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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. The authors randomly selected 1,000 study respondents located in 20 villages in Singair, Bangladesh. The main outcome was the change in knowledge of arsenic from baseline to follow-up 4 to 6 months after the household received the intervention. This was assessed through a pre- and postintervention quiz concerning knowledge of arsenic. Respondents were between 18 and 102 years of age, with an average age of 37 years; 99.9% were female. The knowledge of arsenic quiz scores for study participants were significantly higher at follow-up compared with 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 increased the proportion of respondents who 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. This study demonstrates that a household-level arsenic educational program can be used to significantly increase arsenic awareness in Bangladesh.

Keywords

arsenic, developing countries, educational intervention

In Bangladesh, it has been estimated that half of the 10 million tubewells in the country do not meet the World Health Organization guideline for arsenic of 10 µg/L because of naturally occurring arsenic in the groundwater of the Bengal Basin (Ahmed et al., 2006). Drinking water containing elevated levels of arsenic has been associated with cancers of the skin, bladder, and lung (Chen & Ahsan 2004; Marshall et al., 2007; Morales, Ryan, Kuo, Wu, & Chen, 2000); reproductive and developmental effects (Calderon et al., 2001; Wasserman et al., 2011); cardiovascular disease (Chen, Factor-Litvak, et al., 2007; Chen et al., 2011); skin lesions (Ahsan et al., 2006; Haque et al., 2003); reduced intellectual function in children (Wasserman et al., 2004; Wasserman et al., 2007; Wasserman et al., 2011); and mortality (Argos et al., 2010).

Arsenic mitigation in Bangladesh, though significant, has impacted less than half of the affected population (Ahmed et al., 2006). The most common arsenic mitigation option in Bangladesh at 29% is well switching, which involves switching from an arsenic unsafe well to an arsenic-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 arsenic. Arsenic mitigation options such arsenic filters and pond sand filter were used by only a very small proportion of the population. The current scientific literature suggests that the temporal variability of arsenic in tubewell water is low (Cheng, van Geen, Seddique, & Ahmed, 2005; Dhar et al., 2008;

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Fendorf, Michael, & van Geen, 2010; Steinmaus, Yuan, & Smith, 2005; Thundiyil, Yuan, & Smith, 2007).

Despite the growing literature on the health implications of arsenic, millions of people in Bangladesh continue to drink well water containing elevated levels of arsenic even though arsenic-safe water is often available from other wells located within a short walking distance (100 m; van Geen et al., 2002). The majority of the arsenic communication materials developed in Bangladesh 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 arsenic 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 on 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 (Glanz, Rimer, & Viswanath, 2008). Our educational materials focused on increasing perceived susceptibility and severity to arsenic-related illnesses and increasing self-efficacy to arsenic-related illnesses through arsenic testing and well labeling to identify arsenic-safe wells located in a respondent's village.

In 2010, an arsenic education and water arsenic testing intervention was developed for rural villages in Singair, Bangladesh, to increase awareness of the health implications of arsenic and methods to reduce arsenic exposure. A causal pathway was proposed in which the provision of household-level arsenic awareness education and water arsenic testing services would increase awareness about arsenic in these communities and thereby encourage households to use arsenic-safe drinking water sources, leading to a reduction in urinary arsenic. A decline in arsenic exposure, resulting from our intervention, has been described elsewhere (George et al., 2011). The purpose of this article is to describe the arsenic education intervention itself and evaluate the effectiveness of the intervention in improving arsenic awareness as assessed through a pre- and postintervention knowledge of arsenic quiz.

Method

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 arsenic concentrations present.

Study Design

This study was an evaluation of an arsenic educational program disseminated to 1,000 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 6,746 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: arsenic 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 arsenic 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 (a) be the person in the household responsible for primary drinking water collection, (b) be using an untested well, and (c) be 18 years of age or older. Individuals were excluded if (a) they had an arsenic filter, (b) they obtained water from an arsenic treatment plant, and (c) they did not have a primary well from which they collected most of their household's drinking water.

Intervention

This arsenic educational program provided household-level arsenic education to study households based on the current scientific literature concerning the health implications of arsenic, previous studies assessing arsenic awareness in the population (Aziz, Boyle, & Rahman, 2006; Caldwell et al., 2006; Parvez et al., 2006; Paul, 2004), and the results of our own 3-month arsenic educational pilot study.

Twenty village workers, selected by Christian Commission for Development Bangladesh 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 (Table 1). 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 5-day intensive training on how to effectively disseminate arsenic education and measure the arsenic content of wells using a field testing kit.

The arsenic testers went to each study household at least once to conduct a structured 40-minute arsenic educational session, measure the arsenic concentration of the household's primary well, and assist participants with unsafe wells to locate a nearby "arsenic-safe" drinking water source. The arsenic testers conducted these tasks in each study village for 3 months.

Table 1. Characteristics of Arsenic Testers

	Arsenic Testers (N = 10)
Age in years (Mean ± SD [Range])	23 ± 6 (18-54)
Educational level (Mean ± SD [Range])	10 ± 1 (8-13)
Female	55%
Muslim	80%
Hindu	20%

The arsenic educational awareness session focused on disseminating 10 key arsenic educational messages on the health implications of arsenic and recommendations to reduce arsenic exposure. These key messages are presented in the supplementary materials (http://heb.sagepub.com/supplemental). 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 and 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 postintervention quiz to assess the respondents' knowledge of arsenic. Each study respondent was interviewed at baseline and at follow-up, 4 to 6 months after receiving the intervention. In the baseline and follow-up questionnaires, information was obtained on sources of knowledge about arsenic and sociodemographic characteristics.

In the quiz, respondents were asked questions on the health implications of arsenic and arsenic mitigation options. This quiz can be found in the supplementary materials (http://heb.sagepub.com/supplemental). One point was given for a correct item and zero points for an incorrect item. Possible quiz scores ranged between 0 and 20.

Statistical Methods

The primary hypothesis was that the provision of arsenic education and water arsenic testing would significantly increase knowledge of arsenic in the study population at follow-up in comparison with baseline. The outcome variable was change in knowledge of arsenic quiz score between baseline and follow-up. McNemar tests were used to compare differences between the baseline and follow-up knowledge of arsenic quiz scores. The determinants of baseline and follow-up knowledge of arsenic 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 were used to account for within-village differences (Pan, 2001). All analyses were performed using SAS, Version 9.2 (SAS Institute, Inc., Cary, NC).

Table 2. Characteristics of Study Population

Characteristics	Frequency	Percentage
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
Elementary or higher	443	46
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% to 60%	632	65
More than 60%	338	35
Minutes 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

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, 1,000 participants received the arsenic 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 2. 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 arsenic. Household arsenic education sessions had between 2 and 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 arsenic. A total of 585 participants (60%) reported obtaining the most information from television. The second most common source reported was radio. Twenty-nine percent reported receiving no information from media sources, and 4% reported receiving information from leaflets, posters, and books.

Pre- and Postintervention Arsenic Quiz Score Comparison

The knowledge of arsenic quiz scores for study participants were significantly higher at follow-up compared with 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 arsenic were examined using generalized estimating equations models (Table 3). 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, whereas age was negatively associated with scores ($p < .02$).

Respondents who received arsenic information from television and/or radio prior to the baseline survey were found to have a significantly higher scores at baseline when compared with those who received no information from media sources (p for ANOVA <.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 <.05). Follow-up knowledge of arsenic quiz score was significantly greater in those with unsafe wells who had more wells tested to locate an arsenic-safe drinking water source ($p = .0002$).

Pre- and Postintervention Quiz Item Comparison

All the responses to quiz items significantly improved at follow-up compared with baseline. Table 4 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 arsenic 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 arsenic, 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 arsenic-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 arsenic-contaminated water for drinking and cooking. At baseline, more than 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 who could correctly identify the health implications of arsenic 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 arsenic.

Discussion

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

Table 3. Determinants of Knowledge of Arsenic Quiz Scores at Baseline and Follow-Up

	Knowledge of Arsenic Quiz Scores			
Characteristics	*N*	Mean	*SD*	*p* Values[a]
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	.0017
Levels 1-5	233	8.8	2.6	
More than Level 5	224	9.8	2.9	
Age (years)				
18-27	242	9.5	3.0	<.0001
27-36	269	8.7	2.8	
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	<.0001
Radio	42	8.3	2.3	
Television	277	8.9	2.7	
Radio and television	370	9.6	2.6	
Follow-up knowledge of arsenic[b]				
Respondent read and write				
Yes	584	13.3	3.4	<.0001
No	386	15.5	3.0	
Head of household educational level				
No formal education	510	13.4	3.4	.0113
Level 1-5	226	14.9	3.3	
More than Leven 5	217	15.1	3.1	
Age (years)				
18-27	223	15.0	3.1	0.0191
27-36	263	14.8	3.3	
36-43	248	14.0	3.2	
44-102	236	12.8	3.5	
Wells tested for arsenic (baseline unsafe-well users)				
1 Well tested	176	14.2	3.4	0.0002
2 Wells tested	129	14.3	3.5	
3 or more wells tested	192	15.1	2.9	

a. *p* Values are from generalized estimating equation models that were adjusted for all variables in each section of the table.
b. Generalized estimating equation model was adjusted for baseline knowledge of arsenic quiz score.

given that this area had received well water arsenic testing of all drinking water sources by the Bangladesh Arsenic Mitigation Water Supply Project program in 2004. The results of the baseline survey also indicated confusion in the population regarding the health implications of chronic arsenic exposure. The majority incorrectly stated that cholera, diarrhea, and vomiting could be caused by arsenic. This is consistent with previous studies that suggest a lack of understanding of the health implications of arsenic exposure beyond skin lesions (Aziz et al., 2006; Caldwell, 2003; Hanchett, Nahar, Van Agthoven, Geers, & Rezvi, 2002; Paul, 2004). At baseline, nearly 70% of participants incorrectly stated boiling could remove arsenic 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. (2002) reported that 41% of women surveyed (n = 251) thought that arsenicosis was a contagious disease. At baseline, the majority of participants were aware that one should not cook or drink with arsenic-contaminated water. However, more than 80% of respondents incorrectly stated that water from an arsenic-contaminated well should not be used for any purpose. These findings suggest that the current awareness in the population on the health implications of arsenic is low. Furthermore, many

Table 4. Changes in Specific Quiz Items Between Baseline and Follow-Up

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

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

households are unaware of the safe uses of arsenic-contaminated water and how to effectively remove arsenic from water.

At baseline, the majority of study households had obtained their knowledge about arsenic from radio, television, family members, and neighbors. This result is consistent with a nationally representative survey conducted by Caldwell in 2000 (Caldwell et al., 2006). Arsenic information provided through television and radio was significantly associated with increased arsenic awareness in the study population at baseline. However, the majority of respondents still had an incomplete understanding of the health implications of arsenic 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 arsenic education program was successful in increasing arsenic awareness. We observed a significant increase in follow-up knowledge of arsenic quiz scores compared with baseline quiz scores demonstrating support for our primary study hypothesis. The most important messages for reducing one's arsenic exposure were understood by almost the entire study population, that is, 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 arsenic standard in Bangladesh. The education program was also effective in increasing awareness on most of the safe uses of arsenic-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 arsenic 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 arsenic. 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 nongovernmental organization in Bangladesh, involved training community members to test tubewells for arsenic and provide arsenic 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 arsenic exposure (Hadi, 2003). A second study of the 18 District Towns Project, an arsenic education and water arsenic testing program, found that many people were unaware of the less visible symptoms of arsenic exposure such as cancers and effects on child and maternal health (Hanchett et al., 2002). These results indicate that future research is needed to develop effective media communication strategies to dispel these misconceptions.

A reduction in arsenic exposure associated with our intervention has been previously reported (unpublished data). The two main outcome variables used to assess arsenic exposure were self-reported well switching and change in urinary arsenic concentration from baseline to follow-up. Overall, 53% of respondents with unsafe wells at baseline reported switching to alternative wells at follow-up. Among unsafe-well owners, the most commonly reported reasons for not switching wells were the following: (a) long distance to a safe well (57%), (b) family ownership of well (20%), and (c) owner(s) of safe wells near the respondent's home do not want to share (11%). Follow-up knowledge of arsenic quiz scores were positively related to well switching, although not significantly so. The average urinary arsenic concentrations for those with unsafe well at baseline who switched to safe wells at follow-up decreased significantly (unpublished data). 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 with 35% well switching in villages with ≥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 (Chen, van Geen, et al., 2007; Opar et al., 2007; Schoenfeld, 2005). A recent report of a nationwide survey in Bangladesh indicated that 77% of the population lives in areas with between 0% and 60% arsenic contamination (Department of Public Health Engineering, 2010). Therefore, our intervention is a viable option for the majority of the population residing in arsenic-affected areas of Bangladesh.

A limitation of this study was that there was no control group. Therefore, we are unable to distinguish the impact of the arsenic testing itself and the arsenic education that we provided on the knowledge of arsenic. A second limitation was the relatively short 3-month duration of our program. We assume that the impact of the intervention would be greater if provided over a longer duration.

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

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References

Ahmed, M. F., Ahuja, S., Alauddin, M., Hug, S. J., Lloyd, J. R., Pfaff, A., . . . van Geen, A. (2006). Epidemiology. Ensuring safe drinking water in Bangladesh. *Science, 314*, 1687-1688.

Ahsan, H., Chen, Y., Parvez, F., Zablotska, L., Argos, M., Hussain, I., . . . Graziano, J. H. (2006). Arsenic exposure from drinking water and risk of premalignant skin lesions in Bangladesh: Baseline results from the Health Effects of Arsenic Longitudinal Study. *American Journal of Epidemiology, 163*, 1138-1148.

Argos, M., Kalra, T., Rathouz, P. J., Chen, Y., Pierce, B., Parvez, F., . . . Ahsan, H. (2010). Arsenic exposure from drinking water, and all-cause and chronic-disease mortalities in Bangladesh (HEALS): A prospective cohort study. *Lancet, 376*, 252-258.

Aziz, S. N., Boyle, K. J., & Rahman, M. (2006). Knowledge of arsenic in drinking-water: Risks and avoidance in Matlab, Bangladesh. *Journal of Health, Population, and Nutrition, 24*, 327-335.

Calderon, J., Navarro, M. E., Jimenez-Capdeville, M. E., Santos-Diaz, M. A., Golden, A., Rodriguez-Leyva, I., . . . Díaz-Barriga, F. (2001). Exposure to arsenic and lead and neuropsychological development in Mexican children. *Environmental Research, 85*(2), 69-76.

Caldwell, B. (2003). Tubewells and arsenic in Bangladesh: Challenging a public health success story. *International Journal of Population Geography, 9*, 23-28.

Caldwell, B. K., Smith, W. T., Lokuge, K., Ranmuthugala, G., Dear, K., Milton, A. H., . . . Mitra**, S. N.** (2006). Access to drinking-water and arsenicosis in Bangladesh. *Journal of Health, Population, and Nutrition, 24*, 336-345.

Chen, Y., & Ahsan, H. (2004). Cancer burden from arsenic in drinking water in Bangladesh. *American Journal of Public Health, 94*, 741-744.

Chen, Y., Factor-Litvak, P., Howe, G. R., Graziano, J. H., Brandt-Rauf, P., Parvez, F., . . . Ahsan, H. (2007). Arsenic exposure from drinking water, dietary intakes of B vitamins and folate, and risk of high blood pressure in Bangladesh: A population-based, cross-sectional study. *American Journal of Epidemiology, 165*, 541-552.

Chen, Y., Graziano, J. H., Parvez, F., Liu, M., Slavkovich, V., Kalra, T., . . . Ahsan, H. (2011). Arsenic exposure from drinking water and mortality from cardiovascular disease in Bangladesh: Prospective cohort study. *British Medical Journal, 342*, d2431.

Chen, Y., van Geen, A., Graziano, J. H., Pfaff, A., Madajewicz, M., Parvez, F., . . . Ahsan, H. (2007). Reduction in urinary arsenic levels in response to arsenic mitigation efforts in Araihazar, Bangladesh. *Environmental Health Perspectives, 115*, 917-923.

Cheng, Z., van Geen, A., Seddique, A. A., & Ahmed, K. M. (2005). Limited temporal variability of arsenic concentrations in 20 wells monitored for 3 years in Araihazar, Bangladesh. *Environmental Science & Technology, 39*, 4759-4766.

Dhar, R., Zheng, Y., Stute, M., van Geen, A., Cheng, Z., Shanewaz, M., . . . Ahmed, K. M. (2008). Temporal variability of groundwater chemistry in shallow and deep aquifers of Araihazar, Bangladesh. *Journal of Contaminant Hydrology, 99*(1-4), 97-111.

Department of Public Health Engineering. (2010, June). *Situation analysis of arsenic mitigation 2009*. Dhaka, Bangladesh: Department of Public Health Engineering Bangladesh and Japan International Cooperation Agency.

Fendorf, S., Michael, H. A., & van Geen, A. (2010). Spatial and temporal variations of groundwater arsenic in South and Southeast Asia. *Science, 328*, 1123-1127.

George, C. M., Geen, A. V., Slavkovich, V. N., Singha, A., Levy, D., Islam, T., . . . Graziano, J. (2011). A cluster-based randomized controlled trial promoting community participation in arsenic mitigation efforts in Bangladesh. *Environmental Health, 11*, 41.

Glanz, K., Rimer, B. K., & Viswanath, K. (Eds.). (2008). *Health behavior and health education: Theory, research, and practice*. San Francisco, CA: Wiley.

Hadi, A. (2003). Fighting arsenic at the grassroots: experience of BRAC's community awareness initiative in Bangladesh. *Health Policy and Planning, 18*, 93-100.

Hanchett, S., Nahar, Q., Van Agthoven, A., Geers, C., & Rezvi, M. D. F. J. (2002). Increasing awareness of arsenic in Bangladesh: lessons from a public education programme. *Health Policy and Planning, 17*, 393-401.

Haque, R., Mazumder, D. N., Samanta, S., Ghosh, N., Kalman, D., Smith, M. M., . . . Smith, A. H. (2003). Arsenic in drinking water and skin lesions: Dose-response data from West Bengal, India. *Epidemiology, 14*, 174-182.

Marshall, G., Ferreccio, C., Yuan, Y., Bates, M. N., Steinmaus, C., Selvin, S., . . . Smith, A. H. (2007). Fifty-year study of lung and bladder cancer mortality in Chile related to arsenic in drinking water. *Journal of the National Cancer Institute, 99*, 920-928.

Morales, K. H., Ryan, L., Kuo, T. L., Wu, M. M., & Chen, C. J. (2000). Risk of internal cancers from arsenic in drinking water. *Environmental Health Perspectives, 108*, 655-661.

Opar, A., Pfaff, A., Seddique, A. A., Ahmed, K. M., Graziano, J. H., & van Geen, A. (2007). Responses of 6500 households to arsenic mitigation in Araihazar, Bangladesh. *Health & Place, 13*, 164-172.

Pan, W. (2001). Akaike's information criterion in generalized estimating equations. *Biometrics, 57*, 120-125.

Parvez, F., Chen, Y., Argos, M., Iftikhar Hussain, A. Z. M. I., Momotaj, H., Dhar, R., . . . Ahsan, H. (2006). Prevalence of arsenic exposure from drinking water and awareness of its health risks in a Bangladeshi population: Results from a large population-based study. *Environmental Health Perspectives, 114*, 355-359.

Paul, B. K. (2004). Arsenic contamination awareness among the rural residents in Bangladesh. *Social Science & Medicine, 59*, 1741-1755.

Schoenfeld, A. (2005). *Area, village, and household response to arsenic testing and labeling of tubewells in Araihazar, Bangladesh*. New York, NY: Columbia University, Department of Earth and Environmental Science Journalism.

Steinmaus, C. M., Yuan, Y., & Smith, A. H. (2005). The temporal stability of arsenic concentrations in well water in western Nevada. *Environmental Research, 99*, 164-168.

Thundiyil, J. G., Yuan, Y., & Smith, A. H. (2007). Seasonal variation of arsenic concentration in wells in Nevada. *Environmental Research, 104*, 367-373.

van Geen, A., Ahsan, H., Horneman, A. H., Dhar, R. K., Zheng, Y., Hussain, I., . . . Graziano, J. H. (2002). Promotion of well-switching to mitigate the current arsenic crisis in Bangladesh. *Bulletin of the World Health Organization, 80*, 732-737.

Wasserman, G. A., Liu, X., Parvez, F., Ahsan, H., Factor-Litvak, P., Kline, J., . . . Graziano, J. H. (2007). Water arsenic exposure and intellectual function in 6-year-old children in Araihazar, Bangladesh. *Environmental Health Perspectives, 115*, 285-289.

Wasserman, G. A., Liu, X., Parvez, F., Ahsan, H., Factor-Litvak, P., van Geen, A., . . . Graziano, J. H. (2004). Water arsenic exposure and children's intellectual function in Araihazar, Bangladesh. *Environmental Health* Perspectives, *112*, 1329-1333.

Wasserman, G. A., Liu, X., Parvez, F., Factor-Litvak, P., Ahsan, H., Levy, D., . . . Graziano, J. H. (2011). Arsenic and manganese exposure and children's intellectual function. *Neurotoxicology, 32*, 450-457.