study was that it was a convenience sample of nursing school employees and therefore may not be generalizable. Furthermore the sample size was small as only 32 adults highly exposed to arsenic were included in the study. Further research should be done to corroborate these findings.

In Pakistan, a cross-sectional study of 160 individuals ($\geq$15 years old) found that elevated WAs exposure ($\geq$ 250 µg/L) was significantly associated with decreased FEV(1) and FVC in comparison to the unexposed group (<10 µg/L) (P<0.05) (172). A cross-sectional study of 287 individuals ($\geq$ 20 years old) in West Bengal found a significant association between a 100 µg/L increase in WAs concentration and decreased FEV(1) (P=0.02), and a marginally significant reduction in FVC (P=0.054) (161). Consistent with these findings is a study in West Bengal of 159 respondents (15-50 years old) which found that chronic arsenic exposure, defined as water arsenic greater than 50 µg/L, presence of arsenic induced skin lesions, and/or having elevated hair or nail arsenic concentrations, was associated with reduced FEV(1) (P=0.0005), FVC (P=0.025), FEV(1)/FVC (P=0.007), and peak expiratory flow rate (P=0.0002) (162). These findings indicate an association between both chronic arsenic exposure and reduced lung function.

In Bangladesh, a cross-sectional study of 218 individuals found that water As exposure (136-1000 µg/L) was significantly associated with chronic bronchitis (Crude prevalence ratio: 2.9 [95% CI: 1.6 – 5.4]) and chronic cough (Crude prevalence ratio: 2.9 [95% CI: 1.5 – 5.4] compared to unexposed individuals. However this study had two major limitations, it lacked individual level exposure information and only reports the crude prevalence ratios. Further, it

only focused on a population with skin lesions (173). In West Bengal, India, a small study of 38 As exposed (>400 µg/L) individuals found that those with skin lesions had a 10-fold increase in prevalence of bronchiectasis compared to those without skin lesions (OR: 10 (95% CI: 2.7 – 37)) (164).

An ecological study in Chile comparing an area highly As exposed (860 µg/L) between 1958-1970 to an area of low As exposure found a significant increase in the rate ratios of pulmonary tuberculosis observed for men starting in 1968 (10 years after the exposure began), and for women starting in the period of 1971-1985 in the highly As exposed areas (168). Another ecological study in the same region of Chile found that a birth cohort born right *before* the high exposure period (1950-1957) had significantly increased standardized mortality ratios (SMR) for bronchiectasis in comparison to the rest of Chile (SMR: 12.4 (95% CI: 3.3-31.7)). Furthermore those born *during* the high exposure period (1958-1970) also had significantly higher SMR for bronchiectasis (SMR: 46.2 (95% CI: 21.1-87.7)) (87). These results suggest that As exposures prenatally and during early childhood increase mortality from nonmalignant lung disease later in life.

In a recent evaluation by our research group, the results of the HEALS cohort study of 11,746 participants followed for 4 years in Bangladesh was used to determine the association between As exposure and respiratory symptoms. These respiratory symptoms included frequent cough, cough accompanied by blood, and difficulty breathing. The adjusted HRs over 4 years for respiratory symptoms were calculated comparing the following quintiles of WAs concentrations: ≤ 7 (referent group), 7-40, 40-90, 90-178, and >178 µg/L. The adjusted HRs were 1.27 (95% CI: 1.09 -1.48), 1.39 (95% CI: 1.19 -1.63), 1.43 (95% CI: 1.23 - 1.68) and 1.43 (95% CI: 1.22 - 1.68)

with increasing quintiles of WAs. This model was adjusted for age, gender, BMI, smoking, education, the presence of skin lesions, and well switching status. Similar findings were observed when UAs was used as the biomarker of exposure (166). These results demonstrate a strong dose response relationship between As exposure and respiratory symptoms. Furthermore these findings demonstrate a significant relationship between chronic As exposure and respiratory symptoms below the Bangladesh As standard in the 7-40 µg/L WAs range.

In a cross-sectional study of 241 nonsmoking individuals by our research group it was found that the serum level of Clara cell protein (CC16), a biomarker for respiratory illness was significantly inversely associated with UAs concentrations (β=-0.13, p=0.01) in those individuals with skin lesions. Furthermore there was a positive association between the SMI for UAs and CC16 levels. These results suggest that a higher As methylation capacity may be protective against the development of adverse respiratory effects (103). Collectively, these findings indicate that chronic As exposure can result in respiratory diseases.

Possible Mechanisms

Animals studies have found As in drinking water to cause immune suppression which is suspected to affect the pulmonary defense system (113, 170, 174-177). Arsenic has also been shown to induce apoptosis in lung tissues through oxidative stress in cell culture (178). In West Bengal, a study of 38 individuals with and without skins lesions found a significant dose dependent suppression of concanavalin A induced T-cell proliferation in those with arsenic induced skin lesions compared to the unexposed group (P<0.001) (179). In Mexico, a study of 90 children found that increased urinary As was associated with a reduced proliferative response to phytohemaglutinin stimulation (P=0.005), decreased interleukin-2 secretion levels (P=0.003),

and increased granulocyte-macrophage colony-stimulating factor (GM-CSF) secretion by mononucleated cells (P <0.0001). These findings suggests that As exposure may alter the activation of T cells causing immune suppression and that GM-CSF may cause chronic inflammation (180).

2.3.5 Arsenic and Neurological Function

Several studies have indicated a potential association between As exposure and neuropathy (99, 181-188). Early studies in Bangladesh and India indicated that there was an increased prevalence of sensory neuropathy in highly As exposed areas (181, 183, 189). Neuropathy, presenting as a progressive slowing of motor conduction velocity and segmental demyelinating polyradiculoneuropathy, has been observed in individuals with acute As exposure (190-192). In China, a factory accident led to acute As exposures in 104 workers. Forty three percent of the workers developed peripheral neuropathy and 24% showed a decrease in motor and sensory nerve conduction velocity. Furthermore, in comparison to chronically exposed and control subjects, the factory workers with acute As exposure had an elevated proportion of MMA in urine (193).

A cross-sectional study of 137 participants between the ages of 20-50 by our group investigated the relationship between chronic As exposure and subclinical sensory neuropathy in Bangladesh. A significant relationship was found between elevated toe vibration threshold and cumulative WAs index (Regression Coefficient (B): 0.019 [Standard Error (SE): 0.007] P=.009) and UAs (B: 0.014 [SE: 0.012] P=.02) (182).

Consistent with this finding, in Scandinavia, a cross-sectional study was conducted of 47 copper

smelter workers chronically exposed to airborne As and 50 matched industrial workers who were not exposed to As. A statistically significant association was found between As exposure and reduced nerve conduction velocity in three peripheral motor nerves (P<0.05) (184). Another study conducted in Sweden of 43 smelter workers chronically exposed to As for 13-45 years and a matched unexposed referent group found a significant negative association between cumulative As exposure and nerve conduction velocity (P<0.01) (194). A potential limitation of these studies however was that industrial workers were exposed to multiple heavy metals simultaneously therefore the impact of arsenic exposure alone was not assessed. In Georgia, a cross-sectional study of 203 participants found a strong significant association between As exposure from dust and soil and peripheral neuropathy ((OR=5.1; P=0.004) (195). A methodological limitation of these studies however are that they do not measure individual level exposure.

In Taiwan, a cross-sectional study was conducted of 130 children 12-14 years of age to investigate the association between WAs exposure and slow nerve conduction velocity. A significant association was found between a high cumulative lifetime As dosage (>100 mg) and the development of slow nerve conduction velocity (OR: 2.9 (95% CI: 1.1,7.5) (185). Consistent with this finding a cross-sectional study of 160 participants in Taiwan found that residing in As endemic villages, individual level exposure data was not collected, was significantly associated with higher current perception threshold, a indicator of subclincal sensory nerve defects (196).

In summary, these findings indicate that chronic As exposure can result in adverse effects on neurological function. However, a potential weakness of the studies presented is that they are all cross-sectional. Further, they vary widely in their exposure classification. Future studies should

prospectively evaluate the impact of As exposure on neurological function.

2.3.6 Arsenic and Cardiovascular Diseases

Chronic As exposure has been associated with hypertension (34, 96, 167, 197), ischemic heart disease (97, 198), cerebrovascular disease (199), acute myocardial infarction (AMI) (200, 201), atherosclerosis (86, 202), high pulse pressure (96), and less conclusively peripheral vascular disease (32), heart attack (203), mortality from cardiovascular diseases (204), circulatory problems (203), and bypass surgery (203).

In the most recent evaluation by the Columbia University HEALS study, the results of this cohort study of 11,746 participants followed for 6.6 years was used to determine the association between As exposure and mortality from cardiovascular diseases. Mortality from cardiovascular diseases was defined as deaths from diseases of the circulatory system using the International Classification of Diseases, 10th revision. The adjusted HRs for mortality from cardiovascular diseases were calculated comparing the following quartiles of WAs exposure: 0.1-12.0 (referent group), 12.1-62, 62.1-148.10, and 148-864.0 µg/L. The adjusted HRs were 1.22 (95% CI: 0.65, 3.32), 1.35 (95% CI: 0.71, 2.57), and 1.92 (95% CI: 1.07, 3.43), respectively (P=0.0019 for trend). Furthermore a significant synergistic interaction was found between As exposure and cigarette smoking for morality from ischemic heart disease (97).

A cross-sectional study of this same population was conducted using this cohort to determine the relationship between WAs exposure and blood pressure. A significant relationship was found between high pulse pressure (> or =55 mmHg) and increasing time-weighted well As concentrations (TWA) in those with lower than average dietary intake of vitamin B and folate. A

weak association was found between systolic blood pressure and TWA, however no significant relationship was found between TWA and general or diastolic hypertension (96). A pilot study of 66 adults by our research group found that participants with higher carotid intimal thickness (IMT) (>0.75 mm) had greater past As exposure (UAs, WAs, cumulative arsenic index) than those with low carotid IMT (<0.75 mm), however this difference was not statistically significant (205).

In Chile, an ecological study was conducted to investigate the association between chronic As exposure and mortality from 1950 to 2000. This evaluation compared a region of Chile that was highly exposed to WAs (860 μg/L) from 1958 to 1970 with an unexposed region of the country. Mortality risk ratio (RR) were significantly higher for AMI in both men (1.48 [95% CI: 1.37, 1.59]) and women (1.26 [95% CI: 1.14, 1.40]) residing in the highly exposed area between 1958 to 1970. Furthermore, it was found that men born *during* the high exposure period had the highest mortality RR for AMI (3.23 [95%: 2.79, 3.75]). These results suggests that in utero and early childhood As exposure are important risk factors for AMI related mortality later in life (201).

An ecological study in Spain found that low (1-10 μg/L) to moderate (10-118 μg/L) WAs exposure was associated with increased cardiovascular disease mortality. The municipality's cardiovascular disease mortality was significantly higher in the low As (2.2% (-0.9% to 5.5%)) and moderate As (2.6% (-2.0 to 7.5%)) categories respectively compared to referent areas with <1 μg/L WAs concentrations (P-value for trend 0.032) (204). Similarly, in a cross-sectional study of 1185 respondents in Wisconsin it was found that respondents with greater than 2 μg/L of As exposure were significantly more likely to report high blood pressure (OR 1.68 (95% CI:

1.13, 2.49), circulatory problems (OR 2.64 (95% CI: 1.17, 5.95), heart attack (OR 2.08 (95% CI: 1.10, 4.31)), and bypass surgery (OR 2.34 (95% CI: 1.12, 4.90)) compared to those individuals exposed to less than 2 μg/L (203). These results suggest that the impacts of As exposure on cardiovascular diseases can be observed at concentrations below the WHO guideline. However these findings have not been replicated elsewhere and have methodological limitations because they are either ecological or cross-sectional. Future studies should prospectively evaluate the impacts of low level arsenic exposure on cardiovascular disease.

In Taiwan, a cross-sectional study of 462 respondents was conducted to investigate the association between long-term As exposure and ischemic heart disease. The ORs were calculated comparing the following tertiles of cumulative As exposure: 0 (referent group), 0.1-14.9, >15.0 mg/L year. The ORs were 1, 1.60 (95% CI: 0.48, 5.34), and 3.60 (95% CI: 1.11, 11.65), respectively. These results indicated a significant dose-response relationship between cumulative As exposure and ischemic heart disease (198). In another cross-sectional study of 8102 respondents in Taiwan the association between long-term As exposure and cerebrovascular disease was investigated. The ORs for cerebrovascular disease were calculated comparing the following WAs exposure categories: <0.1 (referent group), 0.1-50, 50.1 to 299.9, and >300 μg/L. The ORs were 1, 2.53 (95% CI: 1.47, 4.35), 2.78 (95% CI: 1.55, 4.97), and 3.6 (95% CI: 1.83, 7.11), respectively. The results of this study demonstrated a significant dose response relationship between WAs exposure and both cerebral infarction and cerebrovascular disease (199).

In a third cross-sectional study in Taiwan of 479 men and women a significant dose response relationship was found between cumulative As exposure and peripheral vascular disease. The

multivariate-adjusted ORs were calculated comparing the following tertiles of cumulative As exposure: 0 (referent group), 0.1-15.4, >15.4 mg/L year. The ORs were 1, 3.41 (95% CI: 0.74, 15.78), and 4.62 (95% CI: 0.96, 22.21), respectively. This study also found that individuals with higher As exposure and an higher PMI (MMA(V)/(As(III) + As (V))) were at a higher risk of developing peripheral vascular disease (32). Further, a case control study in an As endemic area of Taiwan of 372 hypertensive subjects and 499 controls found that hypertensive participants had higher percentages of MMA in urine compared to those without hypertension, suggesting that inefficient methylation may be a risk factor for hypertension (34). A second case control study in Taiwan of 163 carotid atherosclerosis cases and 163 controls found that having high MMA% ($\geq$ 16.5%) and high homocysteine levels ($\geq$ 12.7 micromol/l) was associated with a 5.4-fold increased (95% CI: 2,15.0) risk of developing atherosclerosis (33). However, occupational studies assessing the impact of As exposure on cardiovascular diseases have yielded mostly inconclusive results (206). These findings indicate that chronic As exposure and inefficient methylation can increase the risk of cardiovascular disease.

2.3.7Arsenic and Mortality

An evaluation was conducted by our research group of the HEALS prospective cohort of 11,746 participants followed from 2000-2009 to determine the association between WAs exposure and all cause mortality. The multivariate adjusted HRs for all cause mortality were calculated comparing the following ranges of WAs exposure: $\leq$10 (referent group), 10.1-50, 50.1-150, 150.1-864.0 μg/L. The HRs were 1.34 (95% CI: 0.99, 1.82), 1.09 (95% CI: 0.81, 1.47), and 1.68 (95% CI: 1.26, 2.23), respectively. These results indicate a significant increase in all cause mortality from As exposure greater than 150 μg/L (104).

2.3.8 Arsenic and Diabetes Mellitus

The relationship between chronic As exposure and diabetes mellitus (DM) has been largely inconsistent. Many of the studies conducted vary widely in their exposure and disease classification (207, 208).

A case control study in Mexico of 200 DM cases and 200 controls found that those with the intermediate tertile (63.5–104 µg As /g creatinine) and highest tertile (> 104 µg As /g creatinine) of UAs concentrations were at an increased risk of having diabetes. The ORs for the intermediate and highest tertiles were 2.16 [95% CI: 1.23, 3.79]) and 2.84 (95% CI: 1.64, 4.92), respectively. Diabetes was assessed using the American Diabetes Association criteria (209). Further, a cross-sectional study in Mexico of 258 individuals found the prevalence of diabetes to be positively associated with InAs in drinking water (OR: 1.13 per 10 ppb (1.05, 1.22)). Diabetes was classified as the following: a fasting blood glucose level $\geq$ 126 mg/dL, two-hour blood glucose level $\geq$ 200 mg/dl, and self-reported doctor diagnosis of diabetes or report of use of anti-diabetic medication (210).

In Taiwan, an ecological study was conducted comparing the prevalence of non-insulin-dependent diabetes between As endemic areas (7.5% [CI: 7.4-7.7%]) where a large proportion of the wells exceeded 0.35 mg/L and non As endemic areas (3.5% [CI: 3.5-3.6%]). After adjusting for age and sex, the prevalence OR for diabetes in the As endemic area was significantly higher compared to the non-endemic area (OR= 2.69 [95% CI, 2.65-2.73]) (211). In another ecological study in Taiwan it was found that those living in As endemic areas had significantly greater mortality from DM than in the non endemic areas (212). A limitation of these two ecological studies conducted in Taiwan is a lack of a clear exposure definition. In 2000 a prospective cohort

study in Taiwan found a significant association between cumulative As exposure and diabetes. Four hundred forty six non-diabetic residents at baseline were tested for diabetes biannually by an oral glucose tolerance test. The multivariate-adjusted RR for diabetes from elevated cumulative As exposure (>17 mg/L years) was 2.1 (95% CI, 1.1-4.2) (213).

In the United States, a cross-sectional study of 788 adults 20 years of age or older was conducted using data from the 2003-2004 National Health and Nutrition Examination Survey to evaluate the association between As exposure and type two diabetes. Arsenic exposure was measured using total As, dimethylarsinate, and arsenobetaine in urine. After adjustment for seafood intake, the OR for diabetes were calculated comparing those participants at the 80th vs. 20th percentiles for total UAs (3.58 [95% CI: 1.18, 10.83]), dimethylarsinate (1.57 [95% CI: 0.89, 2.76]), and arsenobetaine (0.69 [95% CI: 0.33, 1.48]). These results demonstrated a 3-fold increase in type two diabetes at low total UAs concentrations of 16.5 vs 3.0 µg/L for the 80th versus 20th quartile, respectively (214). However, this calculation was done including arsenobetaine, a non-toxic organic compound from seafood, in the total As concentration. When this compound was removed from the total As calculation the OR comparing the 20th to the 80th percentile for total UAs became 1.15 (95% CI: 0.53, 2.50) (110).

In the most recent evaluation by the Columbia University HEALS study, a cross sectional study of 11,319 participants was conducted to determine the association between water and UAs, and the prevalence of DM and glucosuria. The adjusted ORs for doctor diagnosed diabetes were calculated comparing the following quintile ranges of WAs exposure: 0.1-8 (referent group), 8-41, 41-91, 92-176, and ≥177 µg/L. The adjusted ORs were 1.35 (95% CI: 0.90, 2.02), 1.24 (95% CI: 0.82, 1.87), 0.96 (95% CI: 0.62, 1.49), and 1.11 (95% CI: 0.73, 1.69), respectively. The

adjusted ORs for diabetes were also calculated comparing the following quintile ranges of UAs concentrations: 1-36 (referent group), 37-66, 67-114, 115-204, and $\geq$205 µg/L. The adjusted ORs were 1.29 (95% CI: 0.87, 1.91), 1.05 (95% CI: 0.69, 1.59), 0.94 (95% CI: 0.61, 1.44), and 0.93 (95% CI: 0.59, 1.45), respectively. Thus, at these moderately elevated level of As exposure there was no association found between DM and the concentration of water or UAs (215).

In a cross-sectional study of 1595 participants in Bangladesh a dose response relationship was found between glucosuria, assessed through a urine strip test, and cumulative As exposure. Culmative As exposure was measured in mg-years/l, calculated by multiplying the As concentration in a well by the number of years it was used by a respondent. When the cumulative As exposure was greater than 10 mg-years/l, an extraordinary high lifetime exposure, there was a significant association between glucosuria and As exposure for those without skins lesions (1.7 [95% CI: 1.0, 2.9]) and those with skin lesions (2.79 [95% CI: 1.6, 5.2]) (216). Similarly, in a case control study in Bangladesh of 163 keratosis cases and 854 controls, the relationship between DM and cumulative As exposure was evaluated. The adjusted prevalence ratios for diabetes were calculated comparing the following cumulative As exposure categories: <0.5 (referent group), 0.5-1.0, and greater than 1.0 mg/liter. The adjusted prevalence ratios were 2.6 (95% CI: 1.2, 5.7), 3.9 (95% CI: 1.8, 8.2), and 8.8 (95% CI: 2.2, 28.4), respectively (217).

In-vitro mechanistic studies suggests that As, particularly the trivalent form, may interfere with transcription factors used for insulin-related gene expression (109, 218). Collectively, these findings indicate that at very high As exposure levels (10 mg-years/l) among those with skin lesions there is an increased risk of DM. However, at moderate to low As exposure levels the results are inconclusive. A limitation of studies to date is that they are all cross-sectional or case-

control. The HEALS study is currently looking at incident DM cases.

2.3.9 Arsenic Effects on Maternal and Neonatal Health

Animals studies have indicated that oral As exposure can cause developmental toxicity such as fetal malformation, mortality, and growth retardation (219-221). Arsenic exposure has been suggested to have an effect on immune function during pregnancy by enhancing placental inflammatory response, reducing placental T cells, and altering cord blood cytokines (222).

In early human studies from a smelter in Sweden where pregnant workers were exposed to As and lead from the production of metals, it was found that As exposure was significantly associated with increased abortion frequency and decreased birth weight (223, 224). A limitation of these studies, however were that they were mostly ecologic, and involved multiple heavy metal exposures simultaneously.

Human studies have indicated that As can pass through the placenta (225-227), however As does not appear to be excreted into breast milk in significant amounts even when the mother is highly exposed (226, 228, 229). Early studies suspected that fetuses and infants may be partially protected by increased methylation of As during pregnancy and lactation (225, 230). However more recent evidence suggests that this increased methylation is likely due to folate supplementation administered during pregnancy to prevent neural tube defects (17, 231). Further, the results of a cross-sectional study of pregnant women in Antofagasta, Chile suggests that selenium intake may correlate with increased UAs excretion and altered As methylation (232).

In an ecological study of 25,648 households conducted in the south east region of Hungary, it was found that there were significantly higher rates of stillbirths and spontaneous abortions in the

As exposed versus unexposed areas (233). In Sweden, an ecological study found that those pregnant women residing in the municipality with the highest WAs concentration had a significantly higher OR for still births (OR: 2.05 [95% CI: 1.08, 3.89]) (234). However these ecological studies have methodological limitations because of the absence of individual level exposure data.

In a prospective pregnancy cohort (n=810) in Antofagasta and Valparaíso, Chile women exposed to higher WAs (40 µg/L) were more likely to be anemic during pregnancy than those unexposed (<1 µg/L WAs) (anemia prevalence 49% (exposed) vs. 17% (unexposed)) (235). In the same cohort it was found that higher WAs exposure was associated with lower mean birth weight (-67 g [-123 , 9]) (236).

A case-control study in Boston, Massachusetts of 286 women having a spontaneous abortion and 1391 having a live-birth found that low WAs exposure between 1.4 and 1.9 µg/L was associated with a 1.7 fold increase in the risk of spontaneous abortion, however not significantly so (237). These findings are consistent with a case control study of still births in an As exposed (As in air from plant releases >100 ng per m^3) community in Texas which found a significantly higher prevalence OR (POR) for still births (POR=4 [95% CI: 1.2, 13.7]) than an unexposed community (238).

In a cross-sectional study in West Bengal there was a significant association between WAs exposure > 200 µg/L and stillbirths (OR=6.07 [1.53-24]) in comparison to an unexposed group. However, there was no association found between elevated WAs exposure and spontaneous abortion or overall infant mortality (239). In a cross-sectional study of 533 women in Comilla and Chandpur districts of Bangladesh there was a significant association found between elevated

WAs exposure (>50 µg/L) and spontaneous abortion (OR=2.5 [95% CI=1.5-4.3]) and stillbirths (OR=2.5 [1.3-4.9]) (240). In a cross-sectional study in the Jessore and Kishorgonj districts of Bangladesh it was found that spontaneous abortion, stillbirth, and preterm birth rates were significantly higher in the As exposed group (>100 µg/L) in comparison to the unexposed group (P=0.008, P=0.046, P=0.018 respectively) (241). A study cross-sectional study of 30,984 pregnancy outcomes from 13 upazillas in Bangladesh found an significant association between As exposure greater than 50 µg/L WAs and stillbirths (OR=1.80 [1.14-2.86]) (111). Another cross-sectional study of 2,006 women in three upazilas of Bangladesh found a small significant association between elevated WAs exposure and birth defects (OR=1.005 [95% CI=1.001-1.010]), however no association was found for stillbirth, low birth weight, childhood stunting, or being under weight in childhood (242).

A cohort study of pregnant mothers (1552 live-born infants) in Matlab, Bangladesh found that those infants born to mothers exposed to the highest quintile of UAs (262-977 µg/L) had a significantly higher risk of developing lower respiratory tract infections (LRTI) (RR=1.69 [1.36 - 2.09]), acute LRTI infections (RR=1.54 [1.21-1.97]), and diarrhea (RR=1.2 [1.01-1.43]) in comparison to the unexposed group (171). There was no exposure-reponse association found with birth weight, birth length, or head and chest circumference in this cohort (243).

Human studies on the effects of As on maternal and neonatal health are difficult to interpret because findings vary widely across studies. Furthermore, the majority of these studies are cross-sectional and vary widely in their As exposure classification.

Chapter 3: Approaches to Arsenic Mitigation

3.1 Arsenic Awareness in the Population

Several studies have assessed the extent of As awareness in Bangladesh. In 2002, a study was conducted to assess As awareness among rural households in Bangladesh. Questionnaire surveys were administered to 356 households in four rural areas. The study population was divided into two groups: 177 respondents were from medium As-risk zones (Narayanganj and Comilla districts) and 179 respondents were from low As-risk zones (Rangpur and Tangail districts). Women accounted for 31% of the study population; the majority of respondents were the head of household. Knowledge of As was assessed from 10 questions. These questions were grouped into the following six categories then combined and weighted to create an As knowledge score: definition of As poisoning, cause/source of As poisoning, symptoms of As poisoning, As related diseases, preventive measures, and solutions to the As problem. The study found that 90% of respondents interviewed were aware of groundwater As contamination. Ninety two percent and 76% of respondents in the medium and high As-risk groups respectively knew that the appearance of As related symptoms was caused by As in the drinking water. However, of the respondents that were aware of As contamination, fifty percent had an incomplete knowledge of the signs, symptoms, and diseases associated with As exposure. These respondents were aware of As-induced skin lesions; however, their knowledge of the chronic diseases associated with As exposure was incomplete (244). This is consistent with results of previous studies that indicate a lack of awareness of the chronic diseases associated with As exposure (245-247).

Paul et al reported that those residing in medium As risk areas had higher As awareness than low As risk areas. Younger respondents had greater As awareness then older respondents. The most influential predictors were As risk area and educational level. The authors recommended intensifying or modifying existing educational campaigns on As to target populations of lower educational level and older age (244).

A study was conducted by Aziz et al in Matlab, Bangladesh in 2004 to determine awareness of As contamination in the population, diseases associated with As exposure, and predictors of the avoidance of As exposure. A questionnaire was administered to 2800 respondents who were the members of their household most knowledgeable about drinking water sources and water use patterns for their household. Seventy eight percent of these respondents were women. For the As awareness section respondents were asked if they were aware of the As problem, and the following health consequences of As exposure: gangrene, cancer, skin lesions, and death. It was found that 70% of the respondents had received some information about the As problem. Furthermore, 64% had switched tubewells and 60% of this switching was because of As contamination. In the survey it was found that although the majority of the study respondents were aware of the skin lesions associated with As exposure, many people were unaware of the less visible signs of As exposure such as cancer (247). Those in poorer health were significantly less likely to avoid As exposure perhaps because it was more difficult for them to obtain As safe drinking water. Higher educational level and increased distance of a tubewell from the respondent's home significantly increased avoidance of As exposure. The study also found that households with children were significantly more likely to be aware that As exposure could lead

to death. Educational level, age, and gender were not found to be significant predictors of the respondent's As awareness(247). One limitation of this work, however, is that it takes place in a study area where there are many ongoing health interventions.

Another study evaluated two nationally representative surveys on access to drinking water and knowledge of As. Data was collected by the Health and Social Research Project: Risks and Benefits of As Mitigation Program in Bangladesh (HSRP). The nationwide survey occurred in 2000, and a follow-up survey was conducted in 2002. The initial sample size was 3780 households, which represented a sampling of 42 households from each of 15 villages in the country's 6 divisions. The follow-up survey was a 30% randomly selected sub-sample. Fifty percent of the respondents were female. The interviews were conducted where possible with the head of household or spouse (248).

In 2000 only 32.2% and 22.3% of male and female respondents respectively had heard about arsenicosis. In the 2002 study, this percentage increased to 62.9% and 59.8%, respectively. The main sources of knowledge appear to be radio, television, NGO, friends, and neighbors. When men and women were asked why they installed or chose to use their current tubewell their answers were very different: 70.3% of men stated that they chose a particular well because it was safe relative to As in contrast to only 31.1 % of women. The most common reasons for women appeared to be convenience (32.3%) and controlling one's own water supply (36.7%). Those respondents with higher formal education were more likely to be aware of skin lesions. The majority of respondents in both surveys were unaware of the health effects of As beyond arsenicosis. Less than 20 percent of respondents were aware that As could cause death,

permanent illness, and "bouts of illness". The authors hypothesized that respondents may not believe that As is connected to chronic diseases because of the long latency period. Although the survey found a great increase in awareness of arsenicosis between 2000 and 2002, there was a low rate of switching to As safe sources. Less than 4 % of respondents reported changing to another drinking water source. The authors pointed out that for people to switch wells they must be aware of As safe water sources located near their home. Furthermore, information should be provided on the most appropriate strategies to avoid As exposure, and As awareness should be increased in the population (248).

Our research group looked at As awareness among 5,967 well owners/ care takers in the HEALS cohort study area in Araihazar, Bangladesh. Respondents were asked if they were aware of the adverse health effects of As and steps they were willing to take to reduce their exposure. Fifty-seven percent of these respondents were women. Sixty-one percent of respondents reported being aware of health problems from As in drinking water, and of these 89% percent were aware that As could cause skin disorders. The study found that age, sex, occupation of head of household, type of house, willingness to adopt a mitigation option, and if their tubewell was previously tested for As were all significantly associated with the respondent's awareness of As (249). Ninety-two percent of respondents stated that they were willing to take action to reduce their As exposure, switching to an As safe water source was the mostly commonly mentioned preferred option (42%) (16).

Table 1. Arsenic Awareness Studies in Bangladesh

Reference	Year Study was Conducted	Location	Characteristics of Study Population	Sample Size (Households)
Paul BK (2004)	2002	Narayanganj and Comilla districts	31% Female	356
Parvez F et al. (2006)	2000	Araihazar, Bangladesh	57% Female	5967
Aziz SN et al. (2006)	2004	Matlab, Bangladesh	78% Female	2800
Caldwell BK et al. (2006)	2000 and 2002	All six divisions of Bangladesh	50% Female	3780 (2000) 1181 (2002)

3.2 Well Switching as an Arsenic Mitigation Option

Of the estimated population of 28-35 million initially exposed to As above the Bangladesh standard, 57% remain exposed (Figure 3). The most common As mitigation option utilized is well switching at 29% (1). This involves unsafe well users switching to low As wells (<50 µg/L As) that are often located close to their home due to the spatially heterogeneous distribution of As in groundwater (250). This was followed by the use of deep tubewells by 12% of the originally exposed population (1). Studies have shown that deep aquifers are generally lower in As. Therefore the installation of deep tubewells is another viable option for areas that have As in shallow groundwater (251). Arsenic mitigation options such as piped water systems, rainwater collectors, dugwells, As filters, and pond sand filter were utilized by only a very small proportion of the population (1).

In the Columbia University study area of Araihazar, Bangladesh, the distribution of As in the groundwater has been found to range from 5-860 µg/L. Because of this variability, 88% of residents live within 100 meters of a safe well. These results suggest that well switching could potentially be a viable option to reduce As exposure for all but 29 upazilas (subdistricts) in Bangladesh where >80% of the wells have an As content greater than 50 µg/L. In a 2002 study by our research group, 43% of respondents interviewed during the survey of 4997 tubewells in Araihazar stated that their preferred As mitigation option was switching to a nearby safe well (250).

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One potential concern for well switching is the temporal variability of the As concentrations in a tubewell over time. A study was conducted in the Columbia University study area of Araihazar, Bangladesh to investigate the temporal variability of As. Six tubwells that were As-safe at baseline were sampled at multiple time points over a 1 year period. There were no significant exceedances of the Bangladesh standard for As observed, and only one time point for a single well exceeded this standard (252). This result is consistent with the current scientific literature which suggests that the temporal variability of As in tubewell water is low (252-256). However, rare events, such as the entry of As contaminated groundwater through cracks in pipes can lead to the contamination of shallow tubewells originally labeled as As safe (252).
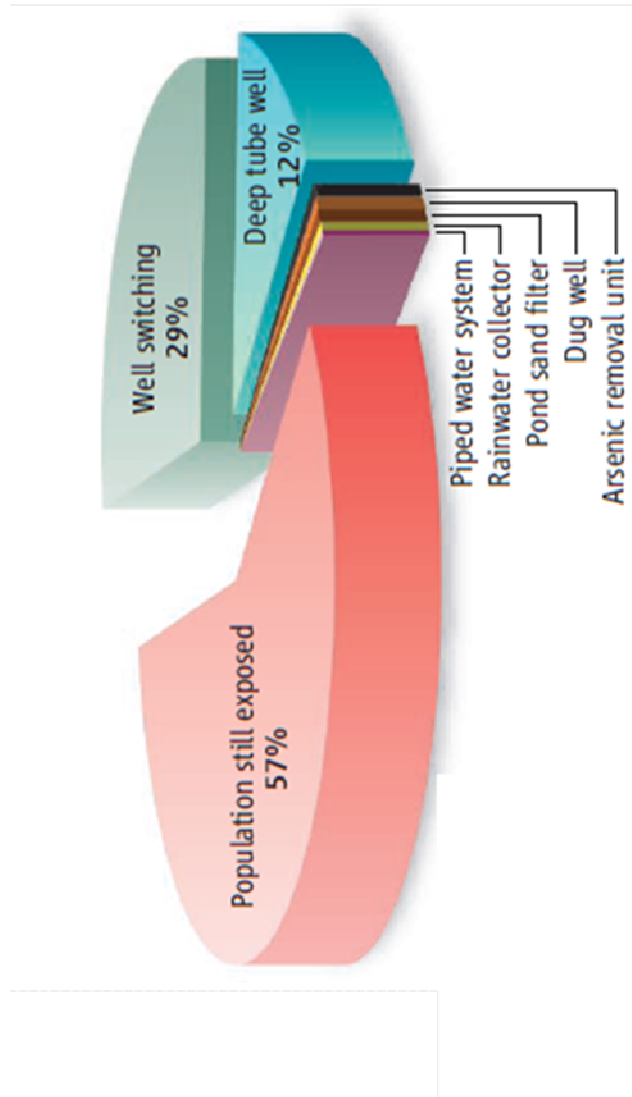
Figure 3. Impact of Arsenic Mitigation in Bangladesh. This pie chart presents the estimated population of 28-35 million initially exposed to arsenic above the Bangladesh arsenic standard of 50μg/L in drinking water. Source: Source: Ahmed MF, Ahuja S, Alauddin M, Hug SJ, Lloyd JR, Pfaff A, et al. Epidemiology. Ensuring safe drinking water in Bangladesh. Science 2006;314(5806):1687-8.

3.3 Arsenic Educational Interventions

Several studies have assessed the impact of As educational intervention programs in Bangladesh. In 1999, a study was conducted to evaluate an As education and testing program implemented by the 18 District Towns Project. Well users were given the following four key educational messages: (1) red marked wells should not be consumed, but it can be used for washing and other domestic purposes; (2) for emergency measures aerated water and alum can be used for As removal; (3) red well users were advised to switch to safe drinking water sources such as green marked wells for cooking and drinking; and (4) green well users were urged to share. A questionnaire survey was administered to 694 well users, and interviews were conducted with 306 well users. After the intervention it was found that 80% of respondents who participated in the program knew the meaning of a red and green marked tubewell, in contrast to 25% of respondents who had not participated in the program. However many people in the population were unaware of the less visible symptoms of As exposure such as cancers and effects on child and maternal health. Forty-one percent of the women in the study thought that As related illness were contagious. Furthermore many respondents continued to drink (57%) and cook (54%) with As contaminated water (246).

Through focus group discussions, this same study also identified misconceptions about As. Some participants thought that the As in the ground was new and that the earth had changed while others confused As with iron. Barriers to well switching were identified such as safe well owners feeling burdened by too many people using their tubewell, safe well owners who refused to share, and in some areas inadequate numbers of safe wells for households to use. The focus

groups and interviews also indicated that some households are shifting to untested tubewells because they believe that at least they have a chance of not being As contaminated. The authors made the following recommendations for future interventions: (1) the water testing event should be used as an opportunity to provide As education; (2) there should be opportunities for people to ask questions about As, (3) the distinction between iron and As should be explained, and (4) the repetition of the educational messages provided is important (246).

In 2003, a study was published evaluating an As mitigation intervention implemented by BRAC, the largest NGO in Bangladesh, in collaboration with the Department of Public Health Engineering (DPHE) and UNICEF in 1999 in two Upazilas of Bangladesh. The intervention had the following six objectives: (1) Inform communities about the health risks of drinking As contaminated water, safe water options, symptoms of arsenicosis, and mode of transmission and treatment of arsenicosis; (2) Train community members to test all tubewells for As using a field testing kit; (3) Promote community involvement in selecting, implementing, and maintaining As safe drinking water sources; (4) Install demonstration units of As safe drinking water technologies; (5) Identification and treatment of As-affected patients; and (6) Promote the use of As safe drinking water (257).

Communities received As awareness information from Community Health Workers (CHW). The CHWs received a two-day training by professional BRAC staff on how to identify the symptoms of arsenicosis, safe water options, and how to test tubewells for As. The CHWs conducted household visits and community-based meetings in their villages to identify arsenicosis patients, test tubewells for As, and spread As awareness education.

Community members were encouraged to monitor and maintain their safe drinking water options. Systematic random sampling was conducted in both the mitigation area and a comparison area in which there were no BRAC intervention activities. The total sample size for the study was 1240 respondents, including 636 respondents from the mitigation villages and 604 respondents from the comparison villages. An As knowledge tool was developed that contained 12 items on safe water options, signs of arsenicosis, and mode of transmission and type of treatment for arsenicosis (257).

Forty four percent of the respondents in the mitigation group were aware of more than 2 symptoms of As diseases compared to only 8% in the control group. A similar result was found for As safe drinking water options, 42% of respondents in the mitigation group were aware of more than 2 As safe drinking water options in comparison to only 9.8% for the comparison group. These results indicate a low knowledge of the symptoms of As and As safe drinking options in the general population. Forty-four percent of respondents in the mitigation group knew the mode of transmission of As in contrast to fourteen percent in the comparison group. This finding suggests that there is a lack of understanding of the mode of transmission for arsenicosis in the population. It was found that age, years of education, land ownership, and exposure to media were important factors determining one's knowledge of As. In the in-depth interviews it was found that CHWs were the key change agents and were well accepted in the communities. It was also found that child health was an important concern. A woman in one of the sessions said "We don't care about ourselves but our children must be safe (257)."

In 2007, our group at Columbia evaluated the impact of an education intervention in 6500 rural

households in Araihazar, Bangladesh. This intervention included public health education, WAs testing/labeling of tubewells, and the installation of 50 deep community wells. The study population surveyed was the wives of the tubewell owners or a close female family member. Each respondent was administered a questionnaire on the physical state of their tubewell, socioeconomic status, As status of the household tubewell, and water usages. After the intervention, it was found that 65% of respondents with unsafe wells switched to an alternative water source. Fifty five percent of these respondents reported switching to a private tubewell, 21% reported installing a new well, 16% reported switching to a community well, and 8% reported switching to an undetermined source. For safe well owners, a non functioning tubewell was the main reason for switching (40%) (15).

In the univariate analysis it was found that the degree of As contamination and distance to the nearest safe well were significant determinants of well switching. For households with between 50-150 µg/L As in their tubewells the well switching rate was 50%. However for households with 450-1000 µg/L As the well switching rate was 80%. If the nearest safe well was within 50 meters the well switching rate was 68%, while if the nearest safe well was greater than 150 meters away the well switching rate declined to 44%. In their multiple regression model, As concentration of the well, years of education, and distance of a safe tubewell were all found to be significant predictors of well switching (15, 247). The authors recommended that future As mitigation work should include well testing, and that these services should be provided locally and continuously. Furthermore, it was recommended that As contaminated wells should be used for tasks other than drinking and cooking (e.g. hand washing) to promote basic hygiene (15).

In 2007, the Columbia group evaluated an As program implemented for 11,746 participants of the HEALS cohort. The intervention had two parts. The first part was in-person communication of As testing results and the provision of As education. This involved community session with skits, songs, and focus group discussions. The second part of the intervention was the installation of deep low As community wells. At baseline and at follow-up two years later a survey was administered to a total of 10,645 cohort participants. For each of these surveys information was collected on demographics, lifestyles, and drinking water history. Fifty seven percent of the respondents were female (16).

At the two year follow-up, it was found that 58% of unsafe well users and 17% of safe well users had switched to new drinking water sources. Most of the participants with unsafe wells who switched either changed to a Columbia University-installed deep-tubewell, a previously tested tubewell that was safe, or a well installed by an NGO. Twenty-three percent of respondents reported switching to a new tubewell. The majority of respondents with unsafe wells at baseline that switched did so because of As (83%), while most safe wells users at baseline reported switching wells because of convenience (64%) (16).

Well labeling and the village level health education campaigns were found to be positively associated with well switching. Among unsafe wells users, higher baseline As and education was found to be positively associated with switching to a safe well. The authors also indicated that the dose-response relationship observed between baseline As concentration and well switching suggests that households take into account the As concentration in their tubewell, not just the As safe or unsafe status, when making the decision to switch (16).

At baseline, the UAs concentration of the cohort participants using unsafe wells was 397 µg As/g creatinine in comparison to 141 µg As/g creatinine for participants using safe wells. A 46% reduction in UAs (from 375 to 200 µg As/g creatinine) was observed for those with unsafe wells who switched to As safe drinking water sources. Strikingly, even those who switched to a new well or another unsafe well had a decrease in their UAs concentration. This could be because the new source was tested for As by BAMWSP or another party. The reduction in UAs was significantly higher in men, individuals who never smoked, individuals who had a higher BMI, higher education, and had no skin lesions at baseline. For those participants who used a baseline unsafe well and switched to a safe well at follow-up, the reduction in UAs did not significantly differ by the distance to the nearest tubewell. The reduction in UAs increased over time appearing to plateau at approximately 12 months (16).

Table 2. Arsenic Educational Interventions Conducted in Bangladesh

Year Study Conducted	Reference	Intervention Provided	Study Design	Control Group	Sample Size	Organization	Location	Result
1999	Hanchett et al. 2002	Community Health Workers Provided Arsenic Education and Water Arsenic Testing	Cross-sectional	Yes	694	Bangladesh Department of Public Health Engineering (DPHE) and 18 District Towns Project for Drinking Water, Sanitation, and Hygiene	N/A	43% of intervention households with unsafe well switched wells after receiving the intervention
1999	Hadi et al. 2003	Local Government and Project Teams Provided Arsenic Education and Assisted with the Identification of Arsenic Affected Patients, Field Testers Conducted Water Arsenic Testing	Cross-sectional	Yes	1240	BRAC	Southwestern Bangladesh	Well switching results not provided
2004	Chen et al. 2007	Village Health Workers Provided Household level Education and Well Arsenic Testing Services	Prospective Cohort	No	6512	Columbia University	Araihazar, Bangladesh	58% of unsafe well users switched wells after receiving the intervention

Conclusions

In the March 2010 publication by the Bangladeshi government and the United Nations entitled "Towards an Arsenic Safe Environment", it states that "knowledge, especially incomplete or incorrect knowledge, of Arsenic's health danger does not form sufficient motivation for people to seek As safe water (258)." The scientific literature indicates that the majority of the population is aware that a green tubewell is As safe and a red tubewell is As contaminated, and that skin lesions can be associated with As exposure (244, 249, 259). However, many individuals seem to be unaware of the other health implications of As and potential mitigation options (246, 247).

The majority of the As communication materials developed by NGO forum, DPHE, and UNICEF were developed in early 2000. Since that time there has been a substantial increase in the scientific knowledge of the health implications associated with As exposure. Elevated levels of ingested InAs have been associated with many "invisible illnesses" that go beyond the skin lesions that villagers commonly associate with As exposure. These include cancers of the skin, bladder, and lung (88, 92, 133, 260), reproductive and developmental effects (94, 95), and cardiovascular disease (96, 97). Therefore the existing body of As communication materials should be updated to provide this new information, and previous incorrect information should be identified and removed.

Attempts by national and international organizations to reduce As exposure in the population have been largely ineffective (1). Many households do not appear to be using their knowledge of As to seek As safe drinking water sources (244, 246-249, 257, 261). The studies presented

indicate the need for further reinforcement of the As educational messages disseminated during interventions, and that these messages need to include information on the chronic diseases and invisible illnesses associated with As exposure. Furthermore, households can only switch to As safe drinking water sources if they are aware of where they are located in their village. Therefore, there is a need for widespread WAs testing by the government, NGOs, or private companies, as well as the provision of alternative As mitigation options where well switching is not a viable option. These services will likely be most effective if they conducted locally and continuously (187, 246, 248, 250, 257).

Chapter 4: Baseline Survey of Arsenic Tester Intervention

4.1 Study Design

This study is a cluster based randomized control trial of 1000 households located in 20 villages in Singair, Bangladesh. The study villages were divided into the following two groups: 10 villages in which a community member was trained to conduct well WAs testing and disseminate As education; and 10 villages in which an outside person, defined as living outside the study union they were working in, was trained and sent to perform these same tasks. A census of households in each study village was created by conducting a household drinking water survey. From this census fifty randomly selected households with untested wells who met the study eligibility criteria were invited to participate in the study.

At baseline, a questionnaire was administered to the person in each selected study household responsible for primary drinking water collection, and a urine sample was collected where possible. A sample of the household's primary drinking water source was collected by field staff, and a well ID placard was placed on the sampled well. An As Tester training was then conducted for both the outside and community testers to explain to them the use of the As field testing kits, and how to disseminate As awareness education. The outside and community testers then began to provide As testing and disseminate As education in selected study households in their respective villages. In each household, the As tester measured the As concentration of the household's primary drinking water source; and conducted a 40 minute As awareness educational session. If a respondent's primary drinking water source was found to be unsafe

relative to As the As tester provided assistance to locate an As safe drinking water source near

the respondent's home. Four to six months after each household received As testing and

education a follow-up questionnaire was administered. During this visit a sample of the

household's primary drinking water source was collected along with a urine sample where

possible. Figure 5 summarizes the study design.
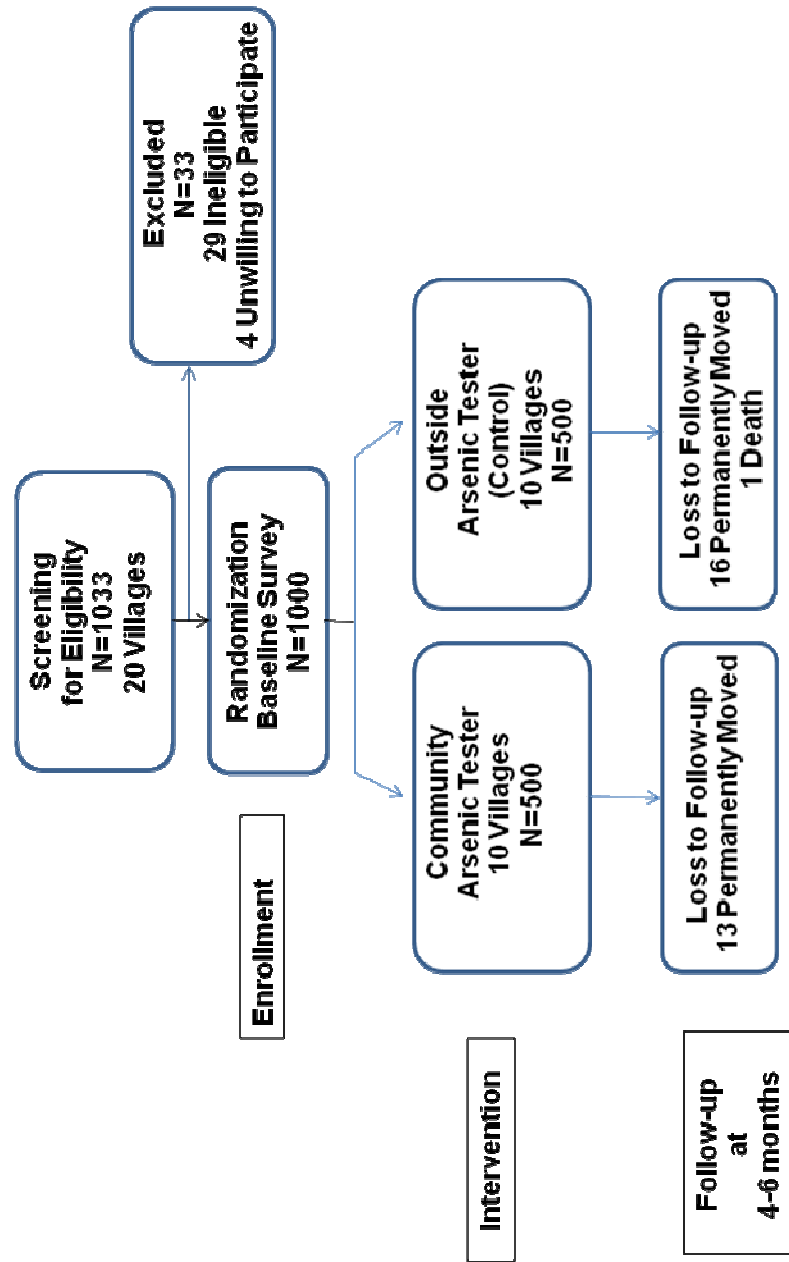
Figure 5. Cluster Based Randomized Controlled Trial Study Design

4.2 Assessment of Arsenic Exposure

The As exposure of study participants was assessed by measuring UAs at baseline and follow-up. At follow-up, we collected information on the As status of each household's primary drinking water source. This allowed us to determine the proportion of study respondents that were drinking from safe/unsafe/untested drinking water sources at follow-up. The validity of these methods of exposure assessment was evaluated by looking at the correlations between WAs concentrations and UAs concentration pre and post intervention for study participants.

4.2.1 Urinary Arsenic Measurements by Graphite Furnace Atomic Absorption Spectroscopy (GFAAS)

Urine samples were collected in 50 ml acid washed tube from study participants during the baseline and follow-up surveying periods. Urine samples were kept cool in portable coolers for up to 8 hours, and then frozen at -20 degrees Celsius at the local laboratory in Dhaka, Bangladesh. They were then shipped on dry ice to the Trace Metals Core Laboratory at Columbia University, and kept frozen at -20 degrees Celsius. Total UAs was measured using a Perkin-Elmer AAnalyst 600 GFAAS system (262), and adjusted for UCr concentrations according to published laboratory methods (263).

4.2.2 Water Arsenic Measurements by Inductively Coupled Plasma Mass Spectrometry

Water samples were collected at baseline and follow-up in 20 ml acid-washed bottles. The samples were acidified to 1% with high-purity Optima hydrochloric acid at least 48 hours before analysis. This has been shown to re-dissolve any iron oxides that could have precipitated during storage (264). The As concentrations were measured as previously described using ICP-MS with a detection limit of 0.1 µg/L at the Geochemistry Research Laboratory at Lamont Doherty Earth Observatory (LDEO) at Columbia University (265). Further details on field sampling and laboratory analysis procedures are described elsewhere (265, 266).

4.2.3 Water Arsenic Measurements by EZ Arsenic Test Kit

Water As field testing was conducted using the EZ As Test Kit designed by *Hach Company*. This kit measures As concentrations in water using a colorimetric scale between 0-500 µg/L at a scale of 0, 10, 25, 50, 100, 250, and 500 µg/L. A 40 minute reaction period was used instead of the 20 minutes recommended by the manufacturer because a previous study found that the increased reaction period reduced inconsistencies relative to Bangladesh As standard in the 50-100 µg/L range (266). This kit has been used successfully by our field team in previous field studies in Bangladesh (266). Water As measurements conducted by the As testers were further verified by comparison to ICP-MS laboratory measurements.

4.3 Household Drinking Water Survey

A household drinking water survey was developed for this study to determine village and household eligibility. The survey was administered to the person in the household responsible for primary drinking water collection in 26 villages comprising a total of 6649 households in Singair, Bangladesh. The surveyors went to every household present in the village. The household drinking water survey allowed us to obtain the following about each household's primary drinking water source: respondent-reported As status, well depth, well installation date, the presence of other existing As interventions in the area, and if the well was painted based on the As concentration. The household survey can be found in Appendix 1.

4.4 Village Selection

For the cluster based randomized control trial, a total of 20 villages were enrolled in the study; ten villages with a community tester and ten villages with an outside tester. These 20 selected villages were located in eight out of the 11 unions in Singair, Bangladesh. The eligibility criteria for village selection were (1) have between 40-60% As unsafe wells relative to the Bangladesh As Standard; (2) have at least 50 households that meet the subject eligibility criteria (see section 4.6); and (3) for community-tester villages, they must have a Christian Commission for Development Bangladesh (CCDB) forum worker living in the village.

Villages were selected based on the results of the household drinking water survey. A total of 26 villages were screened. Of these, three villages were excluded because there were less than 50

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households that met the study eligibility criteria, and three additional villages were excluded because they had less than 25% unsafe wells. The community and outside tester villages were separated geographically to avoid information contamination between the two intervention groups. Using census data from the Bangladesh Bureau of Statistics and our household drinking water survey, we matched the community and outside-tester villages on the proportion of unsafe wells, and total literacy and landownership. These last two variables are known from previous research to be strong indictors of social economic status (101).

The results from the household drinking water survey are summarized in Table 3. Using two sample t-tests, we observed no significant differences between the community and outside tester villages for the proportion of untested, unsafe wells, or for the total number of households in each village. Our study villages had a large proportion of untested wells, ranging from 46-83%. We were not able to locate a sufficient number of villages that met our eligibility criteria of 40-60% unsafe wells. Therefore, we selected study villages that had between 31-72% unsafe wells.

Table 3. Comparison of Community and Outside Tester Villages

	Community Tester Villages N=10	Outside Tester Villages N=10	P-Value*
%Untested Wells Mean±SD (Range)	67%±8% (46-83%)	66%±12% (53-79%)	0.86
%Unsafe Wells Mean±SD (Range)	48%±14% (31-72%)	54%±15% (36-72%)	0.41
Total # Households in a Village Mean±SD (Range)	254±199 (104-751)	234±121 (101-478)	0.79

*P-value calculated using two sample t-tests

4.5 Subject Recruitment

Using the results obtained from the household drinking water survey 50 respondents using an untested well were randomly selected from each study village. A screening tool was then administered to each of these individuals to determine if they were eligible to be enrolled in the study. The screening tool can be found in Appendix 2. The inclusion criteria for study respondents were (1) be the person in the household responsible for primary drinking water collection; (2) use an untested well for the majority of the drinking water collected; and (3) be 18 years of age or older. The exclusion criteria were (1) have an As filter (2) obtain water from an As treatment plant; and (3) not have one well from which they collect most of their household's drinking water. During our baseline survey 1033 individuals were screened. Of these, 0.4% (4) were unwilling to participate in the study. Of the remaining individuals 2.8% (29) were found to ineligible for the following reasons: 2.4% (25) had a current drinking water source that was already tested for As, and 0.4% (4) had no main drinking water source.

4.6 Baseline and Follow-up Questionnaire Procedures

4.6.1 Overview of Baseline and Follow-up Questionnaires

The baseline and follow-up questionnaires can be found in Appendices 3 and 4. The 15 interviewers that administered these questionnaires all had received their Master degrees in Geology at Dhaka University, and had previous experience with quantitative questionnaire tools. The average durations of the baseline and follow-up interviews were 60 and 40 minutes,

respectively. The following is an overview of the information obtained from study respondents at baseline and follow-up:

Baseline Questionnaire

- Demographic information

- Socioeconomic status of respondent (ie, television ownership, land ownership, roof type)

- Identification of current primary drinking water source

- Water collection practices

- Current sources of As information (ie, posters, teachers, neighbors)

- Current knowledge of As exposure and related illnesses (assessed through a quiz)

Follow-up Questionnaire

- Identification of current primary drinking water source

- Reason why the respondent chose to switch or not switch their primary drinking water source

- Current knowledge of As exposure and related illnesses (assessed through a quiz)

- Amount of reinforcement provided by village or outside tester

- Water collection practices

4.6.2 Knowledge of Arsenic Quiz

A 20 item quiz on As was administered to all respondents enrolled in the study to assess their pre- and post-intervention knowledge of As. The respondent was asked questions on the source of As contaminated drinking water, the As standard in Bangladesh, and the meaning of a red or green marked tubewell. 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. Respondents were asked if arsenicosis was contagious, and if As could be removed by boiling water. The respondent was also asked if it was okay to use As contaminated water for the following tasks: drinking, cooking, washing hands, bathing, washing clothes, and washing animals. A quiz score was calculated for each respondent based on the cumulative score from all 20 quiz items. One point was given for a correct item, and zero points for an incorrect item. Possible quiz scores ranged between 0 and 20.

4.6.3   Pilot Phase

Before questionnaires were administered to study respondents, thorough pilot testing was conducted over a period of 2 months. During this period of time, the questionnaire was administered by the field coordinator to individuals in our pilot area in Singair, Bangladesh. We targeted individuals of different ages and educational levels during our pilot to ensure that the language used in the questionnaire tool was appropriate for all respondents. All individuals included in the pilot received As awareness education and well WAs testing. After the questionnaire was administered, a series of questions were asked to determine what

improvements to the questionnaire could be made. The following are examples of the questions asked: (1) Has the length of this questionnaire interfered with your routine today? ; (2) Are there any sections that you felt were particularly difficult to understand?; and (3) Are there any questions that you felt were culturally inappropriate?

4.6.4 Interviewer Household Visit Protocol

Protocols were developed for interviewers to use when administering the baseline and follow-up questionnaires to study households. These protocols can be found in Appendices 5 and 6. During each household visit, the interviewer was instructed to first locate the person in the household responsible for primary drinking water collection. If the individual was found to be eligible to participate in the study based on the screening questionnaire, then the interviewer was instructed to obtain informed consent. The interviewer obtained a signature of informed consent from literate respondents. Oral consent was obtained from illiterate respondents. This oral consent was documented by the thumb print of the study respondent, and the signature of the person obtaining consent and a witness selected by the respondent. The study respondent was then given a *Study Identification Card* with his or her name, bari name (cluster of homes occupied by extended family), village name, and identification code.

At baseline a well ID placard was placed on the household's primary drinking water source, and two water samples were collected. One water sample was used for laboratory analysis of the WAs concentration, and the second sample was used for quality control during the intervention period. The quality control involved retesting a subset of water samples in the Dhaka office using

the Hach EZ kit to confirm the As concentrations found by the As testers in the field. The GPS location of the household and the household's primary drinking water source was also collected. The interviewer then administered the baseline study questionnaire and collected a urine sample where possible using the urine collection protocol. The interviewer then thanked the respondent for their time and participation in the study and explained that an As tester would come to their household in the next few weeks to test their well and disseminate As education. A similar procedure was used for the follow-up survey.

Urine Collection Protocol

The interviewer first explained to the respondent that their urine was being collected to measure its concentration of As, and the amount of glucose and protein present. If the respondent reported having menstruation the interviewer explained that urine collection was not possible, and a later return visit was made. If the respondent did not have to urinate at the time of urine collection they were asked to drink water from their primary drinking water source reported at baseline.

When collecting urine, the following instructions were given to the respondent:
1. Please only fill your urine tube between 20-40ml (mark in red on the urine tube)
2. Please do not add water to your urine tube
3. Please do not touch the inside of the urine tube
4. Please do not have anyone else add urine to your tube
5. The urine cap must always be upright, and should not be put in a dirty place

The interviewer poured 5 ml of urine from the urine tube into a plastic cup to measure the concentration of protein and glucose present using the Uric 3V urine test kit. The result of the urine test kit was given to the study respondent and recorded on the field tracking sheet. If any reading other than "Negative" for glucose or protein was observed, the interviewer was instructed to tell the respondent that they have an abnormal result that may indicate a chronic disease. The respondent was told that the urine result is not conclusive and that they should consult a doctor for conclusive results. The urine tube was sealed in parafilm and placed in a cooler.

4.6.5 Interviewer Training

A five day baseline and follow-up interviewer training session was held. Attendance of all days of each of the training sessions was mandatory for interviewers. The following is an overview of the baseline and follow-up training sessions:

- **Day 1:** Overview of Study Materials and Protocols
- **Day 2:** Mock Interviewers
- **Day 3-4:** Practice Interviewing Sessions in the Field
- **Day 5:** Practice Interviewing Sessions and Problem Identification

On the first day of the training session the interviewers were given an overview of all the baseline and follow-up study materials. Each study question was explained and discussed in both English and Bangla. An "Interviewing Techniques and Rules Guide" was developed to teach

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interviewers techniques such as using neutral probes, and how to administer the As quiz without leading the respondents. A "Frequently Asked Question (FAQ)" guide was also developed to list possible questions that could arise in the field. The interviewers were instructed to use this FAQ guide as a reference tool for their questions and concerns in the field. The FAQ guide can be found in Appendix 7.

The second day of the training involved having the interviewers conduct mock interviews with the study trainers and their fellow interviewers. During the third through the fifth day the interviewers conducted interviews in the field in our pilot area of Singair, Bangladesh. Each interviewer was required to complete at least 4 interviews. Their performance was evaluated by our study trainers on the following criteria: introductions, verbatim reading of study questions, pacing and pauses during interviewing, following skip patterns, using neutral probes, and urine collection procedures and testing. The interviewer evaluation guide can be found in Appendix 8.

4.6.6   Quality Control

During the baseline and follow-up surveying periods, the field coordinator and organizer checked all study questionnaires daily for their completeness and to insure that proper skip patterns were followed. Any incomplete or incorrectly completed questionnaires were sent back to the field for correction. Random follow-up visits and phone calls were made to study respondents to insure that proper study procedures were followed during both the surveying periods. After the baseline survey was completed, 10 percent of the study questionnaires were randomly selected for a screen recheck at Columbia University's data entry center in New York.

The error rate was less than 1 percent. For the follow-up survey, a database was created for a consistency check. Five percent of respondents were randomly selected to be contacted after their follow-up survey and were re-asked the following questions from the follow-up questionnaire: (1) Is this the same well you reported at baseline as your primary drinking water source?; (2) Has the water source you are currently using been tested for As?; and (3) Do you think your current well is unsafe or safe relative to As? Any inconsistencies were follow-up with in the field by the project coordinator.

4.7 Power Calculation

Optimal Design software was used for the statistical power calculation to determine the number of villages (clusters) needed to reject the null hypothesis that there is no significant difference in well switching between the local and outside tester villages at the 95% confidence level (267). We assumed that the proportion of switching in response to outside testing in the control (traditional testing method) villages was 0.33, with a lower bound of 0.2 and an upper of 0.8. This has been previously shown in Araihazar (15, 268). A reasonable assumption for the proportion of switching in response to local testing and reinforcement is 0.66, as previously documented for Columbia's main study area (15). The calculation shows that a total of 18 clusters (villages) of 35 households each would be needed to reach a probability of 0.95 of rejecting the null hypothesis (Fig 6). If the proportion of switching in response to local testing is only 0.57, then the probability of rejecting the null hypothesis is 0.7. Based on these findings, we conducted the study in 50 randomly selected households in 20 villages.
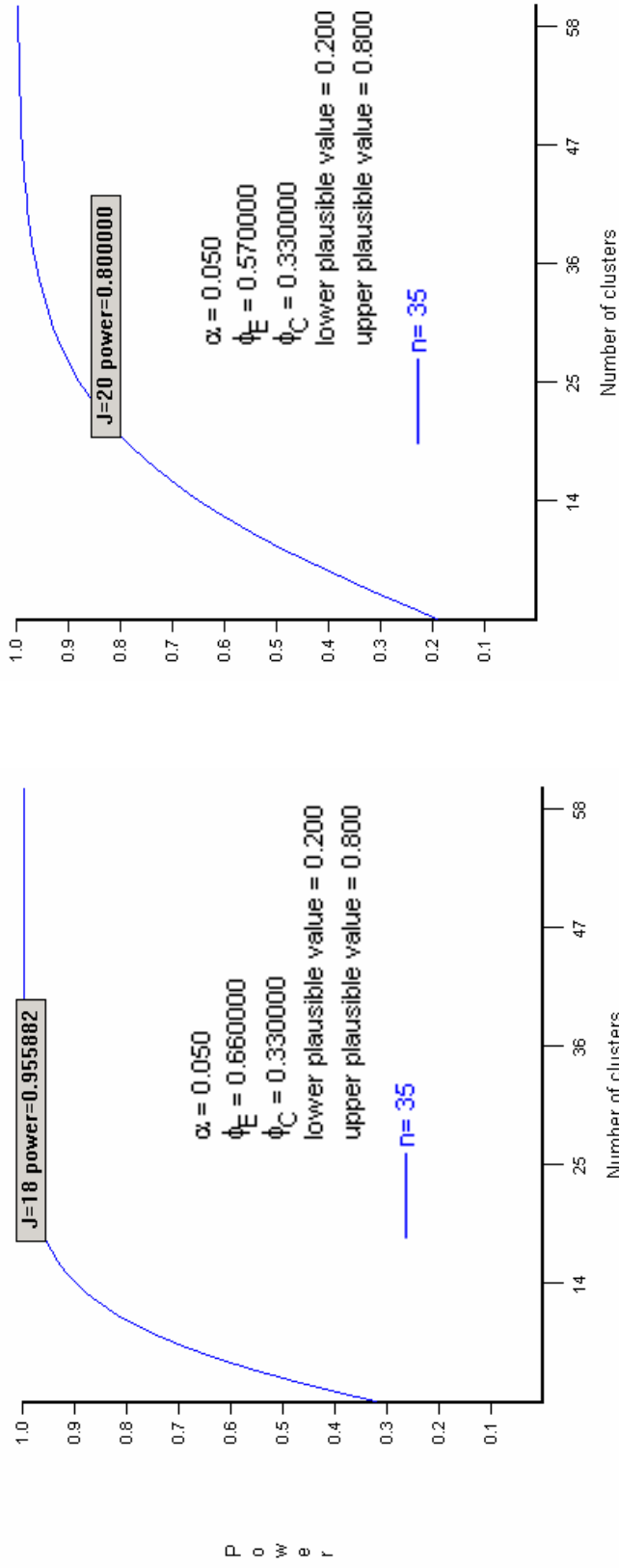
Figure 6. Power calculation for clustered based randomized controlled trial

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4.8 Outcome Variables

Urinary As and questionnaire-reported well switching are the primary outcome variables in this study. The follow-up UAs concentration, adjusted for baseline UAs, was used as the biological index of exposure. Knowledge of As assessed through a pre- and post- intervention As quiz was a secondary outcome variable in this study.

4.9 Statistical Approaches

The distribution of all study variables was determined and log transformed when necessary, and summary statistics were calculated for each of the study groups. Two sample t-tests were used to look at group differences between the quantitative variables. Chi square test were used to detect group differences between the categorical variables. Scatter plots were created to examine the associations between the quantitative variables, and the spearman correlation were calculated and tested.

For model building, first a stratified analysis of study variables by the binary or continuous outcome of interest was conducted, then a univariate analysis of all appropriate study variables in each model was conducted. All conceptual models developed were tested for the presence of interaction. Study variables with a p-value < 0.10 from the univariate analysis were added to the multivariate models.

The generalized linear models with repeated measures were used to examine the associations between predictors and various type of outcome variables including binary and continuous outcomes, while taking into account of correlations among repeated measures. Generalized Estimating Equations use all available data to estimate the model parameters , and give results robust to the specification of the correlation structures. In analysis, we assumed exchangeable correlation for the outcome measures from subjects in the same villages. Once the full model was created, all non-significant variables except for those used in conceptual models (ie. type of As tester) were removed one-by-one, then two-by-two until the model which was most parsimonious with the lowest quasi likelihood information criterion (QIC) was determined (269).

Logistic regression was used for the longitudinal data collected from the cluster based randomized control trial since our main outcome variable, questionnaire-reported well switching, is binary. Regression models were used to determine the significant predictors of: (1) well switching; (2) follow-up UAs after controlling for baseline UAs; and (3) follow-up knowledge of As quiz score after controlling for follow-up knowledge of As.

Chapter 5: Conduct of the Arsenic Tester Intervention

5.1 Conduct of Arsenic Tester Selection

In the As Tester Intervention there were 10 community testers defined as residents of the village where they worked as an As tester, and there were 10 outside testers defined as individuals residing outside of the union where they worked. One As tester was assigned to each study village. The community testers in the intervention were forum workers for the CCDB, a non-governmental organization. CCDB presently works in 65,000 ultra poor households in 36 upazilas in 15 districts of Bangladesh with the focus of comprehensive poverty alleviation. The role of the CCDB forum worker in the village is to organize community activities on health and poverty alleviation. The outside testers were selected with the assistance of the Area Manager of CCDB. All potential As testers in the study area were brought in for an interview, and those who met the eligibility criteria to be As testers were selected. The eligibility criteria for the As testers are as follows: (1) can read adequately to present their As educational script and can write adequately to record field notes in their As Tester Journal (this was assessed through a reading and writing test); (2) can correctly use the As field testing kit, and disseminate As education after receiving the As Tester Training (this was assessed through the evaluation of two household visits by the educational trainers); (3) be 18 years of age or older; (4) can dedicate at least 20 hours per week to their duties as an As tester for the intervention period of 3 months; and (5) the community tester must reside in the village where they will conduct their duties as an As tester.

The demographic information for the As testers enrolled in the study was compared between the local and outside tester groups using two sample t-tests for continuous variables and chi-square tests for categorical variables (Table 4). There was no significant difference in age, educational level, gender, or religion between the two groups.

Reading and Writing Test: All potential As testers were administered a reading and writing test by the study educational coordinator to ensure that they could read and write adequately to perform their duties as As testers. The reading test required the potential As testers to read a newspaper article in Bangla to the study educational coordinator. The writing test involved the study educational coordinator reading a magazine article in Bangla to potential As testers who were required to transcribe this article in their notebooks. Each reading and writing test was scored on a scale from 0-10 based on accuracy. The same educational coordinator scored both the reading and writing test for all potential testers.

Table 4. Comparison of Community and Outside Testers

	Community Testers (N=10)	Outside Testers (N=10)	P-Value*
Age (Years) Mean±SD (Range)	28±10 (18-54)	23±7 (18-37)	0.2648
Educational Level Mean±SD (Range)	10±2 (8-12)	11±1 (9-13)	0.0562
Female	60%	50%	0.6733
Muslim	90%	70%	
Hindu	10%	30%	0.2878

*P-value calculated using two sample t-tests for continuous variables and chi-square tests for categorical variables

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5.2 Conduct of Arsenic Education Pilot Phase

Before the As educational materials were administered to study respondents thorough pilot testing was conducted over a 3-month period in our pilot area of Singair, Bangladesh. During this period, all key educational messages used in the As Educational Script were piloted in the field. We targeted individuals of different educational levels and age to ensure that the language used in the educational script was appropriate for all study respondents. After our pilot As educational sessions, members of the audience were administered the knowledge of As quiz used in our study surveys to determine if they understood the messages explained. Audience members were also asked a series of questions to determine improvements that could be made to the As educational materials. The following are examples of the questions asked: (1) Are there any messages that you felt were particularly difficult to understand?; (2) What aspects of the session did you like?; (3) Which aspects of the session did you not like?; and (4) Has the length of the session interfered with your routine today?

The educational sessions were conducted by the educational coordinator during the first two months of the pilot. In the third month, three community members were trained to be As testers in their respective villages. This provided us the opportunity to observe the effectiveness of As testers of the same age and educational level as the ones that would likely be included in our study.

5.3 Conduct of Arsenic Tester Trainings

A five day As educational training was held for all individuals participating as As testers in our intervention. Attendance for all days of each of the training sessions was mandatory. For each training session there was an educational coordinator present and two educational trainers to assist the As testers. The following is overview of the training.

- **Day 1:** Overview of As and Explanation of the As Tester Protocol
- **Day 2:** Field Practice of WAs Testing Kits and Observation of Household Visits
- **Day 3-4:** Practice Household Visits
- **Day 5:** Practice Household Visits and Problem Identification

On the first day of the training session, all of the As testers were administered a 25 item quiz to determine their background knowledge of As. This quiz was administered pre- and post- training to ensure that the As testers gained the knowledge necessary to effectively disseminate As education in their assigned villages. The pre- and post- As Tester Training Quiz can be found in Appendix 9. After the pre-training quiz the educational coordinator provided the As testers with a thorough overview of As covering the following topics from the As Educational Manual:

- Sources of As
- Scale of the As problem
- Arsenic standard in Bangladesh
- Health implications of chronic As exposure

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- Preventive approaches

- Key As educational messages

- Assistance with well switching

- Techniques to motivate villagers

After background on As was provided to the As testers, group work was done to allow the As testers to conceptualize the materials discussed (ie. role playing). A question and answer session was also conducted to identify any questions or concerns about the materials.

During the afternoon of the first training day the educational coordinator explained the household visit protocol and how to conduct field WAs testing. A FAQ guide was also developed to list possible questions that could arise in the field. The As testers were instructed to use this FAQ guide as a reference tool for their questions and concerns in the field. The FAQ guide can be found in Appendix 10.

The next four days of the training were spent at our pilot area in Singair, Bangladesh. The second day of the training the As testers were taught how to conduct WAs testing in the field. The As testers were divided into groups of four and were sent to conduct WAs testing of wells where the educational trainers already knew the As concentration. If the As test result of the tester was different than the previously found value, the tester was instructed to retest the well. In the afternoon, the As testers observed one of the educational trainers conduct a household visit.

On the third, fourth, and fifth days of the training, the As tester practiced conducting household visits under the observation of the educational trainers. Each day of the training, a problem identification session was held with the trainers and As testers to address any concerns. Each As tester was required to conduct at least four household visits before the end of the training. Their performance was evaluated by our trainers on the following criteria: correct introductions, verbatim reading of the As Educational Script, engaging the audience by having eye contact, encouraging applauses, providing adequate assistance with well switching, addressing questions and concerns of households, and correctly using the As test kit. The As tester evaluation sheet can be found in Appendix 11. In the afternoon of the fifth day, the As testers were administered the post training quiz. These quizzes were immediately scored by the educational trainers and each As tester was told their score and provided clarification on any questions they answered incorrectly.

5.4 Overview Intervention Materials: Arsenic Tester Journal

Each As tester enrolled in the study was given an "As Tester Journal". This journal consisted of the following materials:

1. Arsenic tester household visit forms

2. Arsenic tester test strip forms

3. Arsenic tester household visit protocol

4. Arsenic tester educational script

5. Arsenic tester educational manual

This comprehensive guide was developed to standardize the household visits. This ensured that the information provided was the same between all As testers. Each As tester received a one week training in which they were taught the proper use of all the study materials. The As testers were required to carry their As Tester Journal to all household visits.

5.4.1 Arsenic Tester Household Visit Form

The purpose of the "Household Visit Form" was to document all of the events that occurred during the household visit. The first section of the form recorded the duration of the As educational session, and the number of women, men, and children (<15 year old) that attended the session. In the second section, the As tester recorded the result of the WAs test, and the color of the placard attached to the household's well. There was also a section for "additional wells" which obtained information on the additional wells tested for each study respondent using a unsafe well at baseline (until a safe well was located). In the last section, the As tester recorded the location of the safe well that the study respondent decided to collect drinking water from.

5.4.2 Arsenic Tester Educational Manual

An As educational manual was developed for the As testers to use as a resource to address the questions or concerns that the community members in their assigned village may have about As. The manual started by explaining the scale of the As problem in Bangladesh, and described the current research Columbia University is conducting on As. Diseases associated with As exposure were explained. The guide then focused on preventive approaches that villagers can take to reduce their As exposure and risk of As-related illnesses. There was also a section that emphasized the importance of a good diet. A table was provided that listed sources of vitamins

A, C, E, folate, and protein found in local foods. Sources of As-safe water and acceptable uses of As contaminated water were also explained. The last section of the manual described techniques that the As-testers could use to motivate community members to utilize As-safe drinking water sources. Social mobilization was emphasized as a means of building As awareness in their assigned villages.

5.4.3 Arsenic Test Strip Form

The "As Test Strip" form contained the location and As concentration of all wells tested by the As tester. This form served as a directory for the As tester to assist them in locating previously tested As safe drinking water sources in their assigned village. The As tester attached the test strips for all As test conducted to this form.

5.4.4 Arsenic Tester Educational Script: Arsenic Educational Sessions

The As testers conducted a 40 minute As educational session in all study households. An "As Tester Educational Script" was developed to standardize the As information being provided in these educational sessions. This script was developed based on the current scientific literature available on the health implications associated with As, and our educational pilot conducted in Singair, Bangladesh. The script focuses on disseminating 10 key educational messages on the health implications that can be attributed to chronic As exposure, and how to effectively reduce exposure. The script was accompanied with eight photos displaying the key As educational messages discussed. The educational sessions were designed to be interactive, encouraging the participation of those attending the session by asking the audience questions about the topics being covered. Applause was also used to encourage the participation of the audience. The

following is a list of the Key Educational Messages covered in the script:

Message 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 arsenocosis.*

Message 2: *Those exposed to As can suffer from chronic diseases such as cancer later in life as well as chronic heart and lung diseases. Chronic As exposure does not cause cholera, diarrhea, or vomiting. If you or your children develop diarrhea, it is not from As.*

Message 3: *Arsenic can cause ill health in our children, and may negatively affect their intelligence. For example they may do poorly on their tests in the classroom.*

Message 4: *Pregnant women should not drink or cook with As contaminated water because it can affect the health of their unborn child later in life.*

Message 5: *Arsenocosis does not occur by sleeping with a skin-diseased person. It is not a communicable disease.*

Message 6: *Arsenic cannot be removed by boiling water.*

Message 7: *We should not drink or cook with water from a red marked tube well because they are contaminated with As. However it is okay to use a red marked tube well for hand washing, bathing, clothes washing, and washing animals. This is because As cannot penetrate the skin.*

Message 8: *50 ppb is the As standard in Bangladesh*

Message 9: *We should use water from tube wells marked green for drinking & cooking purpose. Green marked wells have a level of As below 50 ppb.*

Message 10 (Pledge): "Our commitment is that we will inform people to drink and cook with As safe water all the time, and that those with safe wells will share with others"

After the key educational messages were explained, there was a review session in which the audience is asked a series of recap questions to ensure they understood the information provided. The As-tester then encouraged village members to come to them with any questions or concerns they may have about As. At the end of the session, the audience was asked to make a pledge to drink As safe water and share As safe wells with others. The As Tester Educational Script can be found in Appendix 13.

Assistance with Well Switching

The "Assistance with Well Switching" section of the educational script contains directions on how to assist households who were found to be using an unsafe well locate an As safe drinking water source. During the educational pilot phase, we learned that the study respondent's relationship with the well's owner was an important factor determining a household's decision to use a particular As safe well. This meant that the closest well to a study respondent's home may not necessarily be the one they would choose to use, if for example the relationship with the owner of that well was not good. Therefore, we instruct the As testers to first ask the study respondent "Who would you like to share your well with?" Once, a well was selected, the As tester located the owner of the well to ask them if their well had been tested for As, and if they were willing to share with the study household. The following are the possible scenarios that could be encountered by the As tester and the actions that should be taken.

Safe Well→ Ask the well owner if they are willing to share with the study household. If the well owner says "no", return to the study household and ask them to select another well. If the well owner says "yes" test the well for As to confirm the previous As result, and conduct an educational session with the safe well owner while the As test is being conducted. Then inform the study respondent of the As status of the well. If the well is found to be safe encourage the study respondent to collect all of their drinking and cooking water from this well.

Unsafe Well→ Go back to the study respondent and ask them to select another well.

Untested→ Ask the well owner if they are willing to share with the study household. If the well owner says "no", return to the study household and ask them to select another well. If the well owner says "yes" test the well for As, and conduct an educational session with the well owner while the As test is being conducted. Then based on the As result refer to the procedures for a "safe well" or "unsafe well."

5.4.5 Arsenic-Tester Household Visit Protocol

The As testers were required to work five days per week Sunday through Thursday, and dedicate at least four hours per day to being an As tester. This involved conducting at least two household visits per day, unless many wells were tested for a single study household and no safe well was located. The As testers performed their duties for a period of three months. The "As-Tester Household Visit Protocol" was developed for the As-testers to follow when conducting household visits to disseminate As education and provide well WAs

testing. This protocol can be found in Appendix 12.

The As tester was instructed to first locate the person in the study household that was administered the baseline questionnaire, and ask them for their study identification card. The As tester then confirmed the study respondent's subject ID using a directory of all study respondents located in their village. The study respondent was then asked where their primary drinking water source was located, and the well id number was compared with the one recorded for the respondent's well at baseline in the directory. If there was any discrepancy the As tester was asked to contact the educational coordinator.

The As-tester then organized an educational session with the study respondent and invited any individuals present at the time of the session to attend. Arsenic-testers were instructed to try to limit the size of each of their educational sessions to 10 individuals. This was done to allow for a more interactive session where the As tester could ask participants questions to ensure they understood the information provided. If a large number of individuals were interested in attending a session, two smaller sessions were conducted. Once the session was organized, the As tester completed the Household Visit Form, and proceeded to conduct the WAs testing prior to the start of the educational session.

A sample of the household's primary drinking water source was collected in a reaction bottle, and the name of the respondent was recorded on an As test strip and placed onto the lid of the reaction bottle. Reagents were added to the reaction bottle and swirled for 60 seconds. The start time of the reaction period was then recorded, and the reaction bottle was left to sit for the 40

minute reaction period.

While the water sample was reacting, the As tester started the 40 minute As educational session. After the 40 minute reaction period, the test strip was removed from the lid of the reaction bottle, and the As result was recorded in the Household Visit Form and provided to the study respondent. The test strip was then stapled to the As Test Strip Form.

If the WAs concentration of the respondent's primary drinking water source was less than or equal to 50 ppb, the As tester was instructed to place a green placard on the household's well. If the WAs concentration was above 50 ppb, the As tester was instructed to place a red placard on the household's well, and proceed to the section in As Educational Script called "Assistance with Well Switching".

If a study respondent was found to have an unsafe well, additional wells in the village were tested to locate an As safe water source. An As educational session was held at the households where the additional As tests were conducted. The As tester was instructed to complete the section of the household visit form on "additional wells tested".

5.6 Quality Control

The field supervisors conducted weekly visits to their assigned villages. During these visits, they checked the As tester household visit forms for completeness and identified any errors the As tester needed to correct. The field supervisors also copied all the entries from the Household Visit Forms into the Field Supervisor journals.

The field supervisor addressed any problems that occurred in the field such as missing study respondents or if a respondent changed their drinking water source from baseline prior to their household visit by the As tester. They also conducted a random check of two study household visits per week to ensure the following: the educational session was completed, color id placard was attached to the well, and that respondents with unsafe wells were informed about a nearby safe drinking water sources they could use.

Furthermore, thirty percent of the water samples from baseline were randomly selected to be re-tested in the Dhaka office by the field organizer using the Hach EZ As field testing kit to ensure that the As testers were properly conducting their As testing in the field. Laboratory based confirmation of the As concentration of all water samples tested in the field was conducted using ICP-MS at LDEO at Columbia University.

5.7 Problem Identification

During the intervention period, three study respondents were found to be missing after the baseline survey, but before the As tester conducted a household visit. The field coordinator went to these households to record the reason why the study respondent was missing. All three households reported that the study respondent had shifted to another residence. Eleven households were found to have changed their primary drinking water source after baseline, but before the As tester conducted a household visit. The field coordinator went to these households to complete a change of drinking water source form which updated the sections of the baseline questionnaire that pertained to the study household's primary drinking water source. Ten of these

respondents changed wells because their current well was broken, and one respondent switched

wells because of a family quarrel.

During the intervention period, the educational coordinator and trainers completed problem

identification reports to identify concerns that arose in the field. The educational trainers reported

that the most common problem faced by the As testers were study respondents asking for their

own As safe well. Problems were also faced when the As tester tested many wells near a

respondent's household but was not able to identify an As safe well for them to use. These study

households then became frustrated, and sometimes refused to provide anymore recommendations

on additional wells to test for them.

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Chapter 6
Impact on Arsenic Exposure of a Growing Proportion of Untested Wells in Bangladesh

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Impact on Arsenic Exposure of a Growing Proportion of Untested Wells in Bangladesh

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Abstract

Background In many areas of Bangladesh, it has been more than six years since a national campaign to test tubewells for arsenic (As) was conducted. Many households therefore draw their water for drinking and cooking from untested wells.

Methods A household drinking water survey of 6646 households was conducted in Singair upazilla of Bangladesh. A subset of 795 untested wells used by 1000 randomly selected households was tested in the field by trained village workers with the Hach EZ kit, using an extended reaction time of 40 min, and in the laboratory by high-resolution inductively-coupled plasma-mass spectrometry (HR ICP-MS).

Results The household survey shows that more than 80% of the wells installed since the national testing campaign in this area were untested. Less than 13% of the households with untested wells knew where a low-As well was located near their home, even though a significantly higher proportion live within a walking distance of a low-As well that has not been tested. Village workers using the Hach EZ kit underestimated the As content of only 4 out of 795 wells relative to the Bangladesh standard. However, the As content of a 168 wells was overestimated relative to the same threshold.

Conclusion There is a growing need for testing tubewells in areas of Bangladesh where As concentrations in groundwater are elevated. This could be achieved by village workers trained to use a reliable field kit. Such an effort would result in a considerable drop in As exposure as it

increases the opportunities for well switching by households.

Keywords: Arsenic, field kit, well screening, Bangladesh

Background

Elevated exposure to inorganic arsenic (As) is associated with cancers of the skin, bladder, and lung (1-3), reproductive and developmental effects (4, 5), cardiovascular disease (6, 7), and skin lesions (8, 9). In Bangladesh, millions of people are exposed to naturally occurring As concentrations that exceed the World Health Organization (WHO) guideline of 10 μg/L (10). During the 1970s, the United Nations Children's Fund, through the government of Bangladesh, promoted the installation of tubewells to reduce risks from drinking microbial contaminated surface water (11). In the early 1990s, evidence began to emerge that Bangladeshi villagers were presenting signs of arsenicosis due to the consumption of well water with elevated levels of As (12). An As testing campaign relying on field kits and targeting 5 million wells in regions identified to be at risk for As contamination was initiated in 2001 and completed in 2004. By 2005, 1.4 million tubewells were found to have levels of As above the Bangladesh standard of 50 μg/L and were painted red, while another 3.5 million wells were found to be below the standard and were painted green (10). It is estimated that approximately 12% of household presently drink water in Bangladesh that does not meet the Bangladesh standard for As (13).

The impact of As mitigation in Bangladesh, though significant, has been limited to a variety of approaches that currently serve roughly half of the affected population. The most common As mitigation option followed in rural areas has been well switching (10). This involves switching from an As contaminated well to a nearby well that is safe relative to the Bangladesh standard for As in drinking water. Because of the spatial heterogeneity of As in groundwater well switching has been estimated to be a viable option for reducing exposure for all but 13% percent

of the population that lives in areas with greater than 80% arsenic contamination (10, 14).

Testing well water for As has been shown to reduce As exposure in villages of Bangladesh due to switching on the basis of household surveys as well as urinary As measurements (15-17).

In this contribution, we report the results of two phases of a study conducted in Singair upazilla (subdistrict) of Bangladesh: 1) a sizeable household drinking water survey paired with the collection of geographic data; and 2) testing of a subset of wells of unknown status with a field kit by trained village workers as well as laboratory measurements. The household drinking water survey was conducted to determine the status of wells used six years after a blanket testing campaign for As swept through the area.

Methods

Sampling Design

The study was conducted in rural Singair upazilla, located in Manikganj district of Bangladesh. This study area was selected on the basis of an expected wide range of As concentrations and the presence of the Christian Commission for Development Bangladesh (CCDB), a non-governmental organization that assisted with the implementation of this intervention. The first phase of the study was a household drinking water survey conducted in 26 villages; this survey did not involve well testing (Figure 1). The second phase of the study was an As testing intervention in which village workers conducted field As measurements for 1000 randomly selected study households using a well of unknown status.

The household drinking water survey was administered to all 6646 households in the 26 villages that could be contacted from November 2009 to January 2010 (Figure 1). Villages with at least 40% of wells exceeding the Bangladesh As standard (50 µg/L) were selected using data from the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP). Interviewers were sent to every household present in each of the villages to administer the survey questionnaire to the person in the household responsible for primary drinking water collection. For each household, the survey obtained information on the As status of the household's primary drinking water source, the well depth, well installation date, and if the well was painted based on the As concentration. For a subset of 10 villages, the position of each well was determined with hand-held global positioning system (GPS) receivers within an estimated accuracy of ~10 meters. Because a typical private well is shared by several households, two on average (20), information was recorded repeatedly for a significant number of wells.

In the second phase of our study, a subset of 20 villages meeting our study eligibility criteria of having at least 40% of wells exceeding the Bangladesh As standard (50 µg/L), and at least 50 individuals who met the study eligibility criteria using the results of our household drinking water survey were selected to be part of an As testing intervention that was conducted from March to June 2010 (Figure 2). Based on a village census created from the household drinking water survey, 50 households with untested wells were selected at random from each of the 20 villages. Thus, the total study population was 1000 households. The primary drinking water source for each selected household was tested for As by village workers trained as part of the project. Because some of the 1000 study households shared the same tubewell; this survey covers only 795 previously untested tubewells distributed across the 20 study villages.

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Twenty village workers were selected to conduct the As testing intervention by CCDB. They were a convenience sample, selected based on their ability to complete a reading and writing test. Their educational level ranged from completion of secondary school certificate to higher secondary school certificate (Grades 8-13). None had previous laboratory experience or prior experience using this field testing kit. Each of these village workers were trained to use the Hach EZ kit (Part No. 2822800) for one day and assigned a study village to conduct water As field measurements. Village workers were responsible for testing the wells for the 50 households using untested wells randomly selected in their assigned village. Further, additional well were tested to locate an arsenic safe drinking water source for households found to be using unsafe well. After testing, a green or red color placard was placed on each well based on compliance with the Bangladesh standard for As in drinking water.

Field Water Arsenic Measurement

The Hach EZ kit requires the addition of 2 prepackaged reagents, sulfamic acid and zinc powder, into a reaction bottle containing a 50 ml water sample. These reagents produce arsine gas if As is present. This arsine gas is trapped on a reaction strip impregnated with mercuric bromide. The yellow to brown color of the strip is then compared to the reference scale provided by the manufacturer. The scale indicates the intensity of the color expected for As concentrations of 0, 10, 25, 50, 100, 250, and 500 μg/L. A 40 minute reaction period was used in this study rather than the 20 minutes recommended by the manufacturer because a previous study showed that the increased reaction period reduced inconsistencies relative to Bangladesh As standard in the 50-

100 µg/L range (18). The kit has an optional step to eliminate interference by hydrogen sulfide; this was excluded because sulfide levels in Bangladesh are generally too low to cause interference (18).

ICP-MS Analyses

Water samples were collected in 20 mL acid-washed bottles while the wells were tested in the field. The samples were acidified to 1% with high-purity Optima HCl at least 48 hours before analysis. This has been shown to ensure re-dissolution of any As that could have adsorbed to precipitated Fe oxides (27). Water samples were then diluted 1:10 in a solution spiked with ^{73}Ge for internal drift correction and analyzed for As by high-resolution inductively-coupled plasma mass spectrometry (HR ICP-MS), which eliminates the isobaric interference with ArCl. Further details are provided elsewhere (18, 19). The detection limit of the method for As is typically <0.2 µg/L, estimated here by multiplying the As concentration corresponding to the blank by a factor of 3. The long-term reproducibility determined from consistency standards included with each run averaged 4% (1-sigma) in the 40-500 µg/L range.

Results

Household Drinking Water Survey

Approximately 60% (3989) of respondents interviewed for the household drinking water survey were able to recall the depth of their current primary drinking water source, and 95% (6310)

could recall the year of well installation. More than two-thirds of the wells were reported to have been installed within the past 10 years (Figure 2). The rate of installation increased within each 2-year period increased over the past 10 years, but particularly so during the last 2 years. The reported well depths ranged from 12 to 1400 ft, with a median of 75 ft). When the median of reported depths for wells installed since 2000 is subdivided by year of installation, there is no appreciable change in well depth over time. For example, no two years differed in median well depth by more than 5 feet. Each year is represented by at least 90 values.

Of the 6646 respondents interviewed, 3739 (56%) reported that their well had not been tested for As, 2424 (37%) reported that their well had been tested, and 483 (7%) reported that they did not know whether their well had been tested. Of the tested wells, 1053 (43%) were reported to be safe relative to the Bangladesh As standard of 50 μg/L, 868 (36%) were unsafe, and for 444 (18%) the As status of the well was unknown. Ninety-five percent of the wells that were tested no longer had visible labeling of the As status of the well (i.e., green for safe or red for unsafe). The proportion of untested within individual villages ranged from 46 to 83% (Figure 3).

When considering the proportion of untested wells by year of well installation, there is a significant increase over time ($p < 0.001$ by ANOVA) (Figure 3). For example, 25% of wells installed before 2000 were untested, while roughly 90% of wells installed in the year prior to the survey were untested. Each year is represented by at least 80 values; wells installed in the years prior to 2000 were collapsed to reduce the likelihood of recall bias. A randomly selected subset of 698 households with untested wells were also asked if they knew where a drinking water source considered safe with respect to As was located near their home. Less than 13% (89) of

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these respondents knew where such a water source was located.

Within the subset of wells that were tested, the proportion of unsafe wells changed over time. Considering two-year intervals for robustness, a significant decrease in the proportion of unsafe wells over time is observed: 54% of wells installed prior to 2000 were unsafe compared to 21% of wells installed between 2008-2010 ($p < 0.001$ by ANOVA) (Figure 3).

Arsenic Testing Intervention

Groundwater As concentrations determined by HR ICP-MS are used as the reference for evaluating the performance of the field kit deployed by village workers. The HR ICP-MS data indicate that As concentrations in the sample range from 0.1 to 437 µg/L, with a median of 54 µg/L. Following the standard interpretation of kit results, a reading above 50 µg/L classifies a well as unsafe relative to the Bangladesh standard for As in drinking water. According to this criterion, the EZ kit underestimated the As content of groundwater relative to these two thresholds for only 4 out of a total 795 samples (Table 1). At the same time, the EZ kit overestimated the As content of groundwater relative to the Bangladesh standard for 163 out of 795 samples. For the vast majority of the overestimates relative to Bangladesh standard, As concentrations were in the 10-50 µg/L range (Figure 4).

Discussion

The largest As testing program in Bangladesh was the BAMWSP survey, conducted between 2001 and 2004 (17). That survey tested and labeled for As nearly half of the country's 10 million tubewells (16, 21). Thus, in many regions it has been more than six years since the nationwide testing program was conducted. In a study conducted in Araihazar, Bangladesh, it was found that the number of tubewells approximately doubles every two years (20). If this is the case in other As affected areas, this would imply that the majority of wells in the country are untested for As. In a 2009 national survey conducted by UNICEF and the Bangladesh Bureau of Statistics, it was found that 44% of tubewells in the country were untested (13). Although there have been many attempts by NGOs and government agencies to provide access to As testing services, many households continue to collect water from untested wells (10, 22-28).

Our results from Singair indicating that more than 80% of the tubewells installed during the past 6 years are untested for arsenic is alarming, but not inconsistent with previous observations. The distribution of well ages may provide some evidence for the reason underlying the continuing installation (Figure 3). Unless there is a recall bias, there is no reason to believe the rate of well installation really was actually higher during the past 2 years compared to the four previous 2-year intervals. The apparent sudden increase might suggest instead that a significant fraction of wells are abandoned within the first two years of installation, as suggested based on observations elsewhere in Bangladesh (15).

Beyond the first ~100 ft (30 m), the concentration of As generally decreases with depth in

aquifers of Bangladesh and there is no reason to believe this wouldn't apply to Singair. The decreasing proportion of unsafe wells within the subset of tested wells over time may therefore at first sight seem surprising given that the depth of wells has not changed. Comparison of trends in well depth over time suggests a possible explanation when tested and untested wells are distinguished (Figure 5). About 25% of the tested wells installed over the past decade in Singair were >200 ft deep whereas this is the case for only 15% for wells of untested wells. The difference is even more striking for wells >300 ft deep, typically community wells primarily installed by NGOs or the government. The proportion of deep wells has increased markedly within the group of tested wells whereas very few such wells were untested. This suggests that deep wells installed by NGOs and the government, as well as a sizeable fraction of wells >200 ft presumably installed by relatively wealthy households, are tested while the shallower wells are not. The trend towards a greater proportion of safe wells within the tested subgroup probably reflects this bias rather more effective targeting of safe aquifers by all new installations.

To quantify the impact of a growing proportion of untested wells on access to As safe drinking water relative to the Bangladesh As standard as determined by BAMWSP testing, the distance to the nearest well known to be safe from previous testing was calculated for a subset of 499 study households located within 10 villages for which the position of both wells and study households was known (Figure 6). This calculation shows that only 27% of households reside within 50 m of an As safe well and another 28% within 50-100 m of a low-As well (Figure 7).

Previous work has shown that households rarely switch to a private low-As well if it requires traveling more than 100 m each way several times a day (Opar et al., 2007; Chen et al., 2007). If

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the nearest safe well is within 50 meters, the well switching rate in one study area was shown to be 68%, while if the nearest safe well was greater than 150 meters away the well switching rate declined to 44% (15). Ten stimulations were conducted to estimate the potential impact of testing all the untested wells in the same area by randomly assigning a status to untested wells based on the proportion of safe and unsafe wells observed in the study area (50%). The average of all simulations for each distance category shows that testing all of the untested wells within the study area could increase the proportion of study households living within 50 meters of an As safe drinking water source from 27 to 67%, and decrease the proportion of households living greater than 100 meters away from an As safe drinking water source from 45% to 17%. Collectively, these findings indicate that renewed As testing could significantly reduce exposure.

The results obtained by village workers using the EZ kit and extended reaction time of 40 min are encouraging and consistent with previous observations (18). The increased reaction markedly reduces the number of wells for which the As content is underestimated relatively to the WHO guideline, but there is clearly a trade-off. Testing takes longer but the number of wells incorrectly classified as unsafe relative to the guideline also increases. This reduces the number of wells that a household with an unsafe well could switch to. Given the growing evidence of significant health effects of As exposure in the 10-50 µg/L range, on the other hand, overestimates are clearly preferable to underestimates of the As content of well water (29-31), The WHO guideline is currently not applied in Bangladesh but our results show that (32, 33), using a 40 min reaction time, the Hach EZ kit underestimated the As content of 10 out of 795 wells relative to the 10 ug/L threshold (Table 1). The Hach EZ kit also overestimated the As content of wells for 43 wells relative to the WHO guideline.

Conclusions

Our household drinking water survey confirmed that there is an urgent need for water As testing in affected areas of Bangladesh. A simple spatial simulation based previous observations shows that testing of wells of unknown status is likely to significantly reduce As exposure by providing information on available As safe drinking water sources households can utilize. Our evaluation of the Hach EZ kit using a 40 min reaction time shows that trained village workers will in the vast majority of cases correctly classify wells relative to the current Bangladesh standard for As in drinking water, and could even do so relatively the WHO guideline.

List of Abbreviations

As: Arsenic; BAMWSP: Bangladesh Arsenic Mitigation Water Supply Project; ICP-MS: Inductively-Coupled Plasma Mass Spectrometry ; LDEO: Lamont Doherty Earth Observatory; NGO: Non-governmental Organization; WAs: Water Arsenic; World Health Organization: WHO

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

CMG directed the field study, performed the statistical analysis, and wrote the manuscript. AVG and JHG directed the studies and revised the manuscript. JM was involved in the laboratory analysis of the water samples collected and revised the manuscript. All authors read and approved the final manuscript.

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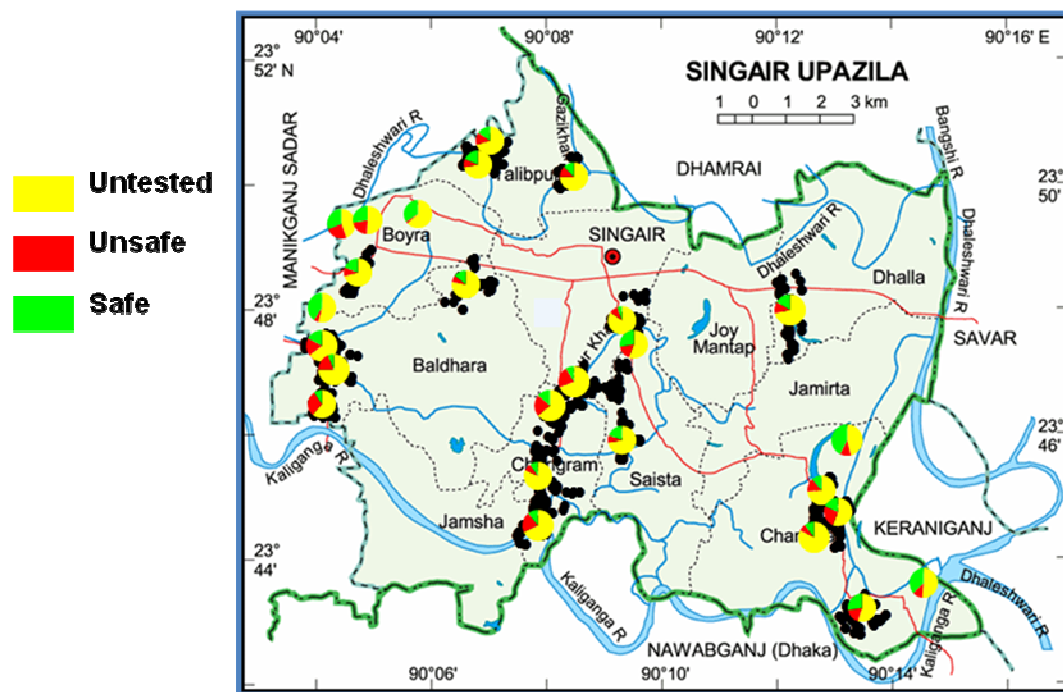
Figure 1. Map of study area. Pie charts represent the proportion of untested, safe, and unsafe wells based on household recollection in 26 villages. Black dots indicate the location of 1000 study households with an untested well randomly selected from a subset of 20 out of 26 villages where the household drinking water survey was conducted.
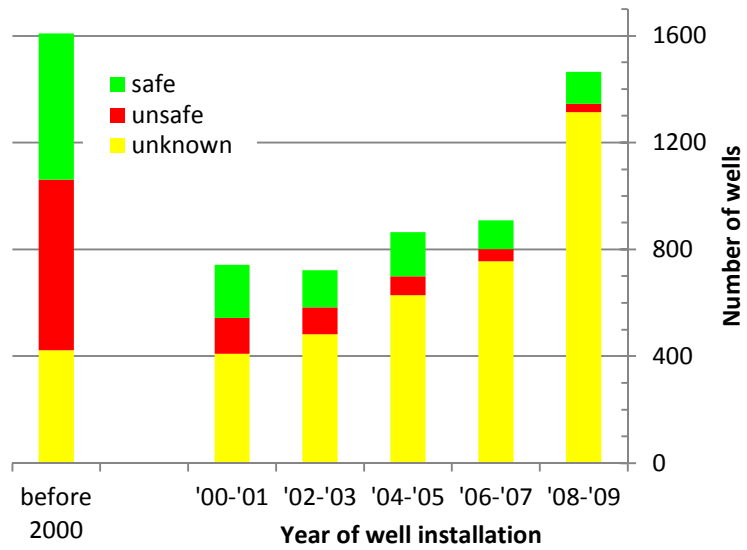
Figure 2. Status and year of installation of wells reported by 6649 households residing in 26 villages of Singair upazilla.
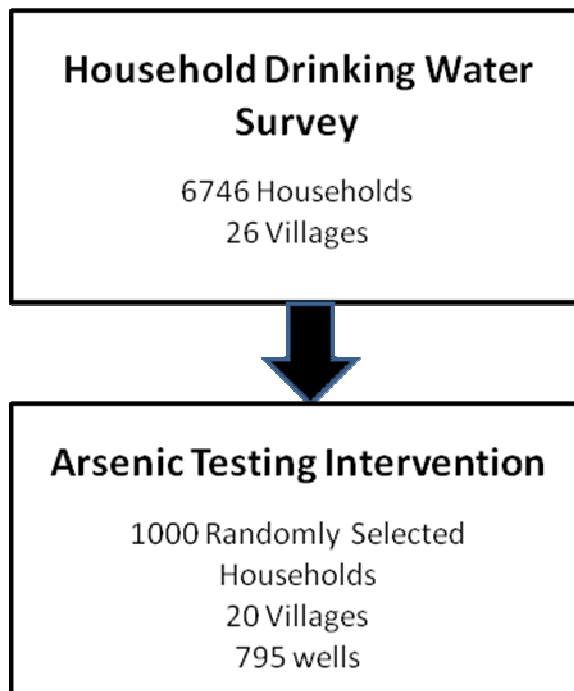
Figure 3. Study design of household drinking water survey and arsenic testing intervention in Singair, Bangladesh.
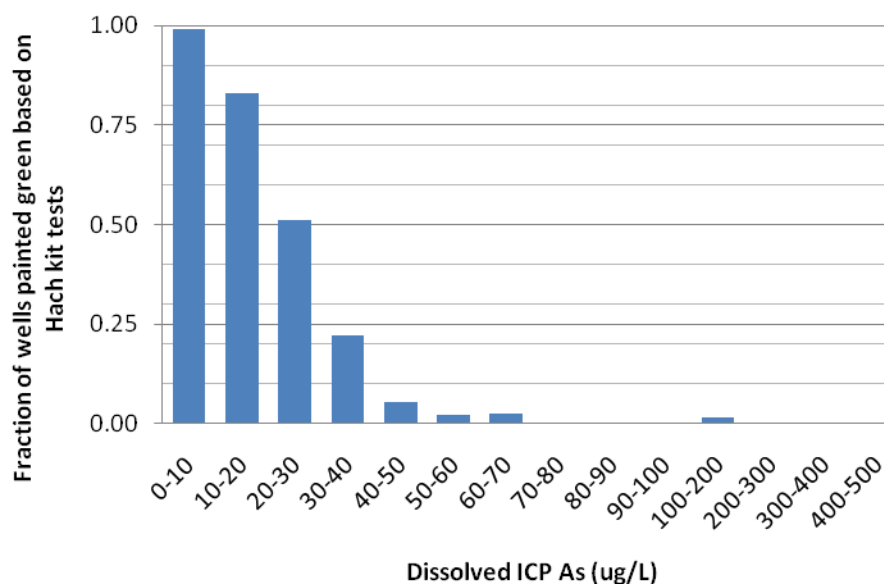
Figure 4. Results obtained by village workers using the Hach EZ kit with a 40 min reaction time relative to the Bangladesh standard of 50 ug/L for As in drinking water.
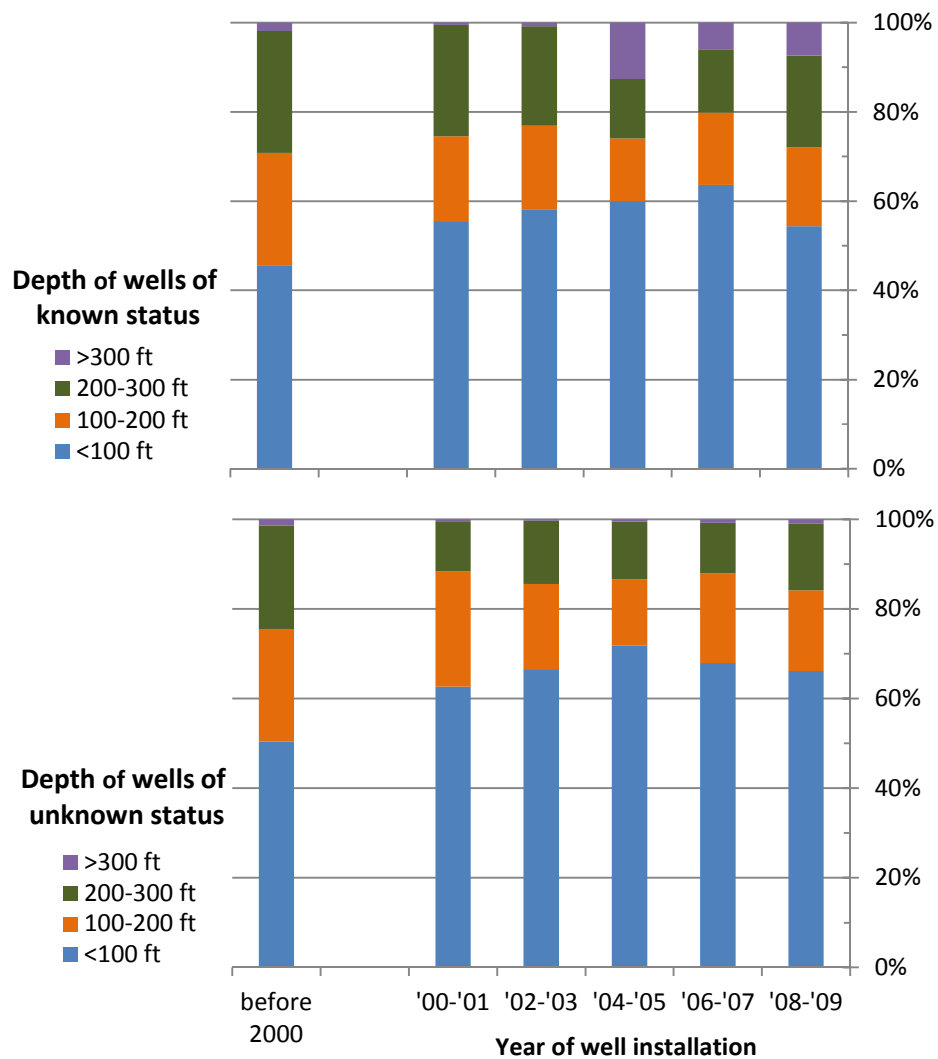
Figure 5. Comparison of depths of wells of known (1325 households) and unknown status (2648 households) of wells as a function of installation year in 26 villages of Singair upazilla.
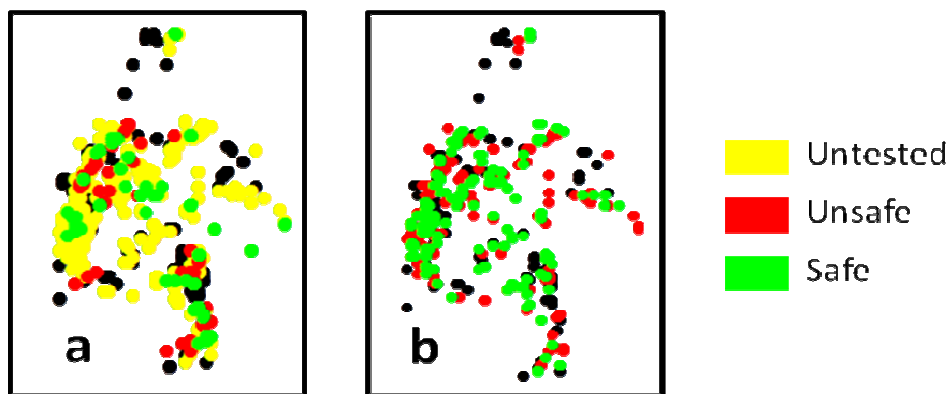
Figure 6. Close-up view of the spatial distribution of well status in 3 study villages based (a) on the survey and (b) on of the 10 simulations.
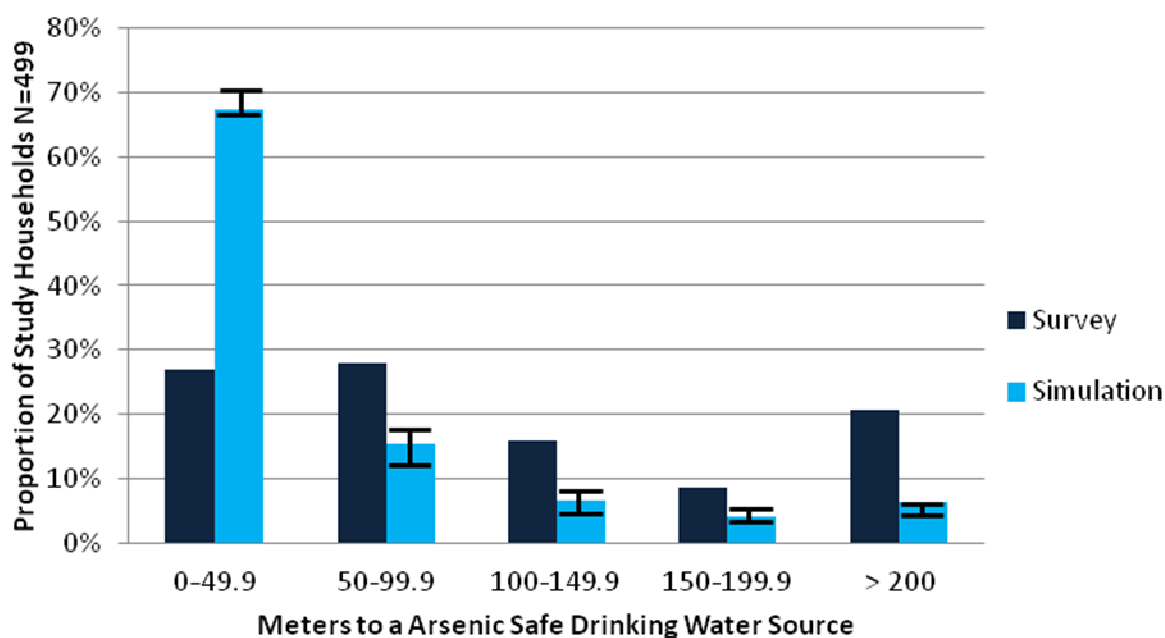
Figure 7. Distribution of distances to the nearest well for a subset of 499 study households residing within villages for the location of every well was determined. The area includes 299 unsafe wells, 294 safe wells, and 1208 untested wells. The survey calculation considers wells known to be safe only; the simulation randomly assigned a safe/unsafe status to the wells of unknown status reflecting the 50/50 proportion throughout the study area. Vertical error bars indicate the range in the proportion of distance categories observed for ten such simulations.

Table 1. Comparison of Laboratory and Field Kit Results for 795 Wells Tested by Village Testers				
ICP-MS As Results	<10 µg/L	10-50 µg/L	50-100 µg/L	>100 µg/L
N	198	292	166	139
Field Kit Incorrect Unsafe relative to above 10 µg/L	43	9	0	1
Field Kit Incorrect Unsafe relative to 50 µg/L	2	161	2	2

Chapter 7

A Cluster-Based Randomized Controlled Trial Promoting Community Participation in Arsenic Mitigation Efforts in Singair, Bangladesh

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A Cluster-Based Randomized Controlled Trial Promoting Community Participation in Arsenic Mitigation Efforts in Singair, Bangladesh

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Summary

Objective: To reduce Arsenic (As) exposure, we evaluated the effectiveness of training

community members to perform water arsenic (WAs) testing and provide As education

compared to sending representatives from outside communities to conduct these tasks.

Methods: We conducted a cluster based randomized controlled trial of 20 villages in Singair,

Bangladesh. Fifty eligible respondents were randomly selected in each village. In 10 villages, a

community member provided As education and WAs testing. In a second set of 10 villages an

outside representative performed these tasks.

Results: Overall, 53% of respondents using unsafe wells at baseline switched after receiving the

intervention; this did not differ significantly by type of As tester (Odds ratio =0.77[95%

confidence interval 0.37-1.61]). At follow-up, among those using unsafe wells who switched to safe wells, average urinary As concentrations significantly decreased.

Conclusion: Community and outside testers were equally effective at encouraging households to use As-safe water sources. The overall intervention was effective in reducing As exposure provided there were As-safe drinking water sources available. These findings suggest that community members can effectively reduce arsenic exposure in their villages.

Introduction

Exposure to elevated levels of inorganic arsenic (As) is associated with cancers of the skin, bladder, and lung (1-3), developmental effects (4, 5), cardiovascular disease (6, 7), and skin lesions (8, 9). Chronic As exposure is also associated with deficits in childhood cognitive and motor function (5, 10, 11). Recent data suggest associations between chronic As exposure from drinking water and mortality (12).

Groundwater pumped from approximately half the estimated 10 million tubewells in Bangladesh do not meet the World Health Organization (WHO) guideline for As of 10 µg/L (13). In 2006, Ahmed et al reported that 57% of the estimated population of 28-35 million initially exposed to As above the Bangladesh standard of 50 µg/L remains exposed. The most commonly used As mitigation option is well switching (67%), followed by the use of deep tubewells (28%). Mitigation options such as piped water systems, rainwater collection, dugwells, As filters, and pond sand filters are utilized by a very small proportion of the population (13, 14).

Even when provided with As education, households do not always seek As-safe drinking water sources (15-18). Testing programs typically involve a representative from an outside organization coming into a village to test the well water for As. These staff label the spout of each well red if the As concentration is greater than 50 µg/L and green if the As concentration in the well is less than 50 µg/L. After the results of the As test are provided, the representative typically leaves the village without providing the resources or in-depth knowledge to address health concerns or mitigation options (15). The lack of resources at the local level, we

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hypothesize, may be an important factor limiting the impact of As testing programs. Previous interventions have found that the provision of As education and WAs testing can encourage households with unsafe wells to switch to alternative drinking water sources (14, 19-21). However, no studies to date evaluated the effectiveness of having a community member, rather than an outside representative, provide these services.

In 2010, we developed an As education and WAs testing intervention for rural villages in Singair, Bangladesh. Our study objective was to evaluate the effectiveness of having community members, compared to outside representatives, conduct WAs testing and As education. The primary study outcome was switching to an As safe well among those with unsafe wells at baseline; the secondary outcome was the change in urinary As (UAs) concentration. We hypothesized that the community tester would be more effective since they could provide additional reinforcement by living in the village. Community involvement in As testing may provide a sustainable and less costly option for communities to monitor As exposure and may represent a model for government or non-governmental agencies to conduct future interventions.

Methods

Setting

This study was conducted in rural villages in Singair Upazila, located in the Manikganj district of Bangladesh. This study area was selected due to its wide range of WAs concentrations, and the presence of the Christian Commission for Development Bangladesh (CCDB), a non-governmental organization that assisted with the implementation of this intervention.

Eligibility and Enrollment

We first administered a household drinking water survey to the person responsible for primary drinking water collection in 6746 households in 26 villages (22). Information was collected about: As status (safe, unsafe, untested), well depth, and well installation date.

Of the 26 villages, 20 met our criteria of having at least 40% of wells exceeding the Bangladesh As standard (50 µg/L), and at least 50 individuals who met the study eligibility criteria (Figure 1). Participants had to: 1) be the person in the household responsible for primary drinking water collection; 2) be using an untested well; and 3) be 18 years of age or older. Villagers 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 from which they collected most of their household's drinking water. After confirming the identity and eligibility of participants the interviewer explained the details of the study and obtained informed consent.

Design

This study was a cluster based, randomized controlled trial of 1000 households. Randomization was performed at the village level; participants were clustered within each village. Fifty eligible households were randomly selected based on the household drinking water survey. Each respondent was interviewed at baseline and at follow-up 7-9 months later (Figure 1). In ten villages, a trained community member conducted well WAs testing and provided As education. In the remaining 10 villages, an outside representative, defined as someone living in a different union, performed these tasks. The two groups of villages were geographically separated. Using

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census data from the Bangladesh Bureau of Statistics, villages were matched on literacy rate and land ownership as these are strong indictors of socioeconomic status (23). We also attempted to match villages on the proportion of unsafe wells based on our household drinking water survey. Villages were randomly assigned by the study project coordinator to each intervention group at baseline using the random number generator in SAS 9.2. Study households in each village were randomly selected in the same manner.

Intervention

The 10 "community-testers" were forum workers for CCDB who organize community activities on health and poverty alleviation. The 10 "outside-testers" were selected with the assistance of CCDB. All As testers were required to be at least 18 years of age and literate. The distribution of age, educational level, gender, and religion did not differ significantly between the community and outside testers.

All testers received a one week intensive training on how to measure the As content of wells and effectively disseminate As education. The tester went to each study household at least once to: 1) measure the As concentration of the household's primary drinking water source using an As field testing kit; 2) conduct a structured 40 minute As education session; and 3) provide assistance to participants with unsafe wells to locate a nearby As-safe drinking water source. These tasks were performed in each study village over a period of 3 months.

The As education materials were developed based on current scientific literature regarding the health implications of As exposure, studies assessing the knowledge of As in the population (16,

17, 24, 25), and our As education pilot study. Education sessions focused on key messages regarding health implications of chronic As exposure, and methods to reduce exposure. The sessions were designed to be interactive by asking participants questions about the topics being covered. If a participant's primary drinking water source was found to be unsafe, assistance to locate a nearby As-safe drinking water source was provided. In such cases, participants were asked from which water source they would like to collect their drinking and cooking water. If this water source was found to be As-safe and the well owner agreed, the As tester encouraged the participant to collect all of their drinking and cooking water from this source.

Data Collection

During the baseline and follow-up surveying periods, interviewers visited each study household to: 1) administer a questionnaire to the person responsible for primary drinking water collection; 2) collect a sample of the primary drinking water source; and 3) collect a urine sample from the study respondent.

Both questionnaires obtained information on water usage, socio-demographics characteristics, and knowledge of As. The participant's knowledge of As was obtained via a 20 item quiz administered at the baseline survey before the start of the intervention and at the follow-up survey. Participants were queried on how to identify As contaminated wells, safe uses of As contaminated water, and the health implications of chronic As exposure. One point was given for a correct item, and zero points for an incorrect item. Possible quiz scores ranged between zero and 20.

Arsenic Measurements

Urinary As concentrations collected at baseline and follow-up were used as a biological index of As exposure. Previous studies have found strong correlations between urinary As and drinking WAs concentrations (20, 26, 27). Switching from an unsafe to a safe well can reduce urinary As concentrations to a level that approaches those of individuals who have been consistently relying on safe wells (20). Urine samples were collected from study respondents in 50 ml acid washed tubes during the baseline and follow-up periods. Urine samples were placed in portable coolers, then frozen at -20°C at the local laboratory in Dhaka, Bangladesh, and shipped on dry ice to Columbia University. Total urinary As was measured using a Perkin-Elmer AAnalyst 600 graphite furnace system, and adjusted for urinary creatinine (Cr) concentrations according to published methods (28). Our laboratory is part of a quality control program for total urinary As which is coordinated by the Institut de Santé Publique du Québec (Québec, Canada). During the course of this study, the intraclass correlation coefficient between our laboratory's values and samples calibrated at the Quebec laboratory was 0.99. The average intra-precision and inter-precision for three control urine samples run daily for this period were 2.6%, and 5.7%, respectively.

WAs field testing was conducted using the Hach EZ As Test Kit (Part No. 2822800) which measures As concentrations in water using a colorimetric scale that ranges from 0-500 μg/L. A 40 minute reaction period was used in these studies rather than the manufacturer recommended 20 minutes because a previous study showed that the increased reaction period reduced inconsistencies in the 50-100 μg/L range (22, 29).

WAs measurements conducted using the Hach EZ As test Kit were verified by laboratory analysis at the Geochemistry Research Laboratory at the Lamont Doherty Earth Observatory (LDEO) at Columbia University. The As concentrations were measured using Inductively-Coupled Plasma-Mass Spectrometry (ICP-MS) with a detection limit of 0.1 μg/L (30, 31).

Statistical Methods

The primary hypothesis of this study was that training a community member to perform As testing and provide As education is more effective than sending a trained person from outside the village to conduct these same tasks, conditional on equal competence and similar observed characteristics of the tester.

Based on a previous study conducted in Araihazar, Bangladesh, we assumed that the proportion of well switching would be 0.33 in our outside tester villages and 0.66 in our community-tester villages (14, 21). We specified the type 1 error at 5% and the type 2 error at 20%. Thus, we required 18 villages with 35 households each. To account for at least a 10% loss to follow up, we selected a sample size of 20 villages of 50 households each.

The outcome variables in this study were: 1) questionnaire reported well switching; and 2) change in urinary As concentration. We evaluated the determinants of well switching for study respondents with unsafe wells at baseline. Safe and unsafe were defined according to the Bangladesh WAs standard of 50 μg/L. Chi-square tests and two sample t-tests were used to

compare differences between the community-tester and outside-tester villages for categorical and continuous variables, respectively.

Logistic regression was used to estimate the odds of well switching controlling for both individual and village level covariates. Generalized estimating equations (GEE) were used to account for clustering within villages. We estimated the most parsimonious model by eliminating all non statistically significant variables (p >0.05), except for those *a priori* specified (ie. Type of As Tester) until the lowest quasi likelihood information criterion (QIC) was determined (32). All analyses were performed using SAS, version 9.2 (SAS Institute Inc., Cary, NC, USA).

Ethics Section

The study protocol was approved by the Columbia University Medical Center Institutional Review Board and the Bangladesh Medical Research Council. Informed consent was obtained from all study respondents.

Results

During our baseline survey, 1033 respondents with untested wells, selected from of our household drinking water survey, were screened for eligibility. Of these, 4 (0.4%) were unwilling to participate and 29 (2.8%) were ineligible. At follow-up, 30 (3%) respondents had either permanently moved (29) or died (1). Urine was collected from 953 (95%) respondents at baseline and 930 (96%) respondents at follow-up.

The distribution of age, literacy, religion, baseline quiz score, and land ownership did not differ significantly between the two intervention groups. However, the community tester intervention group had more well ownership, more unsafe wells, and lived further away from an As-safe well; they also had significantly higher urinary As concentrations at baseline (Table 1). The number of times the participant met with the As tester was significantly higher for the community-tester versus outside-tester villages; 48% of participants in the community-tester villages met with the As tester four or more times, compared to 13% in the outside-tester villages.

Overall, 53% of respondents with unsafe wells at baseline switched during the intervention period. Switching was more common in the outside-tester (63%) versus community-tester villages (44%). However, after adjusting for the availability of arsenic safe drinking water sources, the association between the As tester and well switching was not significant (OR=0.77; 95% CI (0.37-1.61)). Follow-up knowledge of As quiz scores were positively related to well switching, although the association did not reach statistical significance (Table 2). The number of times the participants met with an As tester was positively associated with well switching, when the As tester met with the study respondent at least 4 times (OR=1.67; 95% (1.00-2.79)).

Participants who lived in villages with ≥ 60% unsafe wells were significantly less likely to switch in comparison to those who lived in villages with < 60% unsafe wells (OR=0.27; 95% CI (0.14-0.53)). In addition, participants who required more than 5 minutes to walk to an As-safe drinking water source were significantly less likely to switch in comparison to those who lived within 5 minutes of an As-safe drinking water source (OR=0.57; 95% CI [0.33-0.99]). Finally,

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participants who owned their own well were significantly less likely to switch in comparison to those who did not own their own well (OR=0.40; 95% CI (0.22-0.70)).

Among participants with unsafe wells who changed their drinking water source, the most common reported reason for switching was that their baseline well was unsafe for As (92%). The most common reported reasons for *not* switching wells were: 1) long distance to a safe well (57%); 2) family ownership of well (20%); and 3) owner(s) of safe wells near the respondent's home do not want to share (11%). Eight percent of respondents with *safe* wells at baseline switched. The most common reported reason for well switching among these respondents were: 1) did not like the taste of their previous well water (23%); 2) dug a new well (17%); and 3) previous well broke (17%). Similar reasons were given by participants in the two intervention groups.

Overall baseline mean urinary As concentrations were more than double among respondents with unsafe wells (215 μg As /g Cr) as compared to those using safe wells (91 μg As /g Cr). At follow-up, the overall mean urinary As concentrations for those with unsafe wells who switched to safe wells decreased significantly from 194 to 133 μg As/g Cr (Figure 2); the reduction did not differ between intervention groups. UAs was essentially the same for those who used unsafe wells at baseline but did not switch wells (245 vs 234 μg As /g Cr). Finally, there was no appreciable change in urinary As concentrations for safe well users.

Discussion

Millions in Bangladesh continue to drink groundwater containing elevated levels of As (13). Many households lack access to As testing services, preventing them from knowing the As status of their wells and locating As-safe water sources in their villages. Thus, there is an urgent need for effective As education and WAs testing programs in Bangladesh (13-15).

This study is the first randomized trial evaluating the effectiveness of community participation in As mitigation in Bangladesh. We hypothesized that community-testers would be more effective than outside-testers in terms of reducing As exposure because the former would offer additional reinforcement by living within the community. Although our data did not support this hypothesis, the intervention program was very successful in encouraging households to use As-safe drinking water sources. Fifty-three percent of participants with unsafe wells at baseline switched wells at follow-up, mostly because their baseline well was unsafe relative to As.

We observed that the reinforcement provided by the availability of an As tester within the village was positively related to well switching. Through their continued presence, the community-tester provided significantly more reinforcement in the village than the outside-tester as evidenced by the number of contacts between the participants and the testers. The knowledge of As quiz scores were significantly higher for respondents at follow-up, compared to baseline, for both intervention groups (Unpublished).

We observed significant reductions in UAs concentrations for unsafe well users who reported switching wells at follow-up, indicating that our intervention was successful in reducing a biomarker of As exposure. Previous studies in Taiwan indicate that a reduction of As exposure may reduce associated mortality from renal diseases (33, 34), intracerebral hemorrhage (35), and ischemic heart disease (36). A study in Chile found that reduced As intake was associated with decreased numbers of micro-nucleated cells in the bladder (37).

Our findings are consistent with a study conducted in Araihazar, Bangladesh, evaluating an As program implemented for 11,746 participants. That intervention, administered over a two-year period, involved WAs testing and labeling, village level As education, and the targeted installation of deep tubewells with low WAs. At follow-up, 58% of unsafe well users and 17% of safe well users had switched to new drinking water sources. A 46% reduction in UAs was observed for those with unsafe wells who switched to As-safe drinking water sources (20). Our current intervention was conducted over a much shorter duration and did not involve the installation of deep tubewells, yet we observed roughly comparable results.

The unavailability of As-safe drinking water sources in a village was the greatest barrier to well switching. In villages with less than 60% unsafe wells, 72% of respondents with unsafe wells switched, compared to 35% well switching in villages with greater or equal to 60% unsafe wells. This is consistent with Hanchett et al., who found that the unavailability of As-safe water sources was a barrier to well switching in six districts of Bangladesh (15). In our study, the time to a safe water source was also a significant barrier to well switching. Previous studies have indicated that well switching significantly declines if the nearest safe well is located more than 100 meters

away (14, 20, 21). Well ownership was a significant barrier to well switching, likely because well owners are more reluctant to shift from a well in which they invested their own money.

Our study suggests that WAs testing and As education programs would be most effective in areas where <60% of wells are As-contaminated. A recent report of a nationwide survey in Bangladesh indicated that 77% of the population lives in areas with between zero to sixty percent As contamination (38). Therefore our intervention is a viable option for the majority of the population residing in As affected areas of Bangladesh. For the 23% of the population who reside in areas with > 60% As contaminated wells, this intervention will likely need to be combined with the provision of alternative mitigation options such as the installation of deep tubewells, As filters, or rain water harvesting.

A major limitation of our study was the relatively short three month duration of our intervention period. We hypothesized that community-testers would be more effective than outside- testers because of their additional reinforcement. While we did observe that the community-testers provided significantly more reinforcement than the outside testers, this did not appear to increase their effectiveness in reducing As exposure. We attribute this result in part to the significantly higher proportion of unsafe well located in the community-tester villages and in part to the short duration of the study. Nevertheless, the use of the community-testers provides a sustainable approach for As mitigation because of the continued presence of testers in villages over time to provide additional reinforcement and WAs testing services. Further, community testers will likely be less costly because they do not require transportation costs.

Conclusions

In conclusion, the community and outside-testers were found to be equally effective in terms of encouraging households to use arsenic safe drinking water sources. The findings of this study suggest that As education and WAs testing programs could be used as an effective method to reduce As exposure in many As-affected areas of Bangladesh.

Acknowledgements

Contributors

This study was multidisciplinary international collaboration that required significant expertise of scientists with diverse public health, earth sciences, and social science. For this reason there are twelve authors on the paper. Christine Marie George directed the field study, performed the statistical analysis, and wrote the first draft of the manuscript. Joseph Graziano and Alexander van Geen directed the studies and revised the manuscript. Pam Factor-Litvak assisted with the analysis of the data presented in the manuscript and provided substantial comments to several

drafts. All individuals named on the article provided comments to several drafts of the article and approved the final version.
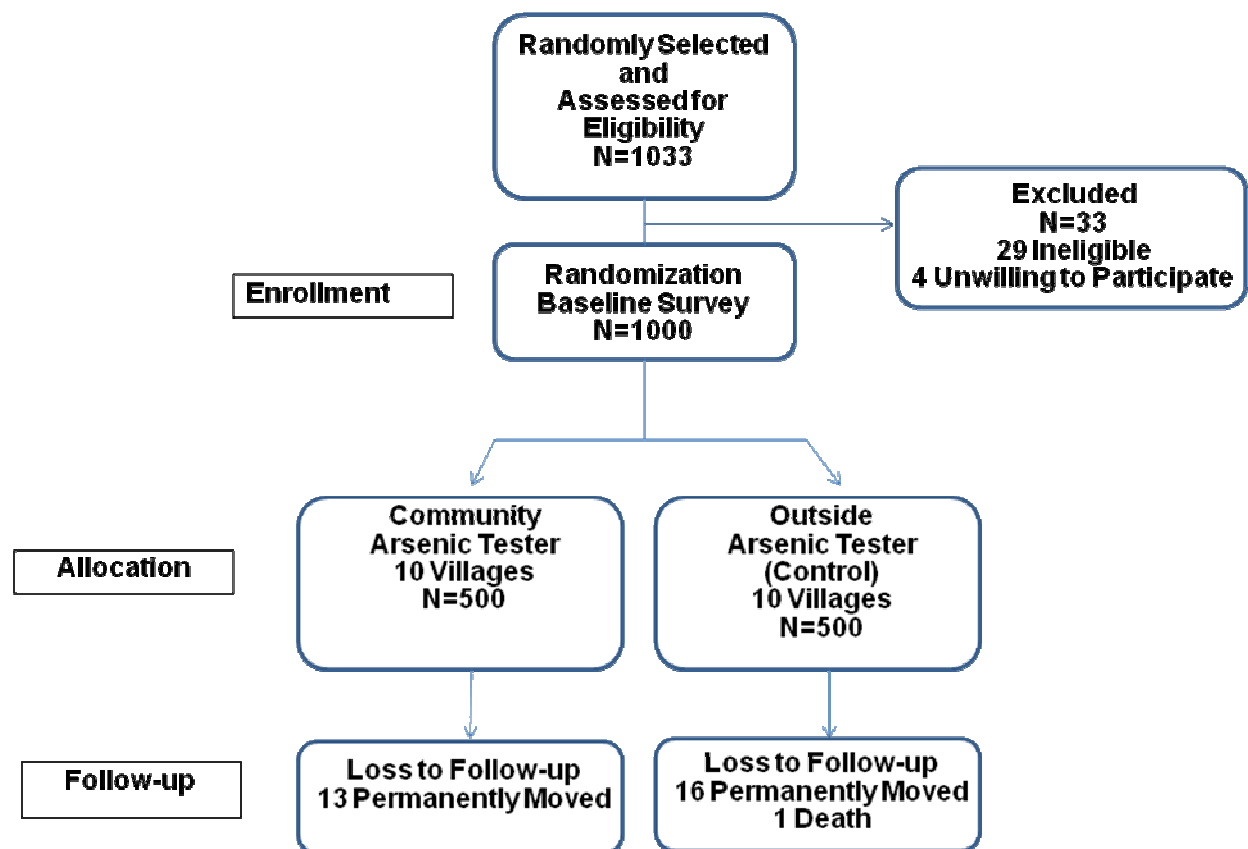
Figure 1. Study Design

Table 1. Baseline and follow-up characteristics by Arsenic Tester Village

Characteristics	Community Tester Villages (N=487)	Outside Tester Villages (N=483)	P-value
Age (yrs) [Mean±SD (Range)]	36.3±11.4 (18-102)	37.8±12.8(18-86)	0.07
Gender (%)			
Female	99.8	100	0.32
Religion (%)			
Muslim	93	95	0.14
Hindu	7	5	
Respondent can Read and Write (%)			
Yes	42	40	0.54
Head of Household Education (%)			
Elementary or Higher	48	45	0.23
Respondent Baseline Knowledge of Arsenic Quiz Score Mean±SD (Range)	8.5±3.0 (0-18)	8.4 ±2.9 (0-17)	0.77
Radio Ownership (%)			
Yes	25	28	0.36
Land Ownership (%)			
No Land Ownership	12	18	
Less than 1 Acre	63	57	0.07
1 to 2 Acres	25	25	
Well Ownership (%)			
Yes	82	75	0.01
Proportion of Unsafe Wells in Respondent's Village (%)			
0-60%	30	68	<.0001
Greater than 60%	70	32	
Minutes to an Arsenic Safe Drinking Water Source for Unsafe well owners (%) (N=587)			
Less than or equal to 5 minutes	68	32	<.0001
Greater than 5 minutes	44	56	
Arsenic Status of Tubewell			
Safe	39	51	0.004
Unsafe	61	49	
Baseline Water Arsenic [µg/L (Mean±SD (Range))]	124±145 (0-500)	117±147 (0-500)	0.66
Baseline Creatinine-adjusted urinary As [µg/g Cr (Mean±SD(Range))]	178±122.0(9-901)	143 ±132(18-1060)	0.0002

*P-values were calculated using a chi-square test for categorical variables and a 2 sample t-test for continuous variables

Table 2. Predictors of well switching among unsafe well users

	Total[1]	% Who Switched[2]	OR for switching (95% CI)[3]
Arsenic Tester			
Outside Arsenic Tester	248	63	1.00
Community Arsenic Tester	295	44	0.77 (0.37-1.61)
Follow-up Knowledge of Arsenic Quiz Score			
Q1 (0-11)	149	50	1.00
Q2 (12-14)	99	43	0.64 (0.32-1.26)
Q3 (15-16)	196	54	1.14 (0.76-1.70)
Q4 (17-20)	99	59	1.27 (0.73-2.21)
Number of Times Met with Arsenic Tester			
1 Time	152	53	1.00
2 Times	138	52	1.18 (0.74-1.87)
3 Times	85	52	1.16 (0.72-1.86)
4 or more times	166	54	1.67 (1.00-2.79)
Proportion of Unsafe Wells in Respondent's Village			
Less than 60%	258	72	1.00
Greater or equal to 60%	285	35	0.27 (0.14-0.53)
Minutes to Safe Drinking Water Source			
Less than or Equal to 5 minutes	282	63	1.00
Greater than 5 minutes	227	43	0.57 (0.33-0.99)
Well Ownership			
No	103	67	1.00
Yes	440	50	0.40 (0.22-0.70)
Baseline Creatinine-adjusted urinary As (μg/g Cr)			
Q1 (0-95)	114	67	1.00
Q2 (96-148)	126	57	0.65 (0.38-1.11)
Q3 (149-270)	153	52	0.79 (0.53-1.17)
Q4 (271-1060)	126	40	0.49 (0.28-0.86)
Radio Ownership			
No	398	54	1.00
Yes	145	50	0.62 (0.42-0.92)

(1) "Total" indicates the number of respondents with each attribute. (2) "% Switching" indicates the percentage of individuals with that attribute that switched wells. (3) OR were adjusted for all variables in the table. Baseline creatinine adjusted urinary arsenic was log transformed. A total of 543 respondents were included in the analysis; participants with unknown information for any of the covariates were excluded.
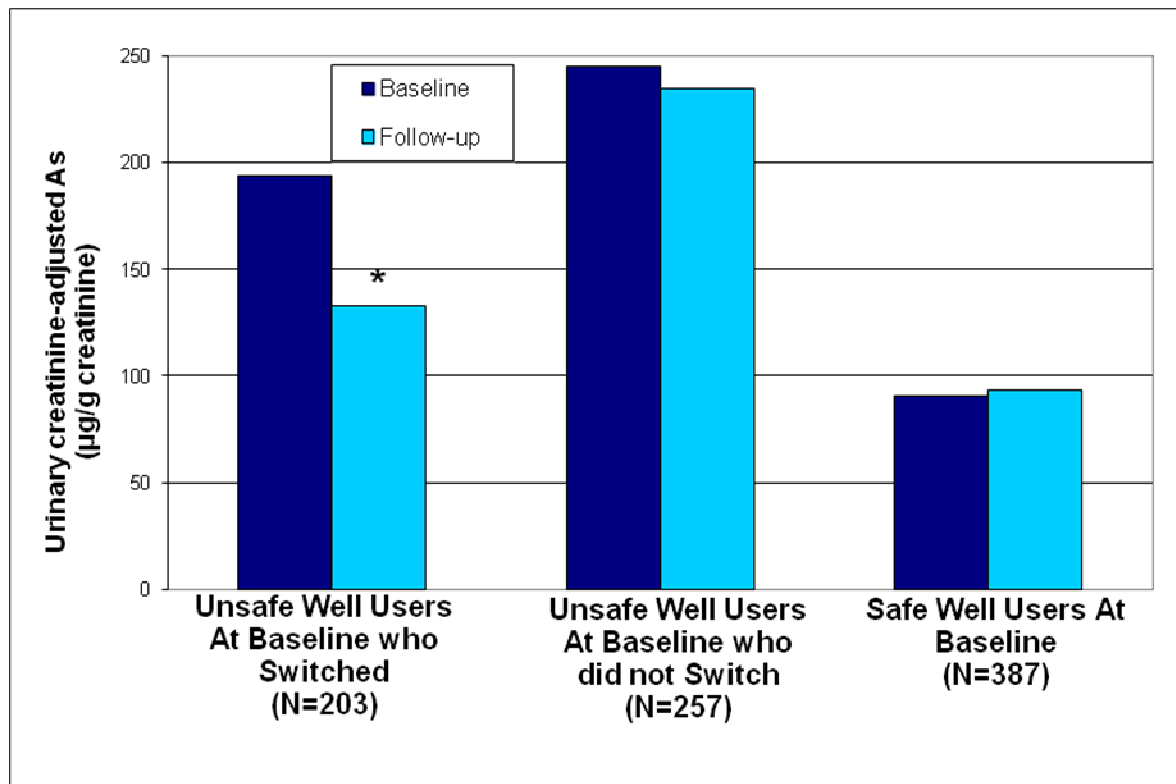
Figure 2. Mean urinary creatinine-adjusted As levels for study respondents *P<.0001 as compared to baseline

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Chapter 8

Approaches to Increase Arsenic Awareness in Bangladesh: An Evaluation of an Arsenic Education Program

Christine Marie George, Pam Factor-Litvak, Khalid Khan, Tariqul Islam, Ashit Singha, Joyce Moon-Howard , Alexander van Geen, Joseph H Graziano

Approaches to Increase Arsenic Awareness in Bangladesh: An Evaluation of an Arsenic Education Program

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Abstract

The objective of this study was to design and evaluate a household level arsenic education and well water arsenic testing intervention to increase arsenic awareness in Bangladesh. We randomly selected 1000 study respondents located in 20 villages in Singair, Bangladesh. The main outcome was the change in knowledge of arsenic from baseline to follow up four to six months after the household received the intervention. This was assessed through a pre- and post-intervention quiz concerning knowledge of arsenic. Respondents were between 18-102 years of age, with an average age of 37 years; 99.9% were female. The knowledge of As quiz scores for study participants were significantly higher at follow-up compared to baseline. The intervention was effective in increasing awareness of the safe uses of arsenic contaminated water and dispelling the misconception that boiling water removes arsenic. At follow-up, nearly all respondents were able to correctly identify the meaning of a red (contaminated) and green (arsenic safe) well relative to arsenic (99%). The educational program also significantly

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increased the proportion of respondents that were able to correctly identify the health implications of arsenic exposure. However, the intervention was not effective in dispelling the misconceptions in the population that arsenicosis is contagious and that illnesses such as cholera, diarrhea, and vomiting could be caused by arsenic. Further research is needed to develop effective communication strategies to dispel these misconceptions. Our study demonstrates that a household-level arsenic educational program can be used to significantly increase arsenic awareness in Bangladesh.

Introduction

In Bangladesh, it has been estimated that half of the 10 million tubewells in the country do not meet the World Health Organization (WHO) guideline for arsenic (As) of 10 µg/L because of naturally occurring arsenic in the groundwater of the Bengal Basin (1). Drinking water containing elevated levels of As has been associated with cancers of the skin, bladder, and lung (2-4), reproductive and developmental effects (5, 6), cardiovascular disease (7, 8), skin lesions (9, 10), reduced intellectual function in children (6, 11, 12)and mortality (13).

The largest As testing program in Bangladesh was the World Bank sponsored Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) conducted between 2001 and 2004 (14). BAMWSP used non-governmental organization (NGO) workers to test and label private tubewells for As in roughly half of the country's 10 million tubewells. Arsenic mitigation in Bangladesh, though significant, has impacted less than half of the affected population (1). The most common As mitigation option in Bangladesh at 29% is well switching, which involves switching from an As unsafe well to an As safe drinking water source. This is followed by the use of deep tubewells by 12% of the originally exposed population. Studies have shown that deep aquifers are generally lower in As. Arsenic mitigation options such as As filters and pond sand filter were utilized by only a very small proportion of the population. The current scientific literature which suggests that the temporal variability of As in tubewell water is low (15-19).

Despite the growing literature on the health implications of As, millions of people in Bangladesh continue to drink well water containing elevated levels of As even though As safe water is often available from other wells located within a short walking distance (100 meters) (20). The majority of the As communication materials developed in Bangladesh by government and non-governmental organizations were created in early 2000. Since that time there has been a substantial increase in the scientific knowledge of the health implications associated with chronic As exposure. There is an urgent need to update the health communication materials on arsenic.

Furthermore, there have been no attempts to develop arsenic educational materials based a theoretical framework. Our educational materials were designed based on constructs from the Health Belief Model . This model is used to predict why people will take action to prevent a potential health outcome. This model assumes that if individuals view themselves as susceptible to a health outcome (perceived susceptibility), believe that the consequences of having the health outcome are severe (perceived severity), believe that there is a course of action available to them to reduce susceptibility or severity of the health outcome (self-efficacy), and believe the benefits of this course of action outweigh the barriers, they are likely to take this action to reduce their health risk (21). Our educational materials focused on increasing perceived susceptibility and severity to As related illnesses, and increasing self-efficacy to As related illnesses through As testing and well labeling to identify arsenic safe wells located in a respondent's village.

In 2010, an As education and water As testing intervention was developed for rural villages in Singair, Bangladesh. The objective was to increase awareness of the health implications of As and methods to reduce As exposure. A causal pathway was proposed in which the provision of

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household level As awareness education and water As testing services would increase awareness about As in these communities, and thereby encourage households to utilize As safe drinking water sources, leading to a reduction in urinary As. A decline in As exposure, resulting from our intervention, has been described elsewhere (22). The purpose of this manuscript is to describe the As education intervention itself and evaluate the effectiveness of the intervention in improving As awareness as assessed through a pre- and post-intervention knowledge of As quiz.

Methods

Setting

This study was conducted in a rural setting in Singair Upazila, located in the Manikganj district of Bangladesh. This site was chosen because of the wide range of water As concentrations present, and the presence of the Christian Commission for Development Bangladesh (CCDB), a non-governmental organization (NGO) that provided assistance with the intervention.

Study Design

This study was an evaluation of an As educational program disseminated to 1000 randomly selected households located in 20 villages in Singair, Bangladesh. Fifty eligible households, with one respondent each, were randomly selected from each village to participate in this study.

Eligibility Criteria

A household drinking water survey was administered to 6746 households in 26 villages as a screening tool for both village and household selection. The household drinking water survey

obtained the following information about each household's primary drinking water source: As status (safe, unsafe, untested), well depth, and well installation date.

To be eligible villages had to have at least 40% of wells exceeding the Bangladesh As standard, and at least 50 individuals who met the participant eligibility criteria. For individuals to be eligible for enrollment in the study they had to: 1) be the person in the household responsible for primary drinking water collection; 2) be using an untested 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; and 3) did not have a primary well from which they collected most of their household's drinking water.

Intervention

This As educational program provided household-level As education. The information provided to study households was based on the current scientific literature concerning the health implications of As, previous studies assessing As awareness in the population (23-26), and the results of our own three month As educational pilot study.

Twenty village workers, selected by CCDB based on the recommendation of local village leaders, participated in this study. The arsenic testers resided in the upazlia where they worked and their demographics were similar to the villages they worked in. These "As testers" were required to be at least 18 years of age and literate, assessed by a reading and writing test. Arsenic testers received a five day intensive training on how to effectively disseminate As education and measure the As content of wells using a field testing kit.

The As testers went to each study household at least once to conduct a structured 40 minute As educational session, measure the As concentration of the household's primary well, and assist participants with unsafe wells to locate a nearby As-safe drinking water source. The As testers conducted these tasks in each study village for three months.

The As educational awareness session focused on disseminating 10 key As educational messages on the health implications of arsenic and recommendations to reduce arsenic exposure. These key messages are presented in the supplementary materials. Anyone present in the community at the time the educational session was conducted was invited to attend. Participants were asked questions about the messages discussed to identify potential gaps in understanding that needed to be further reinforced. Audiences were also encouraged to ask questions. At the end of each session, the audience was asked to pledge their commitment to drink arsenic safe water and share arsenic safe wells with others.

Evaluation of the intervention

The arsenic educational program was evaluated using a 20 item pre- and post-intervention quiz to assess the respondents' knowledge of arsenic. Each study respondent was interviewed at baseline and at follow-up, 4-6 months after receiving the intervention. In the baseline and follow-up questionnaires, information was obtained on sources of knowledge about arsenic and socio-demographic characteristics.

In the quiz, respondents were asked questions on the following: sources of As contaminated water, the As standard in Bangladesh, the meaning of a red or green marked tubewell, and the safe uses of As contaminated water. 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. One point was given for a correct item, and zero points for an incorrect item. Possible quiz scores ranged between zero and 20.

Statistical Methods

The primary hypothesis was that the provision of As education and water As testing would significantly increase knowledge of As in the study population at follow-up in comparison to baseline. The outcome variable was change in knowledge of As quiz score between baseline and follow-up. McNemar tests were used to compare differences between the baseline and follow-up knowledge of As quiz scores. The determinants of baseline and follow-up knowledge of As were evaluated.

Arsenics quiz scores were treated as a continuous variable. Linear regression was used to compare differences in quiz scores between groups of different attributes. Generalized estimating equations (GEE) were used to account for within village differences (27). All analyses were performed using SAS, version 9.2 (SAS Institute Inc., Cary, NC, USA).

Ethics Section

The study protocol was approved by the Columbia University Medical Center Institutional Review Board and the Bangladesh Medical Research Council. Informed consent was obtained from all study respondents.

Results

Overall, 1000 participants received the As educational intervention. The final response rate at follow-up was 97%. A total of 30 respondents had either permanently moved (29) or died (1). The demographic characteristics of the study population are summarized in Table 1. The mean age of the study respondents was 37 years (Range 18-102), and 99.9% were female. The majority of the study population could not read or write (60%). The average village size was 244 households; the population of each village ranged from 104 to 751 households. The baseline primary drinking water source of 46% of respondents was found to be unsafe relative to As. Household As education sessions had between 2 – 31 participants (mean=8). On average, sessions were composed of 5 women, 2 men, and 3 children.

Baseline Sources of Arsenic Information

Participants were asked at baseline to report the media sources from which they obtained the most information about As. Five hundred eighty five participants (60%) reported obtaining the most information from television. The second most common source reported was radio. Twenty

nine % reported receiving no information from media sources, and 4% reported receiving information from leaflets, posters, and books.

Pre- and post-intervention arsenic quiz score comparison

The knowledge of As quiz scores for study participants were significantly higher at follow-up compared to baseline. The average quiz scores at baseline and follow-up were 8.5 and 14.1 (out of 20), respectively. The determinants of baseline and follow-up knowledge of As were examined using GEE models (Table 2). Both at baseline and at follow up, the ability to read and write ($p < .0001$) and the level of education of the head of household ($p < .01$) were positively associated with quiz scores, while age was negatively associated with scores ($p < .02$).

Respondents who received As information from television and/or radio prior to the baseline survey were found to have a significantly higher scores at baseline when compared to those who received no information from media sources (p for ANOVA <0.05). Finally, those who received information from television and radio scored significantly higher than those who received only information from the radio or television alone (p for ANOVA <0.05). Follow-up knowledge of As quiz score was significantly greater in those with unsafe wells who had more wells tested to locate an As safe drinking water source ($p = 0.0002$).

Pre and post intervention quiz item comparison

All the responses to quiz items significantly improved at follow-up compared to baseline. Table 3 summarizes the changes in specific quiz items between baseline and follow-up. The quiz items were divided into the following four sections: Arsenic Standard and Identification of Sources; Health Implications of Arsenic Exposure; Disease Transmission and Removal of Arsenic; and Use of Arsenic Contaminated Water. Regarding the arsenic standard and identification of sources, at follow-up of those who answered incorrectly at baseline 98% and 99% respectively could correctly identify the meaning of a red and green marked tubewell. At follow-up, 61% of those who answered incorrectly at baseline could correctly define the Bangladesh As standard. Of the 20% of respondents who at baseline incorrectly stated the source of arsenic contaminated water, 87% correctly answered this item at follow-up.

Regarding disease transmission and removal of As , 67% of respondents who at baseline incorrectly stated that boiling water could remove arsenic answered correctly at follow-up. However, only 48% of respondents who at baseline incorrectly stated that eating or sleeping with an arsenicosis patient could cause the transmission of the disease answered correctly at follow-up.

Regarding the use of As contaminated water, of the respondents who answered incorrectly at baseline, 100% and 96% respectively correctly stated at follow-up it was *not* okay to use As contaminated water for drinking and cooking. At baseline over 80% of the study population stated incorrectly that it was *not* okay to use arsenic contaminated water for bathing, washing

clothes, and washing animals. The majority of these respondents were able to answer correctly at follow-up. Furthermore, at follow-up it was found that the majority of households using unsafe wells at baseline who switched to alternative drinking water sources continued to use their previous tubewells for washing hands (95%), bathing (59%), and clothes washing (63%).

Regarding the health implications of arsenic exposure, although there was a significant increase at follow-up in the proportion of study respondents that could correctly identify the health implications of As exposure, the majority were still unable to do so. Less than one third of those who answered incorrectly at baseline could correctly state at follow-up that cholera, diarrhea, and vomiting could not be caused by As.

Discussion

This study represents one of only a handful of studies in Bangladesh that provide scientifically rigorous methodology to evaluate the impact an As awareness educational program implemented (28-31). This study provided an opportunity to assess the study population's current awareness of the As problem. The study hypothesis was that the provision of As education and water As testing would significantly increase knowledge of As at follow-up in comparison to baseline.

Arsenic Awareness in the Population

At baseline, nearly 20% of the study population was unaware of the meaning of a red and green tubewell. This was surprising given that this area had received well water As testing of all drinking water sources by the BAMWSP program in 2004. The results of the baseline survey also indicated confusion in the population regarding the health implications of chronic As exposure. The majority incorrectly stated that cholera, diarrhea, and vomiting could be caused by As. This is consistent with previous studies that suggest a lack of understanding of the health implications of As exposure beyond skin lesions (23, 26, 29, 32). At baseline, nearly 70% of participants incorrectly stated boiling could remove As from drinking water, and that eating or sleeping with an arsenicosis patient could cause the transmission of the disease. Similarly, more than a decade ago, Hanchett et al reported that 41% of women surveyed (n=251) thought that arsenicosis was a contagious disease (29). At baseline, the majority of participants was aware that one should not cook or drink with As contaminated water. However, more than 80% of respondents incorrectly stated that water from an As contaminated well should not be used for any purpose. These findings suggest that the current awareness in the population on the health implications of As is low. Furthermore, many households are unaware of the safe uses of As contaminated water, and how to effectively remove As from water.

At baseline, the majority of study households had obtained their knowledge about As from radio, television, family members, and neighbors. This result is consistent with a nationally representative survey conducted by Caldwell in 2000 (24). Arsenic information provided through television and radio was significantly associated with increased As awareness in the study

population at baseline. However, the majority of respondents still had an incomplete understanding of the health implications of As and mitigation strategies. These findings suggest that more effective communication strategies are necessary to effectively disseminate these messages.

Evaluation of the Arsenic Education Program

Overall, the As education program was successful in increasing As awareness. The most important messages for reducing one's as exposure were understood by almost the entire study population, i.e. the meaning of a red and green marked tubewell relative to arsenic (99%), and not to drink or cook with arsenic contaminated water (100% and 96% respectively). The majority of respondents correctly defined the As standard in Bangladesh. The education program was also effective in increasing awareness on most of the safe uses of As contaminated water. Furthermore the majority of households with unsafe wells at baseline who switched to alternative wells continued to use their previous wells for hand washing, bathing, and clothes washing. This is important because using a previously existing, albeit contaminated tubewell for *these* tasks often lessens the time required to collect water, and reduces the burden of sharing a well with another household.

The educational intervention significantly increased the proportion of respondents who were able to correctly identify the health implications of As exposure at follow-up. The majority of respondents who answered incorrectly at baseline correctly stated at follow-up that skin lesions and cancer could occur from arsenic. However, many of the study respondents still incorrectly

reported that illnesses such as cholera, diarrhea, and vomiting could be caused by As. Furthermore, the majority of respondents also incorrectly stated at follow-up that eating or sleeping with an arsenicosis patient could cause the transmission of the disease.

Our findings are consistent with two other educational intervention studies in Bangladesh. A study by BRAC, the largest non-governmental organization in Bangladesh, involved training community members to test tubewells for As and provide As awareness information. One year later the majority of respondents (55%) could not correctly identify the transmission of arsenicosis. Furthermore only 44%, of respondents were able to correctly identify two or more diseases associated with As exposure (28). A second study ,the 18 District Towns Project, conducted an evaluation of an As education and water As testing program . It was found that many people were unaware of the less visible symptoms of As exposure such as cancers and effects on child and maternal health (29). These results indicate that future research is needed to develop effective media communication strategies to dispel these misconceptions , and to address the gaps in knowledge highlighted by this and other studies.

A reduction in As exposure associated with our intervention has been previously reported (22). The two main outcome variables used to assess As exposure were self reported well-switching and change in urinary As concentration from baseline to follow-up. Overall, 53% of respondents with unsafe wells at baseline reported switching to alternative wells at follow-up. The most common reported reasons for not switching wells among unsafe well owners were: 1) long distance to a safe well (57%); 2) family ownership of well (20%); and 3) owner(s) of safe wells near the respondent's home do not want to share (11%). Follow-up knowledge of As quiz scores were positively related to well switching, although not significantly so. The average urinary As

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concentrations for those with unsafe well at baseline who switched to safe wells at follow-up decreased significantly (22). These results demonstrate that this intervention was effective in encouraging the majority of households with unsafe wells to switch to alternative drinking water sources.

The unavailability of As-safe drinking water sources in a village was the greatest barrier to well switching. In villages with < 60% unsafe wells, 72% of respondents with unsafe wells switched, compared to 35% well switching in villages with $\geq$ 60% unsafe wells. Walking time to a safe water source was also a significant barrier to well switching. Previous studies have indicated that well switching significantly declines if the nearest safe well is located > 100 meters away (30, 31, 33). A recent report of a nationwide survey in Bangladesh indicated that 77% of the population lives in areas with between 0-60% As contamination (34). Therefore, our intervention is a viable option for the majority of the population residing in As affected areas of Bangladesh.

A limitation of this study was that there was not a control group. Therefore we are unable to distinguish the impact of the As testing itself and the As education that we provided on the knowledge of As. A second limitation was the relatively short three month duration of our program. We suspect that the impact of the intervention would have been greater if provided over a longer duration.

Designing Intervention Strategies to Motivate Households to Use Arsenic Safe Drinking Water Sources

Future interventions should employ evidence based and theoretical driven approaches to encourage households to utilize available As testing services and As safe drinking water sources.

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In this section I explore the use of constructs from the Health Belief Model, Integrated Model (IM) , Social Cognitive Theory (SCT), and the Extended Parallel Process Model (EPPM) in designing intervention strategies to promote the use of As safe drinking water. Our target behavior is for households to always use As safe water sources for drinking and cooking. The potential health outcomes to be avoided are the many adverse health effects associated with chronic As exposure such as cancers of the skin, kidney, bladder, and lung, reproductive and developmental effects, cardiovascular disease, respiratory effects, neurological effects, and skin lesions. The length of the period for adopting and operationalizing this behavior is for the duration one resides in an As effected area.

Formative Research

A cross-sectional study of these constructs from health behavior theory was conducted by Mosler et al. in Bangladesh. These results indicated that more than two thirds of the 222 respondents surveyed assessed the consequences of arsenicosis to be severe (perceived severity). However, their perceived vulnerability of contracting arsenicosis was low (38.8%) (35). These results suggest that although respondents realize the consequences of arsenicosis are severe, they do not believe they are at risk for contracting this disease.

Despite the fact that nearly all respondents knew how to obtain As safe drinking water, forty percent of the population did not feel confidence in their ability to protect themselves and their families from arsenicosis (self-efficacy). These finding suggests that access to As safe water in

this area is low. Half of the respondents reported that their family members wanted them to collect As free water (injunctive norms) (35).

A multivariable regression model was used to measure which constructs were significant predictors of the use of As safe water. Self-efficacy, belief in one's ability to obtain As safe water, and descriptive norms, whether one's family members were using As safe water, were significant determinants of As safe water use. Perceived barriers to the use of As safe water were also identified these included time to collect As safe water, and social barriers for women travel to collect water (ie. not being able to collect water where many men were present) (35). These are consistent with our own research findings, where we identified that the proportion of unsafe wells in a respondent's village, minutes to an As safe drinking water source, and well ownership were significant barriers to well switching.

These findings indicate that interventions should be developed to (1) increase self-efficacy to obtain As safe drinking water; (2) increase perceived susceptibility to As related illness; and (3) decrease perceived barriers to accessing As safe drinking water sources. The results further indicated that descriptive norms were important in a household's decision to use As safe water sources, therefore interventions should be conducted that encourage the participation of all village members.

Future Intervention Approaches

Based on the evidence from the formative research conducted and our own research findings we decided to apply the following constructs from health behavior theory in our recommended

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intervention approaches: perceived susceptibility, perceived benefits and barriers, self-efficacy, observational learning, and descriptive and injunctive norms.

The EPPM model seems to be a suitable individual level model to use for our intervention design given the results of the formative research which demonstrated that both self-efficacy to obtain As safe water and perceived susceptibility in contracting arseniocosis are low in our target population. Individuals in the population do not perceive a threat from As and therefore likely do not respond to the risk messages provided. Increasing self efficacy to obtain As safe water and increasing the perceived threat of As exposure, according to the EPPM model, would result in a danger control response motivating individuals to take the recommended approach to reduce their As exposure. Therefore, the goal of our intervention strategies will be to increase self efficacy and perceived susceptibility.

Intervention Approaches to Increase Self Efficacy and Perceived Susceptibility

Perceived susceptibility to the health implication of As could be increased through implementing health education at the household and community level using indigenous natural leader such as CHWs. Many individuals only associate As exposure with the development of skin lesions which has a low prevalence in areas of moderate As contamination. By making individuals aware that As can cause many other illnesses such as cancers and developmental effects they will likely feel more susceptible to the effects of chronic As exposure. CHWs could disseminate health communication messages through community level As education sessions, door to door visits to address health concerns on As exposure, school events, and hosting community activities promoting As testing and the use of As safe drinking water sources. Furthermore, CHWs could

also collaborate with schools and local organizations such as women's groups to disseminate their health communication messages.

Perceived barriers to the use of As safe drinking water sources could be addressed through the SCT construct of facilitation. Facilitation is defined as providing resources to make a given health behavior easier to perform (21). For As mitigation this could include: extensive As testing to identify the location of As safe drinking water sources, the installation of deep tubewells in areas where there are few As safe drinking water sources available (ie. >60% As contaminated), or the provision of As removal devices where deep tubewell installation is not possible.

Using SCT we could employ social modeling to increase self efficacy in our study population. Social modeling is defined as showing a person that other individuals like themselves can perform a behavior (21). This could be done through community level meetings with testimonies of women and men who have made the conscious decision to seek As testing and to only use As safe water for drinking and cooking (ie. " I made this decision to seek As testing and use As safe water for my health and the health of my children").

A third construct that could be utilized from SCT to increase self efficacy and perceived susceptibility is observational learning. This construct is defined as learning to perform a new behavior by exposure to media or interpersonal displays (21). In Bangladesh, theater is often used to disseminate health communication messages. Therefore we could employ observational learning by disseminating testimonies and health communication messages through community level theater sessions. This could include entertainment education through role playing of households getting their tubewells tested for As, and collecting water for drinking and cooking from As safe drinking water sources. Furthermore, in the formative research it was found that

descriptive norms were important in a household's decision to use an As safe drinking water source. Therefore activities that involve the entire community such as a community level pledge of one's commitment to use As safe water could be employed, as was done in our own intervention. This also has the added value of encouraging As safe well owners to share their drinking water source with others.

In conclusion, in this section we proposed potential future intervention strategies that could be used to improve access to As testing services, increase perceived susceptibility of As related illnesses, increase self-efficacy to collect As safe water, and reduced perceived barriers to accessing As safe water. We recommend that further formative research be done to investigate the perception of risk and attitudes towards utilizing As testing services and collecting As safe drinking water.

Conclusion

In conclusion, the results of this study suggest that As education coupled with water As testing programs can be used effectively to increase As knowledge in the population. Future research is urgently needed to identify why health messages on As beyond skin lesions are being poorly understood, and to determine the factors that influence the misconception concerning the disease transmission of arsenicosis in the population

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Table 1. Characteristics of Study Population

Characteristics	Frequency	%
Gender (%)		
Female	999	99.9
Male	1	0.1
Religion (%)		
Muslim	913	94
Hindu	57	6
Respondent can Read and Write (%)		
No	584	60
Yes	386	40
Head of Household Education (%)		
No Education	510	54
Level 1-5	226	24
Greater than level 5	217	23
Radio Ownership (%)		
No	713	74
Yes	257	26
Land Ownership (%)		
No Land Ownership	122	15
Less than 1 Acre	475	59
1 to 2 Acres	206	26
Well Ownership (%)		
No	210	22
Yes	760	78
Proportion of Unsafe Wells in Respondent's Village (%)		
0-60%	632	65
Greater than 60%	338	35
Minutes Walking to an Arsenic Safe Drinking Water Source for Unsafe well owners (%) (N=587)		
Less than or equal to 5 minutes	282	55
Greater than 5 minutes	227	45
Arsenic Status of Baseline Tubewell		
Safe	543	56
Unsafe	427	44

Table 2. Determinants of Knowledge of Arsenic Quiz Scores at Baseline and Follow-up

Characteristics	N	Mean	SD	P-values[1]
		Knowledge of Arsenic Quiz Scores		
Baseline Knowledge of Arsenic				
Respondent Read and Write				
No	595	7.7	2.7	<.0001
Yes	406	9.7	2.8	
Head of Household Education				
No Formal Education	526	7.8	2.9	
Level 1-5	233	8.8	2.6	0.0017
Greater than Level 5	224	9.8	2.9	
Age (Years)				
18-27	242	9.5	3.0	
27-36	269	8.7	2.8	<0.0001
36-43	252	8.2	2.7	
44-102	238	7.5	2.9	
Sources of Arsenic Knowledge				
No Radio or Television	312	6.8	2.8	
Radio	42	8.3	2.3	
Television	277	8.9	2.7	<.0001
Radio and Television	370	9.6	2.6	
Follow-up Knowledge of Arsenic[2]				
Age (Years)				
18-27	223	15.0	3.1	
27-36	263	14.8	3.3	0.0191
36-43	248	14.0	3.2	
44-102	236	12.8	3.5	
Head of Household Educational Level				
No Formal Education	510	13.4	3.4	
Level 1-5	226	14.9	3.3	0.0113
Greater than 5	217	15.1	3.1	
Respondent Reads and Writes				
Yes	584	13.3	3.4	<.0001
No	386	15.5	3.0	
Wells Tested to Locate an Nearby Arsenic Safe Well (Baseline Unsafe Well Users)				
1 Well Tested	176	14.2	3.4	
2 Wells Tested	129	14.3	3.5	0.0002
3 or More Wells Tested	192	15.1	2.9	

(1) p-values are from GEE models which were adjusted for all variables in each section of the table (2) GEE model was adjusted for baseline knowledge of arsenic quiz score

Table 3. **Quiz Item Baseline and Follow-up Comparison**

Arsenic Educational Messages	% Incorrect Baseline			% Correct Baseline		
	N (%)	Follow-up % Incorrect	Follow-up % Correct	N (%)	Follow-up % Incorrect	Follow-up % Correct
Arsenic Standard and Identification of Sources						
Arsenic contamination is mainly found in tubewell water*	198 (20%)	13	87	772 (80%)	6	94
Bangladesh arsenic standard is 50 ppb*	950 (98%)	39	61	20 (2%)	50	50
Green marked tubewell is safe for arsenic*	193 (20%)	1	99	777 (80%)	<1	99
Red marked tubewell is unsafe for arsenic*	162 (17%)	2	98	808 (83%)	<1	99
Health Implications of Arsenic Exposure						
Cholera does *not* occur from arsenic exposure*	815 (84%)	78	22	155 (16%)	57	43
Diarrhea does *not* occur from arsenic exposure*	840 (87%)	75	25	130 (13%)	56	44
Vomiting does *not* occur from arsenic exposure*	838 (86%)	77	23	132 (14%)	61	39
Cancer can occur from arsenic exposure*	348 (36%)	39	61	622 (64%)	25	75
Skin Lesion can occur from arsenic exposure*	137 (14%)	9	91	833 (86%)	4	96
Disease Transmission and Removal of Arsenic						
Eating or sleeping with an arsenicosis patient does not cause the transmission of disease*	666 (69%)	52	48	304 (31%)	28	72
Arsenic cannot be removed by boiling water*	685 (71%)	33	67	285 (29%)	15	85
Use of Arsenic Contaminated Water						
It is *not* okay to drink arsenic contaminated water*	45 (5%)	0	100	925 (95%)	0	100
It is *not* okay to cook with arsenic contaminated water*	97 (10%)	4	96	873 (90%)	4	96
It is okay to wash hands with arsenic contaminated water*	798 (82%)	51	49	172 (18%)	29	71
It is okay to bathe with arsenic contaminated water*	835 (86%)	49	51	135 (14%)	25	75
It is okay to wash clothes with arsenic contaminated water*	790 (81%)	44	56	180 (19%)	23	77
It is okay to wash animals with arsenic contaminated water*	821 (85%)	46	54	149 (15%)	27	73

(1) There were a total of 970 respondents included in this table (2) p-values were calculated using a McNemar test for categorical variables and a paired t-test for continuous variables *Indicates significantly difference from baseline at .01 or lower

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Chapter 9

Evaluation of an Arsenic Test Kit for Rapid Well Screening in Bangladesh

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Evaluation of an Arsenic Test Kit for Rapid Well Screening in Bangladesh

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Abstract

The number of villagers in Bangladesh exposed to high levels of arsenic (As) by drinking groundwater is increasing in areas where new and untested wells have been installed since a blanket testing campaign was conducted almost a decade ago. The performance of the Arsenic Econo-Quick (EQ) kit was evaluated by blindly testing 124 wells (a subset of 65 of which twice) in Bangladesh and comparing the outcome with laboratory measurements by inductively-coupled mass spectrometry. By excluding visual readings of exactly 10 µg/L and above, the EQ kit did not underestimate the As content for any of the wells relative to the WHO guideline and, by excluding readings of exactly 50 µg/L and above, did so for only 2 out of a total of 189 readings relative to the Bangladesh standard. However, this modified interpretation of the reference scale provided with the kit leads to overestimating the As content of well water for about 12% of the readings relative to the WHO guideline (actual As concentrations 4-9 µg/L) and 9% of the readings relative to the Bangladesh standard (17-49 µg/L). Given its short reaction time of 10

min and its modest cost compared to existing kits, the EQ kit is on balance the preferred choice for renewed wide-scale testing of tubewells in Bangladesh.

1. INTRODUCTION

Concerns about elevated arsenic (As) concentrations in Bangladesh groundwater were first raised in the mid-1990s. As of 2009, an estimated 22 million people in 2009 were still drinking water that does not meet the Bangladesh Arsenic (As) standard of 50 µg/L and 5.6 million were exposed to As above 200 µg/L (1). Exposure to elevated levels of inorganic As is associated with cancers of the skin, bladder, and lung (2-4), developmental effects in children (5, 6), cardiovascular disease (7, 8), and skin lesions (9, 10).

The most common action taken by villagers in Bangladesh to reduce As exposure over the past decade has been to switch to a neighboring well that is low in As. This was made possible by a combination of (a) blanket testing of close to 5 million wells with field kits throughout the affected portions of the country between 2000 to 2005 and (b) the spatially heterogeneous distribution of As in groundwater (11). In Araihazar upazilla (subdistrict), it has been shown that 90% of the residents lived within 100 meter of a low-As wells even though close to 50% of the wells were high in As within the same region (12). After switching induced by As testing in the field, the installation of an estimated 100,000 deep (>500 ft) community wells by non-governmental organizations (NGOs) and the Bangladesh government, tapping older low-As aquifers, has been the next most effective form of mitigation (11, 13). The impact of other forms of household-level mitigation such as As removal from groundwater, rainwater collection, promotion of dugwells, and pond sand filters has been much more limited and, in some cases, paired with microbial contamination (14).

In many regions of Bangladesh it has been more than six years since the previous nationwide water As testingwas conducted under the Bangladesh Arsenic Mitigation and Water Supply Program (BAMWSP) (16). However, the pace of new well installations, many of which are carried out to replace malfunctioning wells, has not abated markedly and the proportion of untested wells has therefore been growing (17). A survey conducted in Araihazar in 2005 has shown that more recently installed wells were no more likely to be low in As than older wells (11). A larger nationwide survey in 2007 has shown that the As status of one-third of wells was unknown in areas of Bangladesh where blanket surveys had previously been conducted (15, 16). Many Bangladesh villagers may have therefore unwittingly become exposed to elevated levels of As by drinking water from untested tubewells. There is a renewed and urgent need to redirect households from high- to low-As wells by testing millions of household wells.

The growing proportion of untested wells in Bangladesh, and the exposure of villagers in Bangladesh to As resulting from continuing tubewell installations, motivated this evaluation of a field test kit, the Arsenic Econo-Quick (EQ) introduced by Industrial Test Systems Inc. (http://www.sensafe.com/). The new kit appeared promising because the prescribed reaction time of 10 min was short and the cost was low ($0.17/test for a large-quantity order by UNICEF in Bangladesh; $0.60/test list price in the US) . The same manufacturer previously introduced the Arsenic Quick kit (Part No. 481396) which was more costly but has already been shown to perform well when evaluated at 136 water sources in western Nevada (17). The underlying chemistry of both kits (and several more sensitive ones tailored to sample volumes of up to 500 mL) produced by Industrial Test Systems, along with two other kits that are here evaluated in parallel because they have already been widely deployed in Bangladesh, is the classic 19th

century Gutzeit method (18). The method relies on the conversion of As(III) and As(V) to arsine gas (AsH_3), followed by arsine detection on a paper strip impregnated with mercuric bromide. Variations of this method used by different kits may seem minor but they can have significant implications for their effectiveness in the field (21).

2. METHODS

2.1. Recruitment and Sampling Village workers were recruited by the Christian Commission for Development Bangladesh (CCDB), a local non-governmental organization, to sample tubewells and deploy the EQ and Hach EZ Arsenic (EZ) test kits. Their educational level ranged from completion of secondary school certificate to higher secondary school certificate (Grades 8-13). A total of 124 untested tubewells were randomly selected for testing (twice for a subset of 65 wells) with field kits in villages of Singair and Shibalaya upazilas, within the Manikhanj district of Bangladesh. When tubewells were tested in the field more than once, village workers were blinded to the previous results. Each well was tagged with a numbered metal placard for identification. Groundwater from all wells was collected in 20 mL scintillation vials for laboratory analysis. A subset of 63 wells was also tested using the EZ kit using a reaction time that was extended from 20 to 40 min, following the demonstration that this modification reduced the likelihood of classifying a well as meeting the Bangladesh standard for As in drinking water of 50 µg/L when it did not (22).

2.2. Field Measurements The first reagent of the EQ kit (Part no. 481298), added with a scoop to a 50 mL water sample, is tartaric acid amended with small amounts of iron and nickel sulfate, presumably to accelerate the reaction. A second reagent, potassium peroxymonosulfate, provided

with the EQ kit to oxidize hydrogen sulfide that could potentially suppress the signal was not used. Only hydrogen sulfide at $>10^{-6}$ M levels appears to interfere with the measurement and such levels can be ruled out by smell for the majority of groundwater pumped from tubewells in Bangladesh. Skipping this step reduces the total reaction time by 2 min. Unlike the EZ kit, the EQ kit includes a temporary cap for shaking the sample and ensuring that the tartaric acid dissolves completely before the next reagent, Zn powder, is added with another scoop. The Zn powder provided with the EQ kit is finer than that used in the EZ kit and remains in suspension after shaking. This may be another reason why the reaction time is considerably shorter for the EQ kit. After the Zn powder has been added and the reaction vessel has been shaken a second time, it is covered with another cap that supports a suspended strip impregnated with mercuric bromide and left to react for 10 min. Like an older Merck kit whose performance was unsatisfactory (19), the mercuric bromide strip provided with the EQ kit relies on Brownian motion to capture passively AsH_3 released to the headspace. The strip of the EQ kit is more exposed to the water sample than the strip of the EZ kit. Therefore the vessel should not be moved until after the reaction period is completed and the vessel has been opened to read the strip. The reference chart provided with the EQ kit displays the yellow to brown range of colors expected for As concentrations of 0, 10, 25, 50, 100, 200, 300, 500, and 1000 µg/L. Holes punched in the chart through which the test strips are read ensure that the often slightly darker edges of the strip are not considered. Village workers were instructed not to interpolate their readings between categories but instead to select the As concentration on the chart that matched the color of the test strip most closely. In the few cases that the village workers did interpolate, the reading was converted to the closest reference concentration on the strip and, in the even fewer cases when the reported value was exactly midway between two reference concentrations,

the reading was converted to the higher value.

The Hach EZ kit (Part No. 2822800) kit was used for the majority of the tubewells tested under BAMWSP (~$0.60/test). The EZ kit relies on sulfamic acid crystals to acidify a 50 mL sample. A procedure intended to eliminate interference by hydrogen sulfide, in this case cotton impregnated with Pb acetate, was also eliminated. Village workers participating in this study were instructed to use a 40 min reaction time and reported the results as 0, 10, 25, 50, 100, 250, or 500 µg/L As. Here too, readings were converted to the nearest reference concentration on the strip when interpolated concentrations were reported.

2.3. Laboratory Measurements Groundwater samples collected in 20 mL scintillation vials were acidified to 1% with high-purity Optima HCl at Lamont-Doherty Earth Observatory at least 48 hours before analysis. This has been shown to ensure re-dissolution of any As that could have adsorbed to precipitated Fe oxides (24). Water samples were then diluted 1:10 in a solution spiked with [73]Ge for internal drift correction and analyzed for As by high-resolution inductively-coupled plasma mass spectrometry (HR ICP-MS), which eliminates the isobaric interference with ArCl. Further details are provided elsewhere (20, 21). The detection limit of the method for As is typically <0.2 µg/L, estimated here by multiplying the As concentration corresponding to the blank by a factor of 3. The long-term reproducibility determined from consistency standards included with each run averaged 4% (1-sigma) in the 40-500 µg/L range. This is comparable to the previously reported error estimate for single measurements by HR ICP-MS of 4 µg/L augmented by 2% of the measured concentration (22).

Although it is designed to be deployed in the field, the Wagtech Arsenator (Part No. WAG-WE10500) digital As test kit was used in the laboratory, as is typically the case in Bangladesh. A subset of 92 well water samples tested with at least one of two other kits were collected in plastic 60 mL bottles. Before analysis, the samples were acidified with 0.3-0.5 ml of 1:1 HCl to ensure redissolution of any precipitated Fe oxides. The Arsenator relies on additions of sulfamic acid and sodium borohydride to a 50 mL sample to generate AsH_3 over a 20 min reaction time, but additional steps in the procedure increase total processing time to approximately 40 min (21). In addition to its significantly higher purchase price ($1800 for the reading unit and $1/test for reagents), the Arsenator differs from the EQ and EZ kit in that the color of a test strip is measured with a digital reader instead of being estimated visually. If quantification above an As concentration of 100 µg/L is desired using the Arsenator, a sample is diluted and reanalyzed.

3. RESULTS AND DISCUSSION

3.1. ICP-MS Data. Concentrations of As measured in groundwater from 124 tubewells by HR ICP-MS ranged from 0.1 to 452 µg/L, with a mean of 60 µg/L. The set of samples was roughly balanced between 51 (41%) tubewells containing 0.1-10 µg/L As (and meeting the WHO guideline for drinking water), 38 (31%) tubewells with 10-50 µg/L As that do not meet the WHO guideline but still meet the Bangladesh standard, and 34 (28%) tubewells with >50 µg/L As. In this analysis, ICP-MS data are used as the reference to compare the performance of the field kits.

3.2. Performance of the EQ Kit. Readings in the field using the EQ kit were identical for 47 out of 65 wells that were analyzed twice (see Supporting Information). For only one out of the 18 remaining duplicates did the readings differ by more than one interval in the provided reference

chart. Following a standard interpretation of the readings (only As concentrations above the respective thresholds are considered unsafe), the EQ kit underestimated the As content of groundwater relative to the WHO guideline and the Bangladesh standard, respectively, for 17 and 6 out of a total 189 samples (Table 1). On the other hand, if the users of the surveyed wells had been advised not to drink from wells whose testing with the EQ kit resulted in a reading of 10 µg/L and above, not a single well would have been incorrectly identified as safe relative to the WHO guideline. Similarly, only 2 tests would have been misclassified as indicating a safe well if villagers had been advised not to drink from a well based on a reading of 50 µg/L and above using the EQ kit. These two outliers were duplicate measurements for a well containing 193 µg/L, for which both the EZ and Arsenator also indicated a low As content. This suggests that the sample bottle collected from this well for ICP-MS analysis was most likely mislabeled in the field.

Using a conservative interpretation defining wells which are 10 µg/L and higher as unsafe according to the EQ kit essentially eliminates the risk of underestimating the As content of well water but comes at a price by increasing the proportion of overestimates (Table 1). Following the modified interpretation, a total of 21 out of 189 tests containing 4-9 µg/L (ICP-MS) that produced a reading of 10 µg/L or higher would incorrectly identified wells as not meeting the WHO guideline. Similarly, if villagers had been advised not to drink from a well based on a reading of 50 µg/L and above using the EQ kit, 18 out of 189 tests for wells containing 17-49 µg/L As would have been misclassified as unsafe.

3.3 Performance of the EZ Kit. Only 15 readings using the EZ kit fall within the 10-50 µg/L range, compared with 67 in the same range for the EQ kit. Results from the EZ kit and a 40 min reaction time are therefore interpreted according to the standard definition of the WHO guideline and the Bangladesh standard. Relative to 10 µg/L and 50 µg/L, the EZ kit underestimated the As content of only 2 wells and 1 well, respectively, out of a total of 63 that were tested (Table 1). The number of wells for which the As content was overestimated relative to either threshold was 1 and 2, respectively.

3.4 Comparison with Laboratory Measurements. A different way to evaluate the performance of the EQ and EZ kits is to compare concentrations inferred from the visual readings across the entire range of ICP-MS measurements. Although such a comparison is informative, it is less relevant to public health and policy than a binary classification. For this comparison, the boundary between each range of As concentrations was set mid-way between each of the readings illustrated on the two kit's reference charts. The rationale is that the actual As concentration is as likely to be slightly below or as slightly above the reported reading. In the case of the EQ kit, the resulting 8 categories are 0-5, 5-17.5, 17.5-37.5, 37.5-75, 75-150, 150-250, 250-350, and $\geq$500 ug/L. Even when considering these relatively wide ranges and 2-sigma error estimates for the ICP-MS measurements, the EQ kit consistently overestimates the As content of well water above 100 ug/L by about a factor two (Fig. 1a). For the EZ kit, the first 4 categories are the same as for the EQ kit and the next 3 are 75-175, 175-375 and $\geq$500 µg/L. Unlike the EQ kit, discrepancies between EZ kit readings and ICP-MS measurements are not systematically distributed relative to the line corresponding to an exact match (Fig. 1b).

3.5 Performance of the Arsenator. Correspondence between the Arsenator and ICP-MS measurements is improved relative to either of the kits used in the field (Fig. 1c), including for As concentrations in the 0-80 μg/L range (Fig. 1d). The 4 clear outliers, two of which stand out based on EQ and EZ kit readings as well, likely indicate mislabeling in the field, and possibly exchanged labels. The Arsenator, however, was no better than the EZ kit with respect to classify the status of wells relative to the 10 and 50 μg/L thresholds (Table 1). Compared to the modified interpretation of readings with the EQ kit, the Arsenator actually underestimates the As content of well water for a larger proportion of samples relative to the WHO guideline and the Bangladesh standard.

3.6 Practical Implications. Past debates over the usefulness of field kits for testing the As content of tubewell water in Bangladesh and other affected countries have been fraught in part with the notion that it is important to be able to distinguish concentrations around the Bangladesh standard of 50 μg/L. There is essentially no known threshold below which As exposure has no deleterious health effects and, without evidence to the contrary, the impact should be assumed to be proportional to dose.

Correct classification relative to either the 10 μg/L or the 50 μg/L threshold is important because the outcome of field testing has been shown to be the dominant factor determining household behavior (17, 26-27). Our results show that from this perspective, the Arsenator is no better than either the EQ or the EZ kit with respect to underestimating As concentrations relative to either the WHO guideline or the Bangladesh standard, provided that readings of exactly 10 or 50 μg/L are treated as an unsafe outcome in the case of the EQ kit. At the same time, comparison of

results obtained with the Arsenator on a continuous scale confirm that variants of the Gutzeit method are remarkably insensitive to the significant difference in sample matrix across wells. The comparison also shows that the Arsenator can provide a relatively inexpensive form of quality control for field kit measurements.

Relying on the EQ (but not the EZ kit) does increase the chance relative to the Arsenator that a well whose As content is below either threshold will be considered unsafe. This will be a serious shortcoming only in those villages where the proportion of unsafe wells is particularly high because it reduces the opportunity for switching among private wells (12, 17). On balance, considering the reaction time, relative cost, ease of handling, and reliability, widespread use of the EQ kit is clearly preferable. Our results show that this conclusion is independent of whether an ICP-MS threshold of 10 or 50 µg/L is used (22, 23).

3.7 Significance. The Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) sponsored by the World Bank, UNICEF, and other organizations between 2001 and 2004 was the largest of its kind. A significant proportion of these tubewells were probably incorrectly classified as safe relative to the Bangladesh standard of 50 µg/L because of the manufacturer's recommended reaction time of 20 min. It is more important to consider, however, that for many villages it has been more than six years since this national testing campaign has ended. In 2007 already, the majority of wells in a large sample of villages were untested because of continued well installation. A survey of 6746 households in Singair upazilla conducted in 2010 indicated that more than 80% of the wells installed over the past six years remain untested (24). The same survey documented that less than 13% of households using untested wells knew where an As

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safe drinking water source was located near their home. This is consistent with a 2009 national survey conducted by UNICEF and the Bangladesh Bureau of Statistics that found that 44% of tubewells in the country were untested (25). These results underline the urgent need for expanding the availability of well testing, preferably based on the EQ kit, at the village level.

The Ministry of Local Government and Rural Development Cooperatives of Bangladesh, in collaboration with UNICEF and several other developmental agencies, recently piloted a fee-based well-testing program for As through the local government in 8 upazillas of Bangladesh. In an evaluation of the program conducted in Meherpur and Sadar upazilla, it was found that a majority of households were switching to drinking water sources identified by fee-based testing to be safe with respect to As (26). The advantage of fee-based testing is that it provides a financial incentive for the tester to seek out untested wells. UNICEF is planning an expansion of a fee-based testing program at the national scale. Another massive blanket testing campaign that is free of charge would likely again reduce As exposure, but would probably also delay the viability of commercial or subsidized testing for several years. As in the case of the choice of a threshold for distinguishing safe and unsafe wells, the pros and cons of testing-for-a-fee vs. free blanket testing need to be carefully weighed.

a)
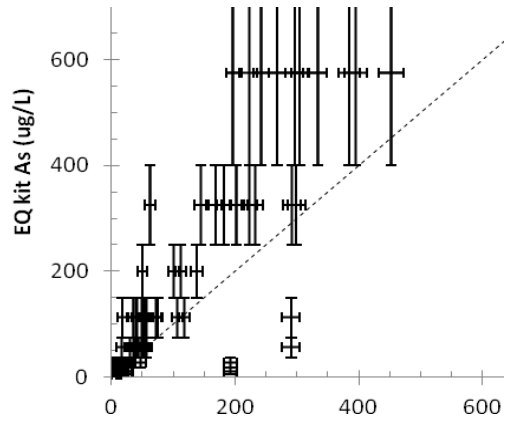
b)
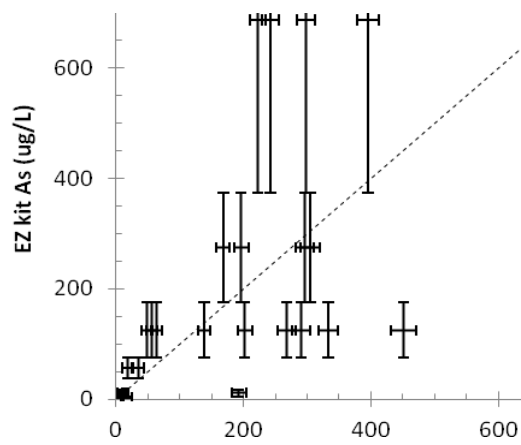
c)
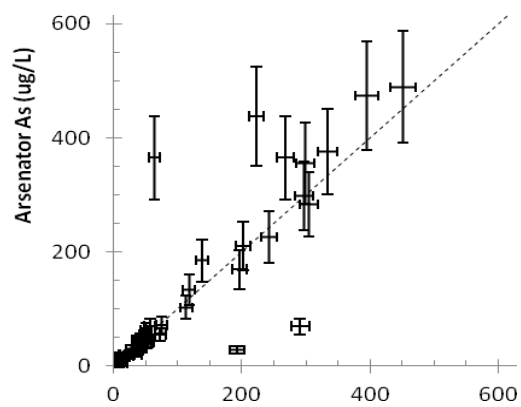
d)
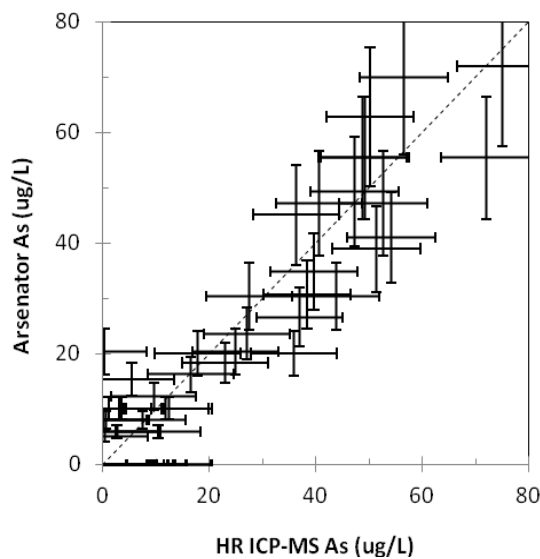
Figure 1. Comparison of As concentrations in water samples measured by inductively-coupled plasma mass spectrometry (ICP-MS) compared with the outcome of field and laboratory testing with three different kits. One tubewell with an EQ reading of 1000 µg/L and an actual concentration of 395 µg/L is excluded from (a) for clarity. The data in (d) are an expanded version of the same data shown in (c). Horizontal bars indicate the estimated 2-sigma errors for HR ICP-MS measurements (22). Vertical error bars in (a) and (b) indicate the full range of As concentrations ranges for the EQ and the EZ kit listed in the text, respectively. Vertical errors bars in (c) and (d) correspond to an estimated error of ±10% of the reported Arsenator readings. The one-to-one relationship indicating a perfect match is shown as a dotted line.

Table 1 Comparison of well status relative to the WHO guideline of 10 µg/L and Bangladesh standard for As in drinking water of 50 µg/L assigned by the three kits. For the EQ kit, the first row is based on assigning an unsafe status to test results of 10 or 50 µg/L *and* above, respectively. The next three rows indicate the performance of all three kits that were tested based on assigning an unsafe status to a well based on readings *above* 10 and 50 µg/L only.

		Relative to ≤10 µg/L guideline		Relative to ≤50 µg/L standard	
		kit		kit	
	n	underestimates	overestimates	underestimates	overestimates
Modified interpretation					
EQ	189	0 (0%)	21 (11%)	2 (1%)	18 (9%)
Standard scale					
EQ	189	17 (9%)	1 (0.5%)	6 (3%)	7 (4%)
EZ (40 min)	63	2 (3%)	1 (2%)	1 (2%)	2 (3%)
Arsenator	92	5 (5%)	3 (3%)	4 (4%)	2 (2%)

Chapter 9 References

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Chapter 10: Summary, Conclusions, and Future Interventions

10.1 Objectives

The overall goal of this dissertation was to evaluate community and individual level intervention strategies that could be used for successful As mitigation in Bangladesh. Specifically the aims were to: 1) develop and implement a training program for village workers on how to effectively disseminate information on the health implications associated with chronic As exposure and to measure the As content of tubewells using field As test kits; 2) evaluate the impact of having someone in a village disseminate As education and perform As testing in terms of reducing As exposure in comparison to sending a trained a person from outside the village using a cluster based design; 3) prospectively evaluate the effects of the As education program on As awareness among study households; 4) evaluate the effectiveness of the Hach EZ and Econo-Quick (EQ) field As testing kits to accurately measure the WAs concentrations of tubewells. This chapter will summarize the research findings from these studies, identify study strengths and limitations, discuss the public health relevance, and recommend future interventions.

10.2 Summary of Results

In Chapter 6, I described the conduct of a household drinking water survey of 6649 households and the results of our arsenic tester intervention in Singair, Bangladesh. The objectives of the survey were to determine: 1) whether households were installing deeper wells over time; 2) how the proportion of untested wells was changing over time; and 3) how the As status of newly installed wells was changing over time. We observed that the depth at which wells are being installed has not substantially changed over the past 10 years. The majority of wells within the

study area were found to be untested relative to As with the proportion of untested wells dramatically increasing over time. In a series of simulations we found that testing all of these untested wells within the study area would more than double the amount of households that lived within fifty meters of an As safe drinking water source. These results demonstrated the urgent need for As testing in the study area. We did observe however that for those wells that had been tested for As, the proportion of unsafe wells appeared to be decreasing over time. In a subset of households, we had village workers use the Hach EZ As kit for a forty minute reaction period and evaluated the results in comparison to laboratory measurements using ICP-MS. We found that the Hach EZ kit, used for a forty minute reaction period, was able to accurately measure the As concentrations of the majority of wells tested in comparison to ICP-MS measurements relative to the Bangladesh Standard and the WHO Guideline for As. Furthermore, the results of this study demonstrated that developing local capacity to conduct As testing services can provide an effective method to screen tubewells for As in Bangladesh.

In Chapter 7, I evaluated a clustered based randomized controlled trial of the impact (in terms of reducing As exposure) of training someone in a village to perform As testing and disseminate As education in comparison to sending a trained person from the outside. Overall, we observed that the majority of study respondents using unsafe wells reported switching after receiving this form of intervention. However, we did not observe a significant difference between the community and outside As testers villages in terms of self reported well switching among unsafe well users. We found that meeting with an As tester four or more times was positively associated with well switching. Furthermore, we observed that the overall mean UAs concentrations for those unsafe well users who switched to safe wells after receiving the intervention significantly decreased from baseline to follow-up. This result demonstrated that the intervention was effective at

decreasing a biomarker of As exposure. We also identified that the proportion of unsafe wells in a study respondents village, minutes to a safe drinking water source, and well ownership were significant barriers to well switching for our study population.

In Chapter 8, I prospectively evaluated the As education program we designed and implemented to determine if the intervention was effective in increasing As awareness within our study population. At baseline I found that the majority of the study population was unaware of the safe uses of As contaminated water, the As standard in Bangladesh, and the health implications of chronic As exposure. I observed a significant increase in the knowledge of As quiz scores for respondents at follow-up compared to baseline. These results demonstrated that the intervention was effective in increasing overall As awareness in the study population. The ability to read and write, head of household educational level, and age were significant determinants of baseline and follow-up knowledge of As. The As education program was effective in increasing awareness in the study population on the safe uses of As contaminated water, and dispelled misconceptions that boiling water removes As. Nearly all study respondents at follow-up were able to correctly identify the meaning of green and red marked tubewells. However, our analyses showed that the intervention was not effective in dispelling the misconceptions that arsenicosis is contagious and that illnesses such as cholera, diarrhea, and vomiting could be caused by As.

In Chapter 9, I evaluated the effectiveness of the EQ kit, a new field WAs testing kit, in comparison to ICP-MS laboratory measurements. This new kit was also compared to the Hach EZ and Wagtech Arsenator field test kits which are the most commonly used As test kits in Bangladesh. Arsenic concentrations were measured in 123 water sources in Singair and Shibalya upazilas of Bangladesh. The EQ kit performed well relative to both the WHO and Bangladesh

Standard for As. The kit did not underestimate the As content of any tubewell tested relative to the WHO guideline and only one well relative to the Bangladesh standard for As in groundwater. Furthermore, the performance of the EQ kit was comparable to that of the Hach EZ kit and the Wagtech Arsenator kit. The EQ kit has the advantage of a substantially shorter reaction time of only 10 minutes in comparison to the 40 minutes suggested for the Hach EZ and Wagtech Arsenator kits. Our study findings suggest that the EQ kit can be used for rapid screening of wells for As in Bangladesh.

10.3 Study Strengths

In this dissertation project, I have included four manuscripts that collectively evaluated community and household level As mitigation strategies that could be used to effectively test well water for As and reduce As exposure.

This study is the first randomized controlled trial (RCT) evaluating community participation in As mitigation efforts in Bangladesh. Furthermore, we used UAs as a biomarker of As exposure. This allowed us to assess the effectiveness of the intervention in reducing a biomarker of As that could confer a potential health benefit (1-5). Through this dissertation project I developed and implemented a training program on how to disseminate household level As education and conduct WAs testing. The results of the RCT trial demonstrated that the program was successful in encouraging the majority of household using unsafe wells to switch to alternative drinking water sources.

The evaluation of our educational intervention represents one of only a handful of studies in Bangladesh that provide scientifically rigorous methodology to prospectively evaluate the impact

of an As awareness education program. It has been nearly a decade since the last such evaluation was conducted. This study also provided an opportunity to assess the study population's current As awareness. Furthermore, our analyses of the intervention demonstrated the As education program was successful in significantly increasing knowledge of As in the study population.

The household drinking water survey we developed can be used to rapidly conduct village wide surveillance to identify households utilizing unsafe, safe, and untested wells. Our household drinking water survey had the benefit of a large size enabling us to examine potential trends between the year of well installation and well depth and the proportion of untested and unsafe wells in our study area.

Through this dissertation project we also evaluated the effectiveness of two field As testing kits that could be used for a nationwide As testing program. Furthermore, we observed that local capacity could be effectively used to measure the As content of untested tubewells, and presents a potential sustainable option for As testing in Bangladesh

10.4 Study Limitations

A limitation of the study we conducted was the lack of a true control group. The outside tester provided the same intervention as the community tester. This was done so that we could evaluate the effectiveness of the community versus outside tester themselves and not the type of intervention they were providing. However, because of this we were unable to evaluate the impact of the As testing alone in increasing well switching and knowledge of As in the study population. Furthermore, As testing in Bangladesh typically involves a person from outside the village providing As testing services then leaving without the provision of As education.

Therefore an ideal control group would have been one that had an outside person only conducting As testing.

A second limitation of the study was the relatively short three month duration of the intervention period. The hypothesis behind the study was that the community As tester would be more effective than an outside As tester because of the reinforcement they could provide through their continued presence in the village over time providing WAs testing and disseminating As education. However, both types of As testers worked in their respective study villages for the same amount of time. Therefore we were unable to evaluate if the community As tester is more effective over a longer period of time. Future studies should evaluate the effectiveness of the community tester for a longer duration (eg. 1 year) to determine if their continued presence in the village over time increases well switching.

A third limitation of our study was the focus on only untested well users. It is possible that households who *already* know their wells are unsafe relative to As would have a different well switching behavior. Future research should evaluate if our selected intervention approach is effective in encouraging unsafe well users that *already* know the As status of their well to seek As safe drinking water sources.

A fourth limitation of the study was the problem we encountered with the attempt to match with respect to the availability of As safe drinking water sources between the community and outside tester villages. Despite our attempts to match based on the proportion of unsafe wells at baseline using the household drinking water survey, we discovered that there was a significantly higher proportion of unsafe wells in the community tester villages compared to our outside testers in villages. In fact, all three barriers to well switching (well ownership, proportion of unsafe wells

in a respondent's village, minutes to a safe drinking water source) identified were significantly higher in the community tester villages compared to the outside tester villages. We speculate that the difference in the proportion of unsafe wells between the intervention arms is due to the high proportion of untested wells in the study area. When our team tested these untested wells there were more unsafe wells in the community versus the outside tester villages. There is little that can be done to prevent this from happening in future studies. Two potential strategies include collecting a drinking water sample of every household's well in the village prior to the start of the study and testing it for As, or having a larger sample size to reduce the likelihood of differences between the intervention arms. To account for the impact of well ownership on well switching, intervention villages could be matched at baseline based on the proportion of well owners.

Furthermore BAs would have been a preferred biomarker of As exposure for this dissertation project because of concerns of potential biases introduced with using creatinine to adjust urinary As for hydration status; however given budgetary constraints this was not possible.

10.5 Public Health Relevance

We demonstrated through this study that training As testers to disseminate As education and provide WAs testing can effectively encourage households to utilize As safe drinking water sources. Furthermore, in areas where there are between zero and sixty percent As contaminated wells the intervention was highly effective, encouraging seventy two percent of households using unsafe wells to switch. A recent report by the Bangladeshi government and UNICEF of a nationwide survey in Bangladesh indicated that seventy seven percent of the population lives in areas with between zero and sixty percent As contamination (6). Therefore our intervention is a

viable option for the majority of the population residing in As affected areas of Bangladesh.

For the twenty three percent of areas with greater than sixty percent As contamination, we recommend that the intervention be combined with the provision of As safe drinking water sources. This could be done through the installation of deep tubewells, and technological As mitigation options such as As removal devices when the provision of deep tubwells is not possible.

Our findings indicate that household level As education is effective in significantly increasing overall As awareness in the population. Therefore our As education program presents a viable option for increasing As awareness in Bangladesh. However, we found that the intervention was not effective in dispelling the misconceptions in the population that arsenicosis is contagious and that illnesses such as cholera, diarrhea, and vomiting could be caused by As. Therefore further research is needed to develop effective communication strategies to dispel these misconceptions.

Our household drinking water survey indicated the majority of tubewells in our study area are untested for As. These findings demonstrate the urgent need for As testing, and are consistent with a national survey conducted by the Bangladesh Bureau of Statistics and UNICEF in 2009 which found that forty four percent of tubewells in the country were untested for As (7). Our stimulations demonstrated that testing all of these untested wells would increase nearly 2.5 fold the amount of households that lived with fifty meters of an As safe drinking water source.

Our evaluation of the Hach EZ and EQ kits identified that both could be used for effective As testing in Bangladesh. Furthermore, the Econo Quick had the advantage of a 10 minute reaction period which substantially reduces the time required for As testing compared to the 40 minute

reaction used by the Hach EZ kit for our main intervention study. Furthermore, utilizing local capacity to provide these services allows for testing of newly installed wells over time.

10.6 Future Interventions

The most effective and sustainable plan for As mitigation in Bangladesh will likely be an evidence based, theory driven, multi-level intervention approach which targets the individual, community, and institutional levels.

Target Population

For As mitigation in Bangladesh, there are two key target populations. There are those using untested wells that need to utilize As testing services to determine the As status of their well, and there are those who have already accessed As testing services and know that their current drinking water source has an unsafe As concentration. The interventions that will be used to motivate these populations to use As safe drinking water sources will likely need to be different. Untested well users first require access to As testing services and the motivation to utilize these services. This requires infrastructure at the community, institutional (ie. NGO), or government level (ie. union or national level) to provide access to As testing services. It is unlikely that households will be able to access As testing services without this support. Once these untested well users access these As testing services they will then need to be motivated to switch to alternative drinking water sources. Unsafe well users who already know the As status of their well for a period of time may behave differently then households who have untested wells. This is because these households have made a conscious decision to continue to using their contaminated drinking water source *after* receiving As testing.

A third target population is safe well owners, since these individuals will likely be asked to share their water source by those currently utilizing unsafe wells. For this reason, these individuals need to be motivated to share their drinking water source with others. This could be done through interventions that include community pledges that encourage safe well owners to share.

Improving Access to Arsenic Testing Services

The results of this dissertation demonstrate the urgent need for access to As testing. Fee-based As testing provides a sustainable option for these services because the fees collected can be used to purchase more As test kits over time. A "willingness to pay" survey item included in our baseline questionnaire indicated that the majority of households were willing to pay 70 cents for their As test. This is more than three times the actual cost of the EQ kit used for our fee-based As testing program. Therefore, the additional fee collected could also be used to pay the overhead cost associated with implementing the As testing program.

There are several different approaches that could be taken to provide As testing services in Bangladesh. Arsenic testing could be provided at the household level through a village worker (door to door), at the community level through a local business (ie. pharmacy-based As testing services), or at the union or upazlia level through a government As testing center. All of these options have the potential to be combined with a health communication program to encourage households with unsafe wells to use As safe water sources for drinking and cooking.

Door to door As testing would be more likely to yield total village coverage than the other mentioned approaches because households would not have to travel to access As testing services. However, this intervention approach is also the most costly and time intensive because it requires

hiring a person to travel to every house in a village and (ideally) reach out to households over time to test newly installed wells. If a CHW or NGO worker incorporated this task in their existing duties it could cut down cost substantially. Working with existing organizations would allow for greater accountability of those providing the As testing, and would make refresher trainings over time easier to organize.

A community testing center at a central location in the village would allow for a place in each village where households could go to seek As testing on demand; however, this is also costly because one person must be hired to conduct this task in every village. One way to address this problem would be to have pharmacy-based As testing, allowing households to travel to a local pharmacy and obtain As testing services. Households already rely on pharmacists to obtain information about their health. Therefore pharmacies could also be used as a resource to provide information on the health implications of As and to motivate households to get their tubewells tested for As and use As safe drinking water sources. Alternatively, this task could be performed by a local shopkeeper who is present in almost all villages of Bangladesh selling foods and household products. The shopkeepers could receive a training certification to provide As testing services in their shops. However, a potential difficulty of both of these approaches would be ensuring the quality of the As testing services provided over time. There would need to be refresher trainings for pharmacist and shopkeepers over time; this may be logistically difficult.

A government As testing center at the union or upazlia level would have the advantage of keeping program cost low. One person could provide As testing services for all of the villages residing in a union or upazlia. The drawback to this approach would be the distance households would have to travel to access these services. This would likely result in lower coverage than that

observed with the door to door or community level As testing services. However, incorporating As testing into the services provided by the DPHE office at the local government level could provide a sustainable approach to improve access to As testing services. These programs would need to be implemented by mandating changes at the policy level. Ideally this service would also be combined with other health communication campaigns by DPHE officials.

10.7 Final Conclusions

Through this dissertation, we have demonstrated that As education and WAs testing programs can be used as an effective method to reduce As exposure and increase As awareness in many As affected areas of Bangladesh. Furthermore, our findings indicated that many households are using tubewells that are untested for As thus demonstrating the urgent need for access to WAs testing services in Bangladesh. Successful As mitigation efforts need to include involvement at the institutional, community, and individual level. This could include the involvement of schools, community organizations, pharmacies, and local government. In areas that are highly As contaminated, government policies need to be put in place that mandate the installation of deep tubewells. Finally, any comprehensive public health program implemented needs to be sustainable and not require extensive donor funding.

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Appendix 1

Screening Questionnaire

Screening Questionnaire
HOUSEHOLD MUST HAVE AN UNTESTED WELL

Barcode: Subject ID
(incorporate union and
village name in ID)

Interview Initial: _____ Interview Date: _____/_____/_____ (dd/mm/yyyy)

1. Name of the Individual:_____ **(Please have the person bring their ID Card)**
(Person in Household Responsible for Primary Drinking Water Collection)

2. Village Name:_____

3. Union Name:_____

4. Date of Birth (dd/mm/yyyy): _____/_____/_____ **- 99 = Don't Know** Age:_____ **- 99 = Don't Know**

5. Gender: 1 = Male   2 = Female

(CHECK THE BOX NEXT TO QUESTIONS WHERE AN INDIVIDUAL DOES NOT MEET STUDY ELIGIBILTY CRITERIA)

6	Are you the person responsible for fetching most of your household's drinking water? **(IF "NO" NOT ELIGIBLE FOR STUDY. MUST FIND PERSON RESONBILE FOR PRIMARY DRINKING WATER COLLECTION IN THE HOUSEHOLD)**	0 = No **INDIVIDUAL NOT ELIGIBLE FOR STUDY** 1 = Yes	☐
7	Are you 18 years or older? **(IF "NO" NOT ELIGIBLE FOR STUDY. MUST BE AT LEAST 18 YEARS OF AGE)**	0 = No **INDIVIDUAL NOT ELIGIBLE FOR STUDY** 1 = Yes	☐
8	Does your household have one main drinking water source?**(IF "NO" NOT ELIGIBLE FOR STUDY)**	0 = No **INDIVIDUAL NOT ELIGIBLE FOR STUDY** 1 = Yes	☐
9	Do you have an arsenic filter or use water from an arsenic treatment plant? **(IF "YES" NOT ELIGIBLE FOR STUDY)**	0 = No 1 = Yes **INDIVIDUAL NOT ELIGIBLE FOR STUDY** If Yes Describe:… ……………………………………	☐
10	Has your current drinking water source been tested for arsenic? **(IF "YES" NOT ELIGIBLE FOR STUDY)**	0 = No 1 = Yes **INDIVIDUAL NOT ELIGIBLE FOR STUDY** -99 = Do not know **INDIVIDUAL NOT ELIGIBLE FOR STUDY**	☐
11	Do you know the arsenic status of your drinking water source? **(IF "YES" NOT ELIGIBLE FOR STUDY)**	0 = No 1 = Yes **INDIVIDUAL NOT ELIGIBLE FOR STUDY**	☐
12	Has your well been painted one of the following colors? **(IF "GREEN OR RED" NOT ELIGIBLE FOR TRIAL)**	0 = Green **INDIVIDUAL NOT ELIGIBLE FOR STUDY** 1 = Red **INDIVIDUAL NOT ELIGIBLE FOR STUDY** 2 = Well was not painted -99 = Do not know -88 = Refuse to answer	☐
13	How many years of school have you completed? **(Select the highest level of education the study participant completed):**	0 = No formal education (0) 1 = Primary: 1, 2, 3, 4, 5 2 = SSC: 6, 7, 8, 9, 10 3 = HSC: 11, 12 4 = Bachelor: 13, 14, 15 5 = Master's: 16 -88 = Refuse to answer	**For Interviewer** 1. Is this person eligible to participate in the study? (NO CHECKED BOXES) 0 = No 1 = Yes 2. (PLEASE ANSWER THIS AFTER ADMINSTERING THE CONSENT FORM) If this person is eligible are they willing to participate in this study? 0 = No 1 = Yes (If Yes Please SKIP 3 and Continue to Baseline Questionnaire) 3. What was the reason they were not willing to participate in the study? 1 = Busy with other tasks 2 = Not interested in study 3 = No reason given 4 = Other/ Please Describe:_____
14	How many acres of land does your household own?	___Decimal (100 Decimal = 1 Acre) 0 = No land ownership 1 = <1 2 = 1 to <2 3 = 2 to <3 4 = 3 to <4 5 = 4 or more -99 = Do not know -88 = Refuse to answer	

Appendix 2

Household Drinking Water Survey

Singair Well Survey

Interviewer Initial :_____Date(Day-Month-Year)_____

Respondent Name:_____

Spouse Name:(Male Head of Household)_____

Well Owner Name:_____

Bari Name:(If applicable)_____

Village Name:_____

Union Name:____ _____

(Well Surveyed should be the Household's PRIMARY DRINKING WATER SOURCE)

Latitude N

Longitude E

(GPS of Household)

1) Has your well been tested for arsenic?**(IF NO OR DON'T KNOW TO SKIP 7)**

   0=No   1=Yes   -99=Don't know

2) Was the result of your arsenic test given to you? **(IF NO OR DON'T KNOW SKIP TO 6)**

   0=No   1=Yes   -99=Don't know

3) What is the arsenic status of this well?

   0=Unsafe   1=Safe   -99=Don't know

4) Has your well been paint or tagged? **(Choose all that apply)**

   A. Red   0=No   1=Yes   -99=Don't know
   B. Green   0=No   1=Yes   -99=Don't know
   C. ID Tag   0=No   1=Yes ID Tag #_____   -99= Don't know

   D. Other_____

5) Is the arsenic status of the household's well visibly indicated?**(Interviewer observes if well is painted or tagged)**

   0=No   1=Yes   -99=Don't know

6) Who tested your well? (Choose all that apply)

   A. Government   0=No   1=Yes   -99=Don't know
   B. BRAC   0=No   1=Yes   -99=Don't know

   C. Other_____

7) When was the well installed?

   1=_____years ago   -99= Don't know

8) What is the well depth?

   1=_____feet   -99= Don't know

9) Are you currently involved in arsenic intervention or trial?

   0=No   1=Yes

   If "Yes" Explain_____

Appendix 3

Baseline Questionnaire

Barcode: Subject ID
(incorporate union and
village name in ID)

Subject ID_____

UNTESTED WELLS ONLY
Community Participation to Effectively Lower Arsenic Exposure in Bangladesh
(Baseline Questionnaire)

Please Write Clearly In English in Upper Case Letters For Numbers and Responses

Interviewer Name:…………………………………………….

Interview Date: ……………………..(day/month/year)   Interview Time……………(hour: minute)

Name of the Participant:…………………………………………. (From ID Card)
(Person in Household Responsible for Primary Drinking Water Collection)

Religion: 1=Muslim   2=Hindu   3=Christian   4=Buddhist   5=Other

Cell Phone Number:…………………………………………………………………………….
(Preferred Participant but Spouse is acceptable)

Spouse Name:……………………………………………………………………….

Name of Head of Household:……………………………………………………………

Father of Head of Household :……………………………………………………………………..

Village Name:…………………………………………………………………….

Union Name……………………………………………………………………………...

Para Name:………………………………………………………………………………

Bari Name…………………………………………………………………………………….

Primary TW ID ☐☐☐☐☐ **(Primary Drinking Water Source)**

Decimal Degrees

Tube well

Latitude N ☐☐☐☐☐☐☐☐☐☐☐   *(GPS of Tubewell)*
Longitude E ☐☐☐☐☐☐☐☐☐☐☐

Household
Latitude N ☐☐☐☐☐☐☐☐☐☐☐   *(GPS of Household)*
Longitude E ☐☐☐☐☐☐☐☐☐☐☐

Please Write Clearly In English in Upper Case Letters For Numbers and Responses

How deep is the well your using? | Feet -99=Dont Know

How many years ago was this well installed? | Years   Month | -99=Don't Know

How many people regularly drink from | this well?
-99=Don't Know

How many years has your household been drinking from this well? -
-99=Don't Know | Years   Month

How many people are currently living in your household ?
99=Don't Know   (including servants)

How many children under age 15 live in this household?

Section A

Socioeconomic status (Please circle the correct answer):

1) What is the level of education of the head of household? (Select the highest educational level completed by the head of household at the time of interview):SKIP QUESTION IF THE STUDY PARTICIPANT IS THE HEAD OF HOUSEHOLD).
    0= No formal education 0
    1= Primary 1 ,2 ,3 ,4 ,5
    2= Secondary School 6, 7, 8, 9, 10
    3= Higher Secondary 11,12
    4= Bachelor 13, 14, 15
    5= Master's: 16
    6=Doctoral Degree
    7=There is no head of household
    -99=Do not know
    -88=Refuse to Answer

2) What is the roof of your house made of? (Only Circle One)(House used for sleeping)
    1. Concrete
    2. Tin
    3. Hay
    4. Leaves
    -99=Do not know
    -88=Refuse to Answer

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3) What are the walls of your house made of? (Only Circle One)(House used for sleeping)
   1=Concrete
   2= Mud
   3= Tin
   4= Biomass
   5= Hay
   -99=Do not know
   -88=Refuse to Answer

4) What is the floor of your house made of? (Only Circle One) (House used for sleeping)
   1. Concrete
   2. Half-concrete
   3. Mud
   -99=Do not know
   -88=Refuse to Answer

5) Do you have a TV at home?
   0=No
   1=Yes
   -88=Refuse to Answer

6) Do you have a radio at home?
   0 = No
   1 = Yes
   -88=Refuse to Answer

7) What is the major source (profession) of household income at the time of the interview? (CHOOSE ONLY ONE) (Most of the year which work is use to be done)
   1 = Farmer(own their own land)
   2 = Agricultural Worker (works on someone else's land)
   3 = Daily labor
   4 = Factory worker
   5 = Rickshaw Puller
   6 = Grocery
   7 = Office job
   8=Carpenter
   9=Business man
   10= Foreign Income (Income from a family member living aboard)
   11= No income
   12 = Others (mention the profession) ....
   -99=Do not know
   -88=Refuse to Answer

8) Can you read and write? (Enough to read and write a few sentences in Bangla)
    0=No
    1=Yes
    -88=Refuse to answer

9) Can someone in your household read and write? (Enough to read and write a few sentences in Bangla)

    0=No
    1=Yes
    -88=Refuse to answer

10) Do you have electricity? (including Solar Panel)
    0=No
    1=Yes
    -88=Refuse to answer

Section B: Quiz

The questions and responses will be read to the study participant. The interviewer should circle the number corresponding to the subject's answer. Tell other individuals present during the quiz to not assist the respondent. Remind respondents that it is okay if they don't know an answer. However do not suggest that a respondent answer "I don't know" to any particular study question.

Knowledge

1. Where is arsenic contaminated water mainly found?
    1= Pond water
    2= River water
    3= Tube well water
    4= Dug well
    5= Canal
    6= Rainwater
    7=None of these
    -99= Do not know
    -88=Refuse to Answer

2. What is the Bangladesh standard to define safe level of arsenic in drinking water?
    1= Less than 100
    2= Less than 70
    3= Less than 50
    4= Less than 10
    -99= Do not know
    -88=Refuse to Answer

3. If there are 4 tubewells of water which contain arsenic of 300, 200, 100, 70 which is the safest to drink?
    - 1= 300
    - 2= 200
    - 3= 100
    - 4= 70
    - -99= Do not know
    - -88=Refuse to Answer

4. Should you drink water that has an arsenic level of 30?
    - 0=No
    - 1=Yes
    - -99=Do not know
    - -88=Refuse to answer

5. Should you drink water that has an arsenic level of 70?
    - 0=No
    - 1=Yes
    - -99=Do not know
    - -88=Refuse to answer

6. Is it safe to drink from a green color tubewell?
    - 0= No
    - 1=Yes
    - -99= Do not know
    - -88=Refuse to Answer

7. Is it safe to drink from a red color tubewell?
    - 0=No
    - 1=Yes
    - -99= Do not know
    - -88=Refuse to Answer

8. I am going to read a list of medical conditions. Please tell me if arsenic exposure can cause these conditions.

> 1=Cholera
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer

> 2=Cancer
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer

> 3=Diarrhea
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer

> 4=Vomiting
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer

> 5=Skin Lesions
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer

9. Can eating or sleeping with an arsenicosis patient cause the transmission of this disease?

> 0=No
> 1=Yes
> -99=Do not know
> -88=Refuse to Answer

10. Can arsenic be removed by boiling water?

> 0=No
> 1=Yes
> -99=Do not know
> -88=Refuse to Answer

11. I am going to read a list of common tasks we do each day. For each task tell me whether or not it is okay to use arsenic contaminated water.

        1=Drinking
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer

        2=Cooking
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer

        3=Washing hands
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer

        4=Bathing
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer

        5=Washing clothes
            0= No
            1=Yes
            -99= Do not know
            -88=Refuse to Answer

        6=Washing animals
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer

Section C

Please only read questions to the study participant. Please circle the number corresponding to the subject's answer. Only circle on reponse

1) Are you a CCDB forum member household?
        0=No (IF "NO" SKIP TO 3)
        1=Yes
        -99=Don't Know(IF "DON'T KNOW" SKIP TO 3)

2) How many times per month do you speak with your CCDB forum worker?
        0= (<1)
        1=1
        2=2
        3=3
        4=4
        5=5
        6=6
        7=>7
        8=I do not have a CCDB forum worker
        9=I do not go to a CCDB forum worker
        10=I am a CCDB forum worker
        -99=Do not know
        -88=Refuse to Answer

Water Collection

3)) What is your household's primary source of drinking water?(CHOOSE ONLY ONE)
        1= Private tubewell
        2= Government tubewell
        3= Community NGO Well   Name of NGO:………………………………….
        4= Dugwell
        5= Pond water
        6= River water
        7= Rainwater
        8= Other:……………………………………………
        -99=Do not know
        -88=Refuse to Answer

4) Who decides where the household obtains its drinking water the majority of the time?(CHOOSE ONLY ONE)
        1= I decide
        2= My husband
        3= My wife
        4= Landlord/keeper
        5= Other family member
        6= Other:
        -99=Do not know
        -88=Refuse to Answer

5) What is your relation to the owner of the tubewell?
  1= My household owns this well
  2= Neighbor
  3= Family Member, same bari
  4= Relative, different bari
  5= Landlord or lender or shopkeeper or employer
  6= I use a government tubewell
  7= Other:
  -99=Do not know
  -88=Refuse to Answer

6) Do any of these problems cause difficulty fetching when drinking water?

  1=Distance of water source
    0=No
    1=Yes
    -99=Do not know
    -88=Refuse to Answer

  2=Weight of carrying water
    0=No
    1=Yes
    -99=Do not know
    -88=Refuse to Answer
  3=Bad Relation with well's owner
    0=No
    1=Yes
    2=I am the owner of the tubewell
    -99=Do not know
    -88=Refuse to Answer
  4=Physical Limitation (ie. bad back, difficulty walking)
    0=No
    1=Yes
    -99=Do not know
    -88=Refuse to Answer

7) Which of these tasks cause greatest difficulty in fetching drinking water? (If the respondent reported no for all of tasks in question 6. Please select "None of these)

  1=Distance of water source
  2=Weight of carrying water
  3=Relation with well's owner
  4=Physical Limitation (ie. bad back, difficulty walking)
  5=None of these
  -99=Do not know
  -88=Refuse to Answer

8) With regard to your tube well, Do you use it for the following tasks?

     1= Drinking (ANSWER SHOULD ALWAYS BE "YES" IF NOT AN ERROR HAS BEEN MADE)
          0= No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer

     2= Cooking
          0= No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer

     3= Feeding animals
          0= No
          1=Yes
          2=I don't have animals
          -99=Do not know
          -88=Refuse to Answer

     4= Watering crops
          0= No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer

     5= Washing your hands
          0= No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer

     6= Bathing
          0= No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer

     7= Washing clothes
          0= No
          1=Yes
          -99= Do not know
          -88=Refuse to Answer

9)How many minutes is your current drinking water source is to your home?(ONE WAY WALKING)

    1= 1 minute or less
    2= More than 1 minute up to 5 minutes
    3= More than 5 minutes up to 10
    4= More than 10 minutes up to 20
    5= More than 20 minutes
    -99= Don't know
    -88=Refuse to Answer

Arsenic

10) People get information about arsenic from many individuals. I will read several possible sources. Please tell me if these individuals have told you information about arsenic. Please respond "yes or "no".

    1= Spouse
        0=No
        1=Yes
        -88=Refuse to Answer
    2= Siblings
        0=No
        1=Yes
        -88=Refuse to Answer
    3= Family members
        0=No
        1=Yes
        -88=Refuse to Answer
    4= Relatives
        0=No
        1=Yes
        -88=Refuse to Answer
    5= Neighbors
        0=No
        1=Yes
        -88=Refuse to Answer
    6= Teacher
        0=No
        1=Yes
        2=I am a teacher
        -88=Refuse to Answer

7= Religious leader
      0=No
      1=Yes
      2=I am a religious leader
      -88=Refuse to Answer
8=Village leaders
      0=No
      1=Yes
      2=I am a village leader
      -88=Refuse to Answer
9= Health Worker
      0=No
      1=Yes
      2=I am a health worker
      -88=Refuse to Answer
10=NGO worker
      0=No
      1=Yes
      2=I am a NGO worker
      -88=Refuse to Answer
11=Other Individuals
      0=No
      1=Yes
          If "Yes" Please Describe:……………………………………………

11) From which individual do you get the most arsenic information? (CHOOSE ONLY ONE) (If all answers are "no" from question 10 please select "None of these")
      1= Spouse
      2= Siblings
      3= Family members
      4= Relative
      5= Neighbors
      6= Teacher
      7= Religious leader
      8= Village leaders
      9= Health worker
      10=NGO worker
      11= None of these sources
      -88=Refuse to Answer

12) People get information about arsenic from many sources. I will read several possible sources. Please tell me if you have gotten information about arsenic from the following sources. Please respond "yes or "no".

        1= Newspaper (They must have read the newspaper themselves)
            0=No
            1=Yes
            -88=Refuse to Answer
        2= Radio
            0=No
            1=Yes
            -88=Refuse to Answer
        3= TV
            0=No
            1=Yes
            -88=Refuse to Answer
        4 = Books(If "yes" than they must have read the book themselves)
            0=No
            1=Yes
            -88=Refuse to Answer
        5 = Leaflets & Posters
            0=No
            1=Yes
            -88=Refuse to Answer
        6=Other Sources
            0=No
            1=Yes
            If Yes Please Specify……………………………………………..

13) From which source do you get the most arsenic information? (CHOOSE ONLY ONE) (If all the responses from 12 are "no" then please select "none of these sources).

            1= Newspapers
            2= Radio
            3= TV
            4= Books
            5= Leaflets & Posters
            6=None of these sources
            -88=Refuse to Answer

14) I am going to read you a list of people. Please tell me if we were to train these individuals about arsenic would you go to them with your questions about arsenic, "yes" or "no".

        1= Spouse
                0=No
                1=Yes
                -88=Refuse to Answer
        2= Siblings
                0=No
                1=Yes
                -88=Refuse to Answer
        3= Family members
                0=No
                1=Yes
                -88=Refuse to Answer
        4= Relatives
                0=No
                1=Yes
                -88=Refuse to Answer
        5= Neighbors
                0=No
                1=Yes
                -88=Refuse to Answer
        6= Teacher
                0=No
                1=Yes
                2=I am a teacher
                -88=Refuse to Answer
        7= Religious leader
                0=No
                1=Yes
                2=I am a religious leader
                -88=Refuse to Answer
        8=Village leaders
                0=No
                1=Yes
                2=I am a village leader
                -88=Refuse to Answer

9= Health Worker
    0=No
    1=Yes
    2=I am a health worker
    -88=Refuse to Answer
10=NGO worker
    0=No
    1=Yes
    2=I am a NGO worker
    -88=Refuse to Answer
11=Other Individuals
    0=No
    1=Yes
        If "Yes" Please Describe:………………………………………….

15) If you had questions about arsenic who would you ask **first**? (CHOOSE ONLY ONE) (If all the responses from 14 are "no" then please select "none of these sources).
    1= Spouse
    2= Siblings
    3= Family members
    4= Relative
    5= Neighbors
    6= Teacher
    7= Religious leader
    8= Village leaders
    9= Health worker
    10=NGO worker
    11= None of these sources
    -88=Refuse to Answer

16) Do you know where an arsenic safe drinking water source is located in your village?
    0=No
    1=Yes
    -99=Don't know(If "don't know SKIP TO 20)

17) How many minutes is the closest arsenic safe drinking water source to your home?(1 WAY)
(Please give respondents time to think about this question)
    1= 1 minute or less
    2= More than 1 minute up to 5 minutes
    3= More than 5 minutes up to 10
    4= More than 10 minutes up to 20
    5= Greater than 20 minutes
    -99= Don't know
    -88=Refuse to Answer

18) How do you know this well is safe?

    1= Paint on the well
       0=No
       1=Yes
       -88=Refuse to Answer

    2= Tin plate on the well
       0=No
       1=Yes
       -88=Refuse to Answer

    3= Some tested this well and I was told the result
       0=No
       1=Yes
       -88=Refuse to Answer

    4= Family members told me
       0=No
       1=Yes
       -88=Refuse to Answer

    5= Friends told me
       0=No
       1=Yes
       -88=Refuse to Answer

    6= Neighbors told me
       0=No
       1=Yes
       -88=Refuse to Answer

    7= Other
       0=No
       1=Yes

If "Yes" Specify:………………………………………………………………………

19) Why don't you use this arsenic safe drinking water source? (CHOOSE ONLY ONE)
    (Please give respondents time to think about this question)
       1=Distance
       2=Bad relation to well's owner(relative)
       3=Bad relation to well' owner(non-relative)
       4=Taste of water
       5=Color of water
       6= Because my family owns our tubewell,
       7=Other   Please Specify:………………………………………………………
       -99=Do not know
       -88=Refuse to Answer

20)Do you know anyone who has fallen ill from arsenic exposure?
        0=No
        1=Yes
        99=Don't know
        -88=Refuse to Answer

21)Do you believe you have an illness associated with arsenic exposure?
        0=No
        1=Yes
        99=I don't know
        -88=Refuse to Answer

Subject ID_____

FIELD TRACKING SHEET **(TO BE COMPLETED BY FIELD STUDY TEAM)**

Interviewer Name:_____

Name of the Participant:…………………………………………………………………

Primary Tubewell ID ☐☐☐☐☐

Screening Tool ☐ Yes ☐ No

Informed Consent ☐ Yes ☐ No

Identification Card ☐ Yes ☐ No

Well ID Placard ☐ Yes ☐ No

Water Collected ☐ Yes ☐ No at AM PM on____/____/_____(dd/mm/yyy)

GPS Coordinates

Household ☐ Yes ☐ No at AM PM on____/____/_____(dd/mm/yyy)

Tubewell ☐ Yes ☐ No at AM PM on____/____/_____(dd/mm/yyy)

Questionnaire ☐ Yes ☐ No at Time ____:____ on____/____/_____(dd/mm/yyy)
Completed

Urine Collected ☐ Yes ☐ No at AM PM on____/____/_____(dd/mm/yyy)

Urine Kit Result

Protein ☐ Negative ☐ Positive Result (Describe):_____

Glucose ☐ Negative ☐ Positive Result (Describe):_____

Collected by……………………………………………………………………………………

If any items are marked "no" please explain below

Remarks/Comments……………………………………………………………………………

………………………………………………………………………………………………………

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Appendix 4

Follow-up Questionnaire

Subject ID_____

Community Participation to Effectively Lower Arsenic Exposure in Bangladesh
(Follow-up Questionnaire)

Write Clearly in English in Upper Case Letters for Responses

Interviewer Name:…………………………………………….

Interview Date: ……………………..(day/month/year)   Interview Time……………(hour: minute)

Name of the Participant:…………………………………………. (From ID Card)
(Person Interviewed at Baseline)

Spouse Name:……………………………………………………………………….

Name of Head of Household:……………………………………………………

Father of Head of Household :…………………………………………………………………..

Village Name:…………………………………………………………………..

Union Name………………………………………………………………………...

Para Name:……………………………………………………………………………

Bari Name…………………………………………………………………………….

Baseline Tubewell ID ☐☐☐☐☐ (From the SUBJECT TRACKING SHEET)

Section A

1) Has an arsenic tester come to your home?
     0= No (PLEASE CONTACT THE FIELD COORDINATOR)
     1= Yes
     -99=Don't know (PLEASE CONTACT THE FIELD COORDINATOR)

2) Have they provided you with arsenic awareness education?
     0= No (PLEASE CONTACT THE FIELD COORDINATOR)
     1= Yes
     -99=Don't know (PLEASE CONTACT THE FIELD COORDINATOR)

3) Has the well that you reported to us as your primary drinking water source at baseline
   been tested for arsenic?
     0= No (PLEASE CONTACT THE FIELD COORDINATOR)
     1= Yes
     -99=Don't know (PLEASE CONTACT THE FIELD COORDINATOR)

4) Has a green leaflet about arsenic awareness been given to you?
        0= No
        1= Yes (HAVE THE RESPONDENT SHOW YOU WHERE IT IS LOCATED)
        -99=Don't know

5) Are currently living in a different household from when we came to your home at baseline?
        0= No
        1= Yes (PLEASE CONTACT THE FIELD COORDINATOR)
        -99=Don't know (PLEASE CONTACT THE FIELD COORDINATOR)

6) Did your arsenic tester live in your village?
        0=No
        1=Yes
        -99=Don't know

7) Since your well was tested, How many times did you MEET WITH your arsenic tester. **ONLY THE ARSENIC TESTER NOT ANY OTHER STUDY STAFF**?
        1=1
        2=2
        3=3
        4=4
        5=5
        6=6
        7=>7
        -99=Do not know
        -88=Refuse to Answer

8) How many Arsenic Educational Sessions did you attend?
        1=1
        2=2
        3=3
        4=4
        5=5
        6=6
        7=>7
        -99=Do not know
        -88=Refuse to Answer

9) Did you ask your arsenic tester questions related to arsenic AFTER your educational session was completed?
0=No (Skip to 11)
1=Yes

10) When did you go to the arsenic tester to ask most of your questions about arsenic?
1=Right After the educational session was over
2= 1 day later
3= 2 days later
4= A few days later
5=1 week later
6= More than 1 week
-99=Do not know

11) What did your arsenic tester state was the arsenic concentration of your baseline drinking water source? (Give the respondent time to think about the question)

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│         │
│         │
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-99=Don't Know

12) Do you think your baseline drinking water source is unsafe or safe relative to arsenic?
   0=Unsafe
   1=Safe SKIP TO 15
   -99=Don't Know (Contact the Field Coordinator)

13) Was your arsenic tester able to locate a safe drinking water source for you to use?
   0=No (SKIP TO 15)
   1=Yes

14) How many minutes from your home was this safe drinking water source the **arsenic tester** located for you?(1 WAY)
   (Please give respondents time to think about this question)
   1= 1 minute or less
   2= More than 1 minute up to 5 minutes
   3= More than 5 minutes up to 10
   4= More than 10 minutes up to 20
   5= Greater than 20 minutes
   -99= Don't know
   -88=Refuse to Answer

15) Do you currently have one water source where you collect most of your household's drinking water ?
   0=No (CONTACT THE FIELD COORDINATOR)
   1=YES

INTERVIEWER DIRECTIONS

(PLEASE READ THE BELOW STATEMENT BEFORE YOU GO TO THE TUBEWELL)
 "In order to understand how this program will work we need to know your truthful answer on what water source your currently using. This is very important for the success of our study."

Right now where is the water source where you collect drinking water from the majority of the time? PLEASE GO WITH THEM TO THE WELL THEY ARE CURRENTLY DRINKING FROM

16) Is this the same well you reported at baseline as your primary drinking water source?
   PLEASE CONFIRM USING YOUR SUBJECT TRACKING SHEET
 0=No **PROCEED TO SECTION 1:** *USING A NEW DRINKING WATER SOURCE(GO TO PAGE 4)*
 1=Yes **PROCEED TO SECTION 2** *USING THE SAME DRINKING WATER SOURCE AS BASELINE (PAGE TO 11)*

SECTION 1: IF RESPONDENT IS USING A NEW DRINKING WATER SOURCE

Please Write Responses Clearly In English in Upper Case Letters

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FOR INTERVIEWER (PLEASE GO TO THE SUBJECT'S PRIMARY DRINKING WATER SOURCE AND COMPLETE THE QUESTIONS BELOW)

1) Is there a Color ID Placard present?
     0=No (SKIP TO 3)
     1=Yes

2) What Color is the Placard?
     0=Red
     1=Green

3) Is there a Well ID tag present?
     0=No **(PLEASE ATTACH A WELL ID PLACARD TO THE NEW WELL AND COLLECT WATER SAMPLE ANDTHE TUBEWELL GPS LOCATION)**
     1=Yes **(RECORD WELL ID NUMBER BELOW AND COLLECT THE TUBEWELL GPS COORINDATE)**

Please Write Tubewell ID Below

ID Tubewell ☐☐☐☐☐

Record in Decimal Degrees

GPS of Tubewell

Latitude N										
Longitude E										

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1. What is your household's CURRENT primary source of drinking water?(CHOOSE ONLY ONE)
     1= Private tubewell
     2= Government tubewell
     3= Community NGO Well   Name of NGO:………………………………….
     4= Dugwell
     5= Pond water (SKIP TO 3)
     6= River water (SKIP TO 3)
     7= Rainwater (SKIP TO 3)
     8= Other:……………………………………………
     -99=Do not know
     -88=Refuse to Answer

2. How deep is the CURRENT well your using?   Feet
     -99=Dont Know

3. How many years ago was your CURRENT water source installed?(ONLY WRITE ONE NUMBER)   -99=Don't Know

Years	Month

4. How many people regularly drink your CURRENT well? -99=Don't Know (ONLY WRITE ONE NUMBER)

5. How long has your household been drinking from this well?   (ONLY WRITE ONE NUMBER)
    -99=Don't Know

Months	Days

6. How long after your Arsenic Tester came to your home did you switch your CURRENT drinking water source?
    1=The same day
    2=Next Day
    3=Within 1 week
    4=Within 2 week
    5=Within 3 weeks
    6=Within 1 month
    7=Within 2 months
    8=Within 3 months
    9=Within 4 months

7. Has the water source you are currently using been tested for arsenic?
    0=No SKIP TO 12
    1=Yes

8. What is the arsenic concentration of your current drinking water source?

-99=Don't Know

9. Do you think your CURRENT well is unsafe or safe relative to arsenic?
        0=Unsafe (SKIP TO 11)
        1=Safe
        -99=Don't Know (SKIP TO 12)

10. Are you sharing your CURRENT arsenic safe tubewell with another household?
        0=No
        1=Yes

11. How do you know if your CURRENT well is unsafe or safe relative to arsenic?
   1=Arsenic Concentration
     0=No
     1=Yes
   2=Color Placard on the well
     0=No
     1=Yes
   3=Paint on the well
     0=No
     1=Yes
   4=Arsenic tester tested this well and you were told the result
     0=No
     1=Yes
   5=Family member told me
     0=No
     1=Yes
   6=Friends told me
     0=No
     1=Yes
   7=Neighbors told me
     0=No
     1=Yes
   8=Other
     0=No
     1=Yes

   If "Yes" Specify:……………………………………………………………………

12. Did the owner of the well you are currently using attend your arsenic tester's educational session?
   0=No
   1=Yes
   2=I am the well owner
   -99= Don't Know

13. Did your arsenic tester help you to locate the drinking water source you are currently using?
   0=No
   1=Yes (SKIP TO 15)

14. How many minutes is your CURRENT drinking water source from your home?(1 WAY)
  (Please give respondents time to think about this question)
   1= 1 minute or less
   2= More than 1 minute up to 5 minutes
   3= More than 5 minutes up to 10
   4= More than 10 minutes up to 20
   5= Greater than 20 minutes
   -99= Don't know
   -88=Refuse to Answer

15. Why did you stop using your previous well from baseline?

    1= You were informed your previous well was unsafe relative to arsenic by your arsenic tester
        0=No
        1=Yes
    2= Your previous tubewell was broken
        0=No
        1=Yes
    3= Too many people were using your previous(baseline) tubewell
        0=No
        1=Yes
    4= You dug a new tubewell for your household
        0=No
        1=Yes
    5= You did not like the taste of your previous tubewell
        0=No
        1=Yes
    6= You did not like the color of the water from your previous tubewell
        0=No
        1=Yes
    7=Other
        0=No
        1=Yes If "Yes" please describe

    Describe:…………………………………………………………………………………………

16. Which of the options previously mentioned were the most important in your decision to stop using your previous well from baseline keep (CHOOSE ONLY ONE) (If all in 15 are "No" select 7=NONE OF THESE)
    1= You were informed your previous well was unsafe relative to arsenic by your arsenic tester
    2= Your previous tubewell was broken
    3= Too many people were using your previous(baseline) tubewell
    4= You dug a new tubewell for your household
    5= You did not like the taste of your previous tubewell
    6= You did not like the color of the water from your previous tubewell
    7=None of these

17. What is your relation to the owner of the tubewell you are currently using?
    1= Your household owns this well
    2= Neighbor
    3= Family Member, same bari
    4= Relative, different bari
    5= Landlord or lender or shopkeeper or employer
    6= You use a government tubewell/NGO
    7= Other: …………………………………………………………………….
    -99=Do not know
    -88=Refuse to Answer

18. Do any of these problems cause you difficulty when fetching water from your current drinking water source?

      1=Distance of water source
          0=No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer
      2=Weight of carrying water
          0=No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer
      3=The owner doesn't like to share
          0=No
          1=Yes
          2=I am the owner of the tubewell
          -99=Do not know
          -88=Refuse to Answer
      4=Physical Limitation (ie. bad back, difficulty walking)
          0=No
          1=Yes
          -99=Do not know
          -88=Refuse to Answer

19. Which one of these tasks cause the greatest difficulty in fetching drinking water? (If the respondent reported no for all of tasks in question 18. Please select "None of these")

      1=Distance of water source
      2=Weight of carrying water
      3=The owner doesn't like to share
      4=Physical Limitation (ie. bad back, difficulty walking)
      5=None of these
      -99=Do not know
      -88=Refuse to Answer

20. With regard to your CURRENT tubewell, Do you currently use it for the following tasks?

    1= Drinking (THE ANSWER SHOULD ALWAYS BE "YES". IF THE RESPONSE IS "NO" AN ERROR HAS BEEN MADE. PLEASE CONTACT THE FIELD COORDINATOR)

        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer

    2= Cooking

        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer

    3= Feeding animals

        0= No
        1=Yes
        2=I don't have animals
        -99=Do not know
        -88=Refuse to Answer

    4= Watering crops

        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer

    5= Washing your hands

        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer

    6= Bathing

        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer

    7= Washing clothes

        0= No
        1=Yes
        -99= Do not know
        -88=Refuse to Answer

21. Are you also collecting water from the tubewell we tagged for your household at baseline (your previous tubewell)?

    0=No(Continue to Section B QUIZ)
    1=Yes

22. With regard to your PREVIOUS well, Do you currently use it for the following tasks?
    1= Drinking
        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    2= Cooking
        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    3= Feeding animals
        0= No
        1=Yes
        2=I don't have animals
        -99=Do not know
        -88=Refuse to Answer
    4= Watering crops
        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    5= Washing your hands
        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    6= Bathing
        0= No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    7= Washing clothes
        0= No
        1=Yes
        -99= Do not know
        -88=Refuse to Answer

SECTION 2: *IF THE RESPONDENT IS USING THE SAME DRINKING WATER SOURCE AS BASELINE*

FOR INTERVIEWER (PLEASE GO TO THE SUBJECT'S PRIMARY DRINKING WATER SOURCE AND COMPLETE THE QUESTIONS BELOW)

1) Is there a Color ID Placard present?
      0=No (SKIP TO 3)
      1=Yes

2) What Color is the Placard present?
      0=Red
      1=Green

3) Is there a Well ID tag present?
      0=No (PLEASE CONTACT THE FIELD COORDINATOR)
      1=Yes

Please Write the Tubewell ID Below.

ID Tubewell   ☐☐☐☐☐

---

1. How many people regularly drink your CURRENT well?   ☐
   -99=Don't Know

2. Do you think your CURRENT well is unsafe or safe relative to arsenic?
      0=Unsafe
      1=Safe (SKIP TO 9)

3. Now I'm going to ask some questions about why you drinking from the same well that you reported at baseline to be your primary drinking water source?
      1= Because the distance of a safe tube was too far.
        0=No
        1=Yes
      2= Because your family has its own tubewell
        0=No
        1=Yes
      3= Because the arsenic safe drinking water source near your home had too many users
        0=No
        1=Yes
      4= Because the arsenic safe well owner located near your home does not want to share
        0=No
        1=Yes
      5= Because I have a physical limitation that prevents me from collecting water from another well
        0=No
        1=Yes
      6=Because alternative arsenic safe wells have a bad taste
        0=No
        1=Yes

7= Because alternative arsenic safe wells have a unusual color
    0=No
    1=Yes
8=Are there any other reasons why you are using the same well as baseline?
    0=No
    1=Yes, If "yes" please describe below ……………………………

4. Which of the options previously mentioned were the most important in your decision to keep using your current tubewell? (CHOOSE ONLY ONE) (If all in 3 are "No" select 8=NONE OF THESE)
    1= Because the distance of a safe tube was too far.
    2= Because your family has its own tubewell
    3= Because the arsenic safe drinking water source near your home had too many users
    4= Because the arsenic safe well owner located near your home does not want to share
    5= Because I have a physical limitation that prevents me from collecting water from another well
    6=Because alternative arsenic safe wells have a bad taste
    7= Because alternative arsenic safe wells have a unusual color
    8=None of these

5. Do you know where an arsenic safe drinking water source is located in your village?
    0=No (SKIP TO 9)
    1=Yes
    -99=Don't know(SKIP TO 9)

6. If you know where an arsenic safe drinking water is located is this the source the arsenic tester found for your household?
    0=No
    1=Yes (SKIP TO 9)

7. How many minutes is the closest arsenic safe drinking water source from your home?(1 WAY)
(Please give respondents time to think about this question)
    1= 1 minute or less
    2= More than 1 minute up to 5 minutes
    3= More than 5 minutes up to 10
    4= More than 10 minutes up to 20
    5= Greater than 20 minutes
    -99= Don't know
    -88=Refuse to Answer

8. How do you know this well is safe relative to arsenic?
    1=Arsenic Concentration
        0=No
        1=Yes
    2=Color Placard on the well
        0=No
        1=Yes
    3=Paint on the well
        0=No
        1=Yes

        4= Family members told you
            0=No
            1=Yes
        5=Friends told you
            0=No
            1=Yes
        6=Neighbors told you
            0=No
            1=Yes
        7=Other
            0=No
            1=Yes (Specify:………………… …………………………………………)

9. With regard to your CURRENT tubewell, Do you currently use it for the following tasks?
        1= Drinking (THE ANSWER SHOULD ALWAYS BE "YES". IF THE RESPONSE IS "NO" AN ERROR HAS BEEN MADE. PLEASE CONTACT THE FIELD COORDINATOR)
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer
        2= Cooking
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer
        3= Feeding animals
            0= No
            1=Yes
            2=I don't have animals
            -99=Do not know
            -88=Refuse to Answer
        4= Watering crops
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer
        5= Washing your hands
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer
        6= Bathing
            0= No
            1=Yes
            -99=Do not know
            -88=Refuse to Answer
        7= Washing clothes
            0= No
            1=Yes
            -99= Do not know
            -88=Refuse to Answer

Section B: Quiz

The questions and responses will be read to the study participant. The interviewer should circle the number corresponding to the subject's answer. Tell other individuals present during the quiz to not assist the respondent. Remind respondents that it is okay if they don't know an answer. However do not suggest that a respondent answer "I don't know" to any particular study question.

PLEASE ASK IF ANY STUDY RESPONDENTS ARE PRESENT. IF SO PLEASE ASK THEM TO LEAVE DURING THE QUIZ. .THEY CANNOT BE PRESENT.

GIVE RESPONDENTS TIME TO THINK ABOUT THE QUESTIONS

Knowledge

1. Where is arsenic contaminated water mainly found?
   1= Pond water
   2= River water
   3= Tube well water
   4= Dug well
   5= Canal
   6= Rainwater
   7=None of these
   -99= Do not know
   -88=Refuse to Answer

2. What is the Bangladesh standard to define safe level of arsenic in drinking water?
   1= Less than 100
   2= Less than 70
   3= Less than 50
   4= Less than 10
   -99= Do not know
    -88=Refuse to Answer

3. If there are 4 tubewells of water which contain arsenic of 50, 30, 20, 10 which is the safest to drink?
   1= 50
   2= 30
   3= 20
   4= 10
    -99= Do not know
    -88=Refuse to Answer

4. If there are 4 tubewells of water which contain arsenic of 300, 200, 100, 70 which is the safest to drink?

    1= 300
    2= 200
    3= 100
    4= 70
  -99= Do not know
   -88=Refuse to Answer

5. Should you drink water that has an arsenic level of 30?

    0=No
    1=Yes
    -99=Do not know
    -88=Refuse to answer

6. Should you drink water that has an arsenic level of 70?

    0=No
    1=Yes
    -99=Do not know
    -88=Refuse to answer

7. Is it safe to drink from a green color tubewell?

    0= No
    1=Yes
    -99= Do not know
    -88=Refuse to Answer

8. Is it safe to drink from a red color tubewell?

    0=No
    1=Yes
    -99= Do not know
    -88=Refuse to Answer

9. I am going to read a list of medical conditions. Please tell me if arsenic exposure can cause these conditions.

> 1=Cancer
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 2=Cholera
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 3=Skin Lesions
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 4=Lung Diseases
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 5=Diarrhea
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 6=Heart Diseases
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 7=Adverse Affects to Pregnant Women
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 8=Vomiting
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer
>
> 9=Adverse Affects to Children
>> 0=No
>> 1=Yes
>> -99=Do not know
>> -88=Refuse to Answer

10. Can eating or sleeping with an arsenicosis patient cause the transmission of this disease?

       0=No

       1=Yes

       -99=Do not know

       -88=Refuse to Answer

11. Can arsenic be removed by boiling water?

       0=No

       1=Yes

       -99=Do not know

       -88=Refuse to Answer

12. I am going to read a list of common tasks we do each day. For each task tell me whether or not it is okay to use arsenic contaminated water.

       1=Drinking

              0= No

              1=Yes

              -99=Do not know

              -88=Refuse to Answer

       2=Cooking

              0= No

              1=Yes

              -99=Do not know

              -88=Refuse to Answer

       3=Washing hands

              0= No

              1=Yes

              -99=Do not know

              -88=Refuse to Answer

       4=Bathing

              0= No

              1=Yes

              -99=Do not know

              -88=Refuse to Answer

       5=Washing clothes

              0= No

              1=Yes

              -99= Do not know

              -88=Refuse to Answer

       6=Washing animals

              0= No

              1=Yes

              -99=Do not know

              -88=Refuse to Answer

Section C

Please only read questions to the study participant. Please circle the number corresponding to the subject's answer.

1. Do you know anyone who has fallen ill from arsenic exposure?
   0=No
   1=Yes
   -99=Don't know
   -88=Refuse to Answer

2. Do you believe you have an illness associated with arsenic exposure?
   0=No
   1=Yes
   -99=I don't know
   -88=Refuse to Answer

FIELD TRACKING SHEET   (TO BE COMPLETED BY FIELD STUDY TEAM)

Interviewer Name:_____

Name of the Participant:…………………………………………………………………

Barcode: Urine Sample ID	Current Tubewell ID ☐☐☐☐☐

Newly Tagged Well ☐ Yes   ☐ No

Well ID Placard   ☐ Yes   ☐ No

Water Collected   ☐ Yes   ☐ No   at   AM   PM   on____/____/_____(dd/mm/yyy)
(Newly Tagged Well)

GPS Coordinates

Tubewell   ☐ Yes   ☐ No   at   AM   PM   on____/____/_____(dd/mm/yyy)

Questionnaire   ☐ Yes   ☐ No   at   Time ____:____ on____/____/_____(dd/mm/yyy)
Completed

Urine Collected   ☐ Yes   ☐ No   at | AM | PM | on____/____/_____(dd/mm/yyy)

Urine Kit Result

Glucose   ☐ Negative   ☐   Positive Result (Describe):_____

Protein   ☐ Negative   ☐   Positive Result (Describe):_____

Urine Collected by………….……………………………………………………………………….

If any items are marked "no" please explain below

Remarks/Comments………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Appendix 5

Baseline Interviewer Household Visit Protocol

Community Participation to Effectively Lower Arsenic Exposure in Bangladesh

Baseline Interviewer Household Visit Protocol

1. Interviewer should administer the person responsible for primary drinking water collection in each household the *Study Screening Questionnaire.* Please confirm that this household has an **UNTESTED WELL** before starting the interview**.**

2. If the person that is responsible for primary drinking water collection in the household is eligible for the study based on the screening questionnaire proceed to STEP 3. If not end the interview and thank the respondent for their time.

3. If the study respondent is eligible to participate in the study based on the Study Screening Questionnaire please read them the *Study Consent Form.* You can summarize the consent form explaining the study design and procedures. Please read the respondents all of their rights. Place a subject id barcode label on the consent form not included in the interviewer packet. Both you and the respondent need to sign both copies of the consent form. If the respondent cannot write please have someone in the village that can read and write be a witness. The respondent should give their person thumb print on both consent forms. The witness must also sign both consent forms. Place and barcode on fill out a *Study Identification Card*.

4. Place ID placard on household's primary drinking water source

5. Write the ID placard number on the side of both the 20ml and 60 ml water bottles. Collect a two samples of household's primary drinking water source

6. Collect GPS location of household's primary drinking water source

7. Collect GPS location of household

8. Administer *Baseline Study Questionnaire*

9. Proceed to the *Urine Collection Protocol.*

10. Complete Tracking sheet on the last page of the study questionnaire

11. Thank the respondent for their time and participation in the study. Explain to respondent that an arsenic tester will come to their household in the next couple of weeks to test their well and provide them with educational information.

Appendix 6

Follow-up Interviewer Household Visit Protocol

Columbia University Arsenic & Health Research Office In Bangladesh

Community Participation to Effectively Lower Arsenic Exposure in Bangladesh

Follow-up Interviewer Household Visit Protocol

1. Please ask the study participant for their Study Identification Card. CONFIRM the subject id number matches with the barcodes you were given for study participant. Please ensure the Name of Study Participant, Name of Head of Household, and Name of Father of Head of Household match with your subject tracking sheet. If any information is INCORRECT contact the Field Coordinators immediately!

2. Proceed to administer the Follow-up Study Questionnaire. Place the subject id barcode on the first page of the study questionnaire. It is IMPORTANT that this is the same barcode as the recorded on your subject tracking sheet for this participant.

3. Place well ID placard on household's primary drinking water source if the following statements are true

   - If the participant has changed their primary drinking water source from baseline

   - If their current drinking water source does not already have a well id placard

4. Write the Well ID placard number on the side of both the 20ml and 60 ml water bottles. Collect the two water samples of the household's primary drinking water source

5. Collect GPS location of household's primary drinking water source if DIFFERENT from baseline EVEN if the tubewell they are using is already tagged.

6. Continue to Administer the *Follow-up Study Questionnaire*

7. During the quiz please ask if any other study respondents are present. THEY CANNOT OBSERVE the quiz of another study respondent.

8. Proceed to the *Urine Collection Protocol.*

9. Complete the Tracking sheet on the last page of the study questionnaire

10. Thank the respondent for their time and participation in the study.

Appendix 7

Frequently Asked Questions (FAQ) List

Frequently Asked Questions (FAQ) List

1) Why is this study being implemented?

This study is being implemented to investigate whether providing well water arsenic testing and arsenic education to households encourages households to switch to low arsenic drinking water sources.

2) What if the respondent is not available?

Please schedule a return visit. Only the person in the household that is responsible for primary drinking water collection can be interviewed. No other individual. If after several attempts this person cannot be reached report this event to the Field Staff Coordinator.

3) What if a respondent does not want to be interviewed?

The interviewer can explain the purpose of the study again, however it is solely the respondent's decision whether they would like to participate in the study. If they decide not to participate please record the reason why if given on the study *Screening Questionnaire*(the "For interviewers" section QUESTION 3).

4) What if the respondent wants to know more about arsenic?

If a household would like to know more about arsenic you can provide them with the following information. Please do not provide any additional information, tell them more information will be given during the actual intervention.

Please record that this information was given in the remarks section of the study questionnaire:

Arsenic is a substance that can be present in elevated levels in drinking water and has been shown to cause adverse health effects. Individuals should avoid drinking water sources known to have elevated levels of arsenic. In this study we will provide you with additional information about how drinking water with arsenic can affect your health, and steps you can take to reduce your exposure.

5) How will the respondent benefit from the study?

The respondent will receive well water arsenic testing and arsenic education, and when necessary assistance with locating a low arsenic drinking water source near ones home.

6) How will the respondent receive the results for the study?

After all the wells in the study villages have been tested and the follow-survey has been completed, a village meeting will be held to disseminate the study results.

7) What if a respondent refuses to answer a question?

If a respondent refuses to an answer question, circle the "Refuse to Answer" choice under the question. Please record in the remarks section the reason if given for refusing to answer the question.

8) What if the respondent refuses to answer any more questions?

The interviewer should end the session. The interviewer can explain the purpose of the study again, however it is solely the respondent's decision whether they would like to participate in the study.

Please record this event in the remarks section of the study questionnaire and contact the Field Coordinator to report this event. Also record the reason if given for refusing to answer any more questions in the remarks section.

9) What if I have to end an interview early?

This is strongly discouraged. Ask the respondent if they will be available another day to complete the interview, and record this event in the remarks section of the study questionnaire. Please contact the Field Coordinator to report this event, and include the reason why the session was ended earlier in the remarks section. Please revisit this household as soon as possible, next working day if at all possible. Ask respondent if they are still using the same drinking water source.

10) When should the urine sample be collected?

The urine sample should always be collected at the end of the interview

11) Does urine have to be from the respondent?

Yes, the urine must be from the individual interviewed.

12) What if the respondent does not have to urinate?

If the respondent does not have to urinate, then give them water to drink from the same tube well water which they always drink, and collect a urine sample in 20 minutes.

If they still don't have to urinate ask the respondent if we can make a return visit to collect a urine sample. Please make this visit the next working day or as soon as possible. On the return visit ask the respondent if they are still drinking from the same water source sampled during the baseline interview. If they are not drinking from the same drinking water source and the questionnaire has already been completed. Tell the respondent that urine collection is no longer possible. Please record this event in the remarks section of study questionnaire and contact the Field Coordinator to report this event.

13) What will be done with this person's urine sample?

The amount of arsenic in the urine will be measured in a laboratory, and their urine will be tested to see if they may be sick.

14) What if a women is currently on their menstrual cycle?

If a woman is currently on her menstrual cycle a urine sample cannot be collected. Ask the respondent if we can make a return visit to collect a urine sample. Please make this visit is at the end of her menstrual cycle. On the return visit ask the respondent if they are still drinking from the same water source sampled during the baseline interview. If they are not drinking from the same drinking water source and the questionnaire has already been completed. Tell the respondent that urine collection is no longer possible. Please record this event in the remarks section of study questionnaire and contact the Field Coordinator to report this event.

15) What if the respondent refuses to give a urine sample?

Record this event in the remarks section of the study questionnaire with the reason why the subject refused to give a urine sample if provided.

16) What if the respondent is not able to provide enough urine?(NEED TO CHECK)

If the respondent can not provide at least 20 ml of urine, give them water to drink from the same tube well water which they always drink, and collect a urine sample in 20 minutes**.**

If the respondent still can not produce enough urine. Ask the respondent if we can make a return visit as soon as possible to collect a urine sample at a later date, however on the return visit ask the respondent if they are still drinking from the same water source sampled during the baseline interview. If they are not drinking from the same drinking water source and the questionnaire has already been completed. Tell the respondent that urine collection is no longer possible. Please contact the Field Coordinator to report this event, and record this event in the remarks section of the study questionnaire.

17) What if the respondent refuses to give a water sample?

Explain to the respondent that this is an important part of the study because it will allow us to know the arsenic concentration in their well. If they still refuse, tell them they can't participate in the study and record this in the remarks section of the study questionnaire. Please contact the Field Coordinator to report this event.

18) What if a household is using multiple drinking water sources?

Ask the person responsible for primary drinking water collection in the household where they collect the majority of their household's drinking water. If they don't have one main drinking water source the household is not eligible to participate in the study. Please record this event in the remarks section of study questionnaire and contact the Field Coordinator to report this event

Appendix 8

Interviewer Evaluation Guide

Community Participation to Lower Arsenic Exposure Effectively in Bangladesh
Interviewer Evaluation

Interviewer: _____Evaluator: _____

Date Evaluated: _____

PRESENTATION -- 5 points each

_____ Introduction to questionnaire

_____ Smooth word for word reading of all questions and introductory statements

_____ Pacing of the interview (i.e., eliminating unnecessary repetition)

_____ Pausing appropriately to give the respondent time to think about the questions during the quiz, and elsewhere instructed

_____ Following appropriate skip patterns

_____ Using correct, neutral probes

_____ Correctly reading answer choices when appropriate

_____ Concise and accurate clarification of questions for respondent

_____ Carefully listening to the study respondent

Urine Collection Protocol (GENERAL) -- 5 points each

_____ Asking the Respondent to Provide a Urine Sample

_____ Providing correct instructions on how the respondent should give a urine sample (5 instructions)

_____ Correct Use of Urine Test Kit

_____ **TOTAL SCORE (out of 60)**

COMMENTS:

301

Appendix 9

Arsenic Tester Pre and Post Training Evaluation Sheet

Community Participation to Effectively Lower Arsenic Exposure in Bangladesh
Arsenic Tester Pre and Post Training Evaluation Sheet
Time: 30 Minute

Name ☐   d

Male ☐   Female ☐

Date:

Knowledge

1. Where is arsenic contaminated water mainly found?
   1= Pond water
   2= River water
   3= Tube well water
   4= Dug well
   5= Canal
   6= Rainwater
   7=None of these
   -99= Do not know
   -88=Refuse to Answer

2. What is the Bangladesh standard to define safe level of arsenic in drinking water?
   1= Less than 100
   2= Less than 70
   3= Less than 50
   4= Less than 10
   -99= Do not know
   -88=Refuse to Answer

3. If there are 4 tubewells of water which contain arsenic of 300, 200, 100, 70 which is the safest to drink?
   1= 300
   2= 200
   3= 100
   4= 70
   -99= Do not know
   -88=Refuse to Answer

4. Should you drink water that has an arsenic level of 30?
   0=No
   1=Yes
   -99=Do not know
   -88=Refuse to answer

5. Should you drink water that has an arsenic level of 70?
    0=No
    1=Yes
    -99=Do not know
    -88=Refuse to answer

6. Is it safe to drink from a green color tubewell?
    0= No
    1=Yes
    -99= Do not know
    -88=Refuse to Answer

7. Is it safe to drink from a red color tubewell?
    0=No
    1=Yes
    -99= Do not know
    -88=Refuse to Answer

8. I am going to read a list of medical conditions. Please tell me if arsenic exposure can cause these conditions.
    1=Cholera
        0=No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    2=Cancer
        0=No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    3=Diarrhea
        0=No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    4=Vomiting
        0=No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer
    5=Skin Lesions
        0=No
        1=Yes
        -99=Do not know
        -88=Refuse to Answer

9. Can eating or sleeping with an arsenicosis patient cause the transmission of this disease?

      0=No

      1=Yes

      -99=Do not know

      -88=Refuse to Answer

10. Can arsenic be removed by boiling water?

      0=No

      1=Yes

      -99=Do not know

      -88=Refuse to Answer

11. I am going to read a list of common tasks we do each day. For each task tell me whether or not it is okay to use arsenic contaminated water.

      1=Drinking

          0= No

          1=Yes

          -99=Do not know

          -88=Refuse to Answer

      2=Cooking

          0= No

          1=Yes

          -99=Do not know

          -88=Refuse to Answer

      3=Washing hands

          0= No

          1=Yes

          -99=Do not know

          -88=Refuse to Answer

      4=Bathing

          0= No

          1=Yes

          -99=Do not know

          -88=Refuse to Answer

      5=Washing clothes

          0= No

          1=Yes

          -99= Do not know

          -88=Refuse to Answer

      6=Washing animals

          0= No

          1=Yes

          -99=Do not know

          -88=Refuse to Answer

12. Can exposure to arsenic for a long period of time (more than 6 months) result in skin and other diseases?
    A. No
    B. Yes
    C. Do not know

13. Can arsenic exposure result in black/white spots on skin?
    A. No
    B. Yes
    C. Do not know

14. Can we reduce arsenic exposure by switching from high arsenic water to a low arsenic (or arsenic free) tube well water?
    A. No
    B. Yes
    C. Do not know

15. Should we advise an arsenicosis patient to eat more vegetables?
    A. No
    B. Yes
    C. Do not know

16. What should we advise to an arsenicosis patient to drink more arsenic free water from a tube well?
    A. No
    B. Yes
    C. Do not know

17. Drinking high arsenic water for a long period of time (few years) can develop cancer or other chronic diseases

    A. No
    B. Yes
    C. Do not know

18. How many minutes does it take to test a well for arsenic?

    a. 60 Minutes
    b. 40 Minutes
    c. 30 Minutes
    d. 20 Minutes
    e. Do not know

19. Is arsenic infectious?
    a. No
    b. Yes
    c. Do not know

Appendix 10

Arsenic Tester Frequently Asked Questions (FAQ) List

Arsenic Tester Frequently Asked Questions (FAQ) List

1. Why am I working in these 50 study households?

   These 50 household were selected randomly (by lottery) we only have enough resources to conduct arsenic testing in these 50 households. If the intervention is effective at encouraging villagers to switch to low arsenic wells. We may be able to continue to test all the wells present in the village.

2. Why can't I test every well in the village?

   We do not have the time or the resources to conduct these well water arsenic test in every household in the village. This is why you must focus on the testing the well of your study households, and only test additional wells if trying to find a safe drinking water source for your study household.

3. What should I say to people if they want their will tested that are not study households?

   We should tell them that we only have enough resources to assistant the 50 households that were randomly selected to find arsenic safe drinking water sources, and we encourage you to share the arsenic safe drinking water sources that we find during our testing.

4. What if I make a mistake while conducting my arsenic test?

   This is okay please record the event in your arsenic tester journal in the remarks section of each study household.

5. What if the study household is not available?

   If the study household is not available you will need to make a return visit. If after several attempts you are not able to locate the household. Please contact our educational trainer and coordinator.

6. What if the household refuses to be part of the educational session?

Strongly encourage them to participate in the study and please contact our educational trainer and coordinator.

7. What if I am not able to complete an educational session with a study household?

   This is strongly discouraged however if it does occur please return back to the study household as soon as possible, and record this event in the arsenic tester journal

8. What if a session participant asks me a question I do not know the answer to?

   Please contact our educational trainer and coordinator, and we will try our best to address your concerns.

9. What If I am running low on any of my arsenic tester materials?

   Please contact our educational trainer and coordinator BEFORE your arsenic tester materials run out. We will replace them with new ones.

10. What if I am feeling ill and am not able to perform my duties as an arsenic tester?

    Please contact our educational trainer and coordinator if you are not able to perform your duties as an arsenic tester.

Appendix 11

Arsenic Tester Evaluation

Community Participation to Lower Arsenic Exposure Effectively in Bangladesh
Arsenic Tester Evaluation

Arsenic Tester: _____ Evaluator: _____

Date Evaluated: _____

PRESENTATION -- 5 points each

__   Correct Introduction

__   Smooth verbatim reading of Arsenic Educational Script

__   Pacing of the session (Speaking slowly and clearly during the session)

__   Engaging the audience by having eye contact

__   Using Applauses during the session

__   Asking the audience questions

__   Proving Well Assistance to study households/ Addressing any questions or concerns of the household

__   **SCORE (out of 35)**

TECHNICAL KNOWLEDGE OF INSTRUMENT (GENERAL) -- 5 points each

__   Correctly using Arsenic Test Kit
        1.   Swirling Reagents for 1 minute
        2.   Writing time and name on test strip
        3.   Waiting 40 minutes for the arsenic result

__   Reading Arsenic Result Properly
        1.   Giving the exact result. If the arsenic result is between 50-100 please set for example 65 or 80

__   Correctly Attaching Color ID Placard to the household's well

__   **SCORE (out of 15)**

____   **TOTAL SCORE (out of 50)**

COMMENT:

Appendix 12

Arsenic Tester Household Visit Protocol

Columbia University Arsenic & Health Research Office In Bangladesh

Community Participation to Effectively Lower Arsenic Exposure in Bangladesh

Arsenic Tester Household Visit Protocol

Each day Sunday through Thursday you should dedicate 4 hours to being an arsenic tester. This will involve conducting 2 household sessions with study participants each day and testing additional wells when necessary.

1. Locate study participant administered baseline questionnaire from the **Subject Tracking Sheet.**

2. Ask the study participant where their primary drinking water source is located. Please confirm that the Placard ID number on this well is the same as the one recorded on the **Subject Tracking Sheet** for this study participant. If this is not the case please contact the field coordinator.

3. Organize an educational session by with the study respondent and invite any individuals present to attend. Tell them the session will begin after "I begin to test this person's well for arsenic".

4. Please record the information of the study participant having their well tested on the **House Visit Form**. Than write the name of individual's well that is being tested on the back side of the test strip (this is the opposite side from where the testing pad is located. Rinse thoroughly your reaction bottle with the lid off. Collect the study participant's drinking water from their TUBEWELL to the black line on the bottle, and place the lid back on the reaction bottle. Please ensure that the lid does not get wet. All water samples should be taken directly from the tubewell, a glass of water CANNOT be tested.

5. Return to a shady location and proceed with the **Water Arsenic Testing Kit Protocol.** Please dispose of the reagent packets into the brown plastic bag in your arsenic test kits. Please use your watch to time the 60 seconds for the swirling of the reagents. Record the time at which the reaction period starts on the test strip.

6. While the water sample is reacting. Please administer the 40 minute **Arsenic Educational Script**. Please encourage other villagers to join in on the session. Any individual that would like to attend can join the session. Be sure that the session begins promptly after the water test is started to ensure there is enough time for the script. Please only read the sections in **BOLD** on the **Arsenic Educational Script** to the session's participants.

7. Please remove the test strip after the 40 minute reaction period has been completed.*(Note: Do not shorten or exceed this time window)*. Please record the arsenic result on the **Test Strip Form,** and attach the arsenic test strip using your stapler to this form.

8. If the water arsenic concentration is below 50 ppb please place a green placard on the study participant's well*.* If the water arsenic concentration is above 50 ppb please place a red placard on the household's tubewell, and proceed to the section in **Arsenic Educational Script** called **"Assistance with well switching".**

9. Follow the same procedure in STEP 3 to test additional wells, Please complete the bottom part of the **Household Visit Form** and the **Test Strip Form** for the additional wells tested to identify a safe drinking water source for each study household. Please only test wells that are UNTESTED.

10. The reaction bottle must be cleaned thoroughly at night otherwise the bottle can be damaged.

Appendix 13

Arsenic Tester Educational Script

Arsenic Tester Educational Script

Inform own identity

30 seconds

My name is ----------. "I am a village forum worker of CCDB" or "I am an arsenic tester selected by Columbia University"

Inform organization identity

1 minute

I am part of the work of the Columbia University Arsenic Research Program in Bangladesh

We are conducting an arsenic project to try to encourage villages to use arsenic safe wells to protect their health. An interviewer has come to your home previously to ask you some questions about your drinking water source and arsenic. Today we will be testing your wells for arsenic and providing you with some educational information on arsenic. Please ask me if you have any questions during our educational outreach session.

Instruction for the Session and Water Testing
1. Find a quiet place to hold the household session
2. Try to limit the session to 10 individuals, if need have two separate sessions
3. Please ask the questions to each study respondent
4. Please have the study respondents sit in front of you not behind
5. Be Polite if incorrect answers are given
6. Please ask distracting individuals to be quiet
7. The study respondent must stay for the entire session
8. Tell the respondent the amount of arsenic present in their tubewell
9. All water samples should be taken directly from the tubewell, a glass of water CANNOT be tested.
10. Clean reaction bottle at night

Educational Instructions

PLEASE READ THE BOLD TEXT ONLY

What is Arsenic?

Arsenic is a component of the earth that has no smell, taste, or color and can move from soil to well water that we use for drinking and cooking. When this happens arsenic can be hazardous to our health.

1. *Message 1: If we drink arsenic 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 arsenocosis.*

Question 1: **What can happen to us if we drink water with arsenic?**
Question 2: **What types of illnesses can we develop?**

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

DISPLAY FLASH CARD 1 AND 2, PASS OUT FLASH CARDS AND THAN COLLECT THEM

If we drink arsenic contaminated water for a long period of time we can develop black or white spots on the chest, or roughness and spots on the palms and sole. This is called arsenocosis.

2. *Message 2: Those exposed to arsenic can suffer from chronic diseases such as cancer later in life as well as chronic heart and lung diseases.*

Question 1: **Do you know of any other diseases we can develop from arsenic exposure?**

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Those exposed to arsenic can suffer from chronic diseases such as cancer later in life as well as chronic heart and lung diseases. Chronic arsenic exposure does not cause cholera, diarrhea, or vomiting. If you or your children develop diarrhea, it is not for arsenic.

Question 2: **What is chronic lung disease?** (Damage to the lung that can cause breathing problems)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Question 3: **What is chronic heart disease?** (Damage to the heart that can cause pain)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

3. *Message 3: Arsenic can cause ill health in our children, and may affect their intelligence.*

DISPLAY FLASH CARD 3, **How can arsenic effect our children?**

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Arsenic can cause ill health in our children in other ways, and may affect their intelligence in a harmful way. For example they may do worst on their test in the classroom.

4. *Message 4: Pregnant women should not drink or cook with arsenic contaminated water because it can affect the health of their unborn child later in life.*

DISPLAY FLASH CARD 4
Question 1: **What happens if a pregnant women drinks from a well with arsenic?** (ANS. The baby gets exposed to arsenic)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Pregnant women should not drink or cook with arsenic contaminated water because it can affect the health of their unborn child later in life.

5. *Message 5: Arsenocosis does not occur by sleeping with skin-diseased person. It is not a communicable disease.*

DISPLAY CARDS 1 AND 2

Question 1: **Can arsenocosis be spread between people?** (ANS. NO)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Arsenocosis does not occur by sleeping with skin-diseased person. It is not a communicable disease.

Question 2: **If we touch people who have skin lesions from arsenic can we get sick?** (ANS. NO, Arsenic is not contagious)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

6. *Message 6: Arsenic cannot be removed by boiling water.*

DISPLAY FLASH CARD 5

Question 1: **How many of you boil your water?** (IF NO ONE SAYS YES SKIP QUESTION 2)
Question 2: **Why do you boil your water?**
Question 3: **Does boiling water remove arsenic?**

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Arsenic can not be removed by boiling water.

7. *Message 7: We should not drink or cook with water from a red marked tube well because they are contaminated with arsenic*

DISPLAY FLASH CARD 6
Question 1: **Should we drink from this well?** (ANS. NO)
USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

We should not drink or cook with water from a red marked tube well because they are contaminated with arsenic. However it is okay to use a red marked tube well for hand washing, bathing , clothes washing, and washing animals. **This is because arsenic cannot penetrate the skin.**

DISPLAY FLASH CARD 6

Question 2: **What can we use this well for?** (ANS. hand washing, bathing , clothes washing, and washing animals)

8. *Message 8: 50 is the arsenic standard in Bangladesh*

50 is the arsenic standard in Bangladesh. (NO PPB)

Question 1: **Is it safe to drink from a well that has an arsenic level of 70?** (ANS. NO)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

Question 2: **Is it safe to drink from a well that has a arsenic level of 30?** (ANS. YES)
Question 3: **If you have a choice of drinking from a well that have an arsenic level of 60 or 40?** (ANS. 40 ppb)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS TO ANSWER QUESTIONS

9. *Message 9: We should use water from tube wells marked green for drinking & cooking purpose*

DISPLAY FLASH CARD 7

Question 1: **Should we drink from this well?** (ANS. Yes)

USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE RESPONDENTS
TO ANSWER QUESTIONS

We should use water from tube wells marked green for drinking & cooking
purpose. Green wells have a level of arsenic below 50.

Question 2: DISPLAY CARD 6
What level of arsenic does this well have? (ANS. More than 50)

Question 3: DISPLAY CARD 7
What level of arsenic does this well have? (ANS. Less than 50)

REVIEW: USE APPLAUSES FOR CORRECT ANSWERS TO ENCOURAGE
RESPONDENTS TO ANSWER QUESTIONS

Question 1: **If someone tries to drink arsenic contaminated water what will you be**
your role in stopping this? (ANS: You should encourage them to use a green tubewell.
You should also encourage your neighbors with safe tube wells to share)
Question 2: **What can you use a red tube well for?** (ANS hand washing, bathing,
clothes washing, and animal washing)
Question 3: **Should we drink from wells that have arsenic level of 100?** (ANS:NO)
Question 4: **Should we drink from wells that have an arsenic level of 20?** (ANS: Yes)
Question 5: **What is arsenocosis?** (ANS: developing black or white spots on the chest, or
roughness and spots on the palms and sole.)
Question 6: **How is arsenic related illness spread?** (ANS: By drinking or cooking with
arsenic contaminated water)
Question 7: **Can arsenic exposure cause cholera?** (ANS.NO)
Question 8: **Can arsenic exposure cause vomiting?** (ANS. NO)
Question 9: **Can arsenic exposure cause such as chronic heart and lung diseases?**
(ANS.YES)
Question 10: **Can arsenic exposure diarrhea?** (ANS.NO)
Question 11: **How must we protect our children?** (ANS. We must ensure they drink
from green tubewells)
Question 12: **What should we do if we see a child drinking from a red tubewell?**
(ANS. Tell them to STOP we must protect the health of our children)
Question 13: **Why is arsenic bad for pregnant women?** (ANS. Can effect the health of
their unborn child)
Question 14: **Does anyone have any questions about the concepts we just discussed?**

CONCLUDING REMARKS

My role as an arsenic tester is to assist you to learn about the arsenic levels of wells in the village so that you can use this information to protect the health of your children and yourselves. If you have any questions or concerns please come and speak with me.

I can test wells located near your home to determine if they are safe for arsenic, and I can provide you with additional educational information on arsenic.

Please come to me with your concerns.

Now that you have received this educational information please take on the role of a arsenic activist among your family members and neighbors.

10. *Message 10: Our commitment is that we should drink As free water & encourage all to drink As free water.*

Question 1: **Who are the safe well owners?** (Refer to your list of safe well owners)
Question 2: **What is your commitment to those who have unsafe drinking water?**
(ANS: You should share wells for the better health of our children and ourselves)

DISPLAY FLASH CARD 8, **Arsenic can be bad for our health. Therefore to protect the health of all of us we should share our arsenic safe water with each other.**

If you have a well that is unsafe for arsenic you should communicate with your neighbors and try to find a arsenic safe well located near your home that you can use.

Every please raise you hand and repeat after me "*Our commitment is that we will inform people to drink and cook with Arsenic free water all the time, and that those with safe wells will share with others"*

Thank you for coming today

These are directions for you to assist households with well switching. These DO NOT need to be read to the session participants:

<div align="center">Assistance with well switching</div>

1. Ask study households with unsafe wells "Who would you like to share your well with?"
2. Go to this person's household to determine the arsenic status of their well, and if they are willing to share
    1. **Safe Well→** Ask the well owner if they are willing to share with the study household. If the well owner says "no", return to the study household and ask them to select another person. If the well owner says "yes" test the well for arsenic to confirm the results, and conduct a household visit with the safe well owner while the arsenic test is being conducted. Inform the study respondent of arsenic status of the well and encourage them to collect all of their drinking and cooking water from this well.
    2. **Unsafe Well→** Go back to study respondent and ask them to select another person.
    3. **Untested→** Ask the well owner if they are willing to share with the study household. If the well owner says "no", return to the study household and ask them to select another person. If the well owner says "yes" test the well for arsenic, and conduct a household visit with the safe well owner while the arsenic test is being conducted. Then refer to the procedures for a "safe well" or "unsafe well"