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George A. Sorial
Jihua Hong

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TABLE OF CONTENTS

Non-point Sources

Wastewater Discharge Management

Drinking Water

Water Quality Assessment/Management

Adsortion/Desorption for Wastewater Treatment

Physico-chemical Wastewater Treatment

Reactions and Degradation of Wastewater Contaminants

Nanotechnology Applications

AIR POLLUTION AND AIR QUALITY CONTROL

Aerosol

Air Quality Assessment

Transport of Pollutants

Waste Gas Control Techniques

Air Pollutant Monitoring

Hazardous Gas Biofiltration

INTRODUCTION

The Fifth International Conference on Environmental Science and Technology 2010 was held in Houston, Texas, USA, July 12-16, 2010. The Program included 16 sections, containing 60 sessions with approximately 600 platform and poster presentations. This conference series strives to provide a platform for an extremely diverse group of environmental topics for engineers and scientists from around the world.

Authors of the presentations accepted for the program were invited to submit their papers to the Conference Organizing Committee. More than 130 papers were received and then reviewed by the editors, session chairs, and the members of the Scientific/Technical Committee of the conference. Those papers and abstracts accepted for publication were assembled into two volumes.

Sections are arranged basically according to their order listed in the original program except the sessions entitled Bio-Assessment and Toxicology and Modeling. This exception was made to balance the length of the two volumes.

The conference also consisted of having a plenary session with four speakers from different universities at the United States and US Environmental Protection Agency. The abstracts of their talks are contained in this proceeding together with a link to their full presentation.

Environmental Science and Technology 2010 (I) contains the following sections:
• Plennary Session
• Water Pollution and Water Quality Control
• Air Pollution and Air Quality Control
• Ecosystem Assessment and Restoration
• Environmental Analysis and Measurements

Sections included in Environmental Science and Technology 2010 (II) are as follows:
• Land (Soil, Waste Solid) Pollution and Remediation
• Bio-Assessment and Toxicology
• Wetlands and Sediments
• Global Warming
• Metals (Distribution, Removal, Remediation, Speciation, and Phytoremediation)
• Characterization and Degradation of Organic Pollutants
• GIS for Environmental Assessment, Database, and Remote Sensing Applications
• Society and the Environment
• Environmental Planning and Management
• Renewable Energy Development

We would like to especially thank the session chairs who were instrumental in the success of the conference. The Conference was sponsored and organized by the American Academy of Sciences, with financial contributions from the co-sponsors and supporting organizations.

The papers in these proceedings represent the authors' results and opinions. No sponsors, cosponsors, participating organizations or editors should be construed as endorsing any specific contents or conclusions in the proceedings.

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STATUS OF ARSENIC CONTAMINATION IN GROUNDWATER OF SOUTHERN BANGLADESH: A POPULATION-BASED SURVEY

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ABSTRACT-This study explores the status of arsenic contamination in tubewell water in southern Bangladesh. Through a survey of 6,593 households, a total of 3,812 tubewells were sampled at baseline (2006/07) and 3,591 at midline (2009). Households were selected through multi-stage sampling procedure where each sub-district was considered as a cluster. Findings reveal that proportion of unmarked (to identify presence of arsenic) tubewells increased from 80% at baseline to 90% at midline ($p<0.001$). Proportion of tested tubewells was significantly decreased from 75% at baseline to 69% at midline ($p<0.001$). Of the tested tubewells, 60% was reported to be free from arsenic contamination. This study underlines that information, education and communication campaigns should be strengthened to raise awareness regarding negative effect of arsenic on health.

Key words: Arsenic, Bangladesh, Groundwater, Ultra poor

INTRODUCTION

The arsenic contamination of groundwater in Bangladesh is the biggest natural calamity in the world in terms of the affected population. When rural people had developed the habit of drinking tubewell water, arsenic was found in tubewell water in many parts of Bangladesh too high concentration which has drastically reduced the coverage of safe water (GED & UNDP, 2009). It was reported that the people in 62 out of 65 districts of Bangladesh were suffering from various diseases because of drinking arsenic-contaminated tubewell water. More than 70% of the country's 150 million people are at risk and 32-52 million are potentially exposed to arsenic contamination above the Bangladesh drinking water standard ($>5\mu gL^{-1}$) where about 90% people live in rural areas (Roy *et al*, 2008). It was reported that some proportion of tubewells are also contaminated with bacteria which are mainly due to poor maintenance. The Department of Public Health Engineering (DPHE) is responsible for marking arsenic-contaminated and arsenic-free tubewells as red and green respectively and warned the villagers against drinking water from the red tubewells.

Arsenic contamination impacts on poor population of Bangladesh. It has been well documented that the first victims of such pollution are the people with low nutrition (often people with low body weight) (IMF, 2006). Women suffer from arsenic not only in terms of physical illness but also social consequences as they cannot get married and are seen as a burden to their families and their communities (SOS, 2010). In a recent survey conducted in all districts of Bangladesh, nearly 19,000 arsenic patients have so for been identified from 104.9 million arsenic-affected population. This may cause many health effects including cancer of the liver, lung, bladder and skin (Smith et al. 1992). The United States Environmental Protection Agency (EPA) said that in Bangladesh with regard to protected future cases of arsenic-related health burden, skin cancer would affect 375,000 people (Roy *et al*., 2008). The estimate also suggested that in Bangladesh approximately 6,500 people may die from cancer every year and 326,000 people in 50 years, while 2.5 million people will develop some kind of arsenicosis during that period. Availability of arsenic mitigation technologies and improving habit for using these technologies are the basic options for safe drinking in the rural areas. Recently, a report on water and sanitation explained necessity of the immediate measures against the menac of arsenic contamination in Bangladesh (World Bank, 2006). Acceptance of alternative arsenic mitigation technologies depends not only on the level of awareness but also physiocultural and socioeconomic variations among communities (BRAC, 2003). Currently 16% population is covered by arsenic mitigation technology and it is expected that the coverage will be increased to about 22% by 2015 (GED & UNDP, 2009).

The government of Bangladesh, incorporating stakeholders, has initiated different schemes to scale up access to safe water in rural areas and small towns. Still many rural people drink tubewell without knowing arsenic contamination level and some people drink even knowing as there is no alternate source of water available to them. Lack of access to safe water and sanitary latrine, and poor hygiene behavior are responsible for death of thousands of people of Bangladesh in every year. Water, Sanitation and Hygiene (WASH) programme of BRAC has been working with the government of Bangladesh since 2006 in 150 sub-districts for providing safe and sustainable drinking water, improving sanitation and hygiene practices to achieve Millennium Development Goals (MDG 7, target 10) by 2015 (BRAC, 2008). Although there are several reports published on the impact of WASH intervention. However, no study has yet been conducted on the impact of WASH intervention for safe water in the arsenic-affected areas of southern Bangladesh. Therefore, the aim of the study was to explore the changes in status of arsenic test and exposures to arsenic-contaminated tubwell water in arsenic prone southern Bangladesh.

MATERIALS AND METHODS

This study was done in 11 sub-districts under BRAC WASH programme where arsenic contamination was found common (TABLE 1). Arsenic-related information was collected by using a structured questionnaire developed during the baseline followed by midline survey. Respondent was adult female member of a household who used tubewell water for drinking.

TABLE 1 STUDY SITES

Name of district	Name of sub-district
Jessore	Monirampur
	Keshobpur
	Jhikorgachha
	Sharsha
Khulna	Dumira
	Digalia
	Fultala
	Rupsha
	Botiaghata
Noakhali	Sonaimuri
	Senbug

Sampling procedure for the household survey. Through survey of 6,593 households, the study sampled 3,812 tubewells in the baseline (2006/07) followed-up 3,591 in the midline (2009) in 11 sub-districts of the southern Bangladesh. Households were selected through multi-stage sampling where each sub-district was considered as a cluster. A total of 600 respondents were selected from each cluster. The economic status of the respondents was classified as ultra poor, poor and non-poor households according to WASH baseline findings (BRAC, 2008). The ultra poor people who were landless or homeless and had no fixed source of income were selected. The household who had up to 100 decimal of land (agricultural and homestead) and used to sell manual labour for living was considered as poor. On the otherhand, the household that do not fall in any of the above category called non-poor.

Data collection and quality control. Data were collected by the trained enumerators who had previous experience and completed at least fourteen years of education. Information on water and other demographic and socioeconomic variables for each sampling unit was collected using structured questionnaires and spot observations. After entry, 20% of the data were rechecked to identify any inconsistencies.

Statistical Analysis. The statistical analysis was performed with SPSS 16.0 software. The groups were compared for all variables using the chi-square test to compare categorical value. The differences were considered statistically significant at the $p<0.05$ (two-tailed test) level with admissible error of 5%.

Ethical consideration. Before the interview verbal informed consent was taken from the participants. The verbal informed consent form was read out to the participants in native language (*Bengali)* by the interviewer. Participants were informed about the objective of the study. They were also informed that their participation was entirely voluntary and they had the right to withdraw from the study at any time.

Furthermore, it was informed that they had right to refuse answers to any questions if they feel uncomfortable. Confidentiality was maintained; survey questionnaire was kept secure with the researcher and was not shared with anybody other than for research purpose. Permission to conduct this study was obtained early from IRPC (Internal Review and Publication Committee) of the Research and Evaluation Division of BRAC.

RESULTS AND DISCUSSION

Profile of the respondents. The ecinomic status, educaton, main occupation, marital status, responsibility to household water collection and age of the participants are presented in TABLE 2. Around 53% respondents were non-poor and 30% were poor and remaining were ultra poor. The main occupation of most of the respondents was household works. Around 36% respondents were illiterate and 30% passed primary education, around 32% secondary, 1.2% higher secondary and remaining passed bachelor degree. More than 90% respondents were married. Among the respondents, 43% were in age limit 10-30 years, 49% in 31-50 years and remaining were in higher ages.

TABLE 2 PROFILE OF THE RESPONDENTS

Indicators		Percent	Indicators		Percent
Economic status			Marital condition		
	Ultra poor	17.7		Married	90.8
	Poor	29.5		Unmarried	2.7
	Non-poor	52.8		Others (widow, separated & divorced)	7.5
Education			Responsible for household water collection		
	Illiterate	35.6		Women	95
	Primary	30.2		Other members	5
	Secondary	31.7			
	Higher secondary	1.2			
	Bachelor	1.3			
Main occupation			Age (Year)		
	Household works	93.2		11-30	43
	Day laborer	1.9		31-50	49
	Student	1.2		51-60	6
	Employee	0.8		61-above	2
	Business	0.2			
	Others (Agriculture, rickshaw pulling, work in bus, etc.)	2.7			
n = 6,593					

Status of tubewell marking. Red-marked tubewells indicate arsenic contamination of water while green-marked tubewells indicate arsenic free. The percentages of unmarked tubewells increased significantly ($p<0.001$) in the midline (TABLE 3) though it was high risk area for drinking tubewell water. This might be because of lack of awareness among the households or lack of monitoring and improper management.

TABLE 3 STATUS OF TUBEWELL MARKING

Status	Baseline	Midline	P value
Red marked (%)	8.9	3.8	
Green marked (%)	8.7	5.9	
Unmarked (%)	82.4	90.3	<0.001
n	3812	3591	

TABLE 4 shows the marking status of tubewells in different districts. Marking of tubewells was less in Khulna district both at baseline and midline where more than 90% of the tubewells were unmarked (TABLE 4). Whereas, most of the tubewells (96%) were unmarked in the Noakhali district, the highest arsenic concentration (4730 μgL^{-1}) area which was a new experience in 20 years in arsenic research [10].

TABLE 4 STATUS OF MARKING OF TUBEWELL IN DIFFERENT DISTRICTS

Marking status	Arsenic contaminated tubewells					
	Jessore		Khulna		Noakhali	
	Baseline	Midline	Baseline	Midline	Baseline	Midline
Red marked	13.9	6.9	1.2	0.9	9.7	1.8
Green marked	12.8	7.7	7.5	5.9	3.0	2.2
Unmarked	73.4	85.4	91.4	93.2	87.3	95.9
n	1685	1584	1191	1246	936	761

TABLE 5 presents the status of marking of tubewells based on economic category of the participants. The proportion of unmarked tubewells increased in the midline among all categories (ultra poor, poor and non-poor) of households. The proportion of unmarked tubewells increased significantly from 81% at baseline to 93% at midline for ultra poor households which were found highest among all categories of households.

TABLE 5 STATUS OF MARKING OF TUBEWELL BY ECONOMIC CATEGORY

Marking status	Household statuses					
	Ultra poor		Poor		Non-poor	
	Baseline	Midline	Baseline	Midline	Baseline	Midline
Red marked (%)	11.5	2.6	8.2	3.7	8.6	4.0
Green marked (%)	7.5	4.0	9.1	6.7	8.8	6.0
Unmarked (%)	81.0	93.4	82.7	89.6	82.6	89.9
n	521	454	1061	998	2230	2128

Status of response on arsenic testing and results of testing tubewell water. The status of responses on arsenic testing and the results of testing in tubewell water among the study households are presented in TABLE 6 and 7. Proportion of tested tubewells significantly decreased from 75% at baseline to 69% at midline. However, around 24% of the tubewells were not tested at baseline and 29% at midline (Table 6). It indicates that though it was a high risk area for drinking tubewell water but people were not much aware of arsenic contamination in tubewell water and its affect on public health.

TABLE 6 STATUS OF RESPONSES ON ARSENIC TESTING OF TUBEWELL WATER

Status of knowledge	Baseline	Midline	P value
Tubewells tested for arsenic identification (%)	74.9	69.3	<0.001
Tubewells not tested for arsenic identification (%)	23.5	28.6	
Don't know whether tunewells water tested/not tested (%)	1.6	2.1	
	2212	2281	

Of the tested tubewells, around 60% were reported to be arsenic-free and 40% had arsenic contamination (TABLE 7) which could be compared with the findings of other research where 43% of tubewells were found to be arsenic-contaminated (Chakraborti *et al*., 2008) Some changes occurred where a small proportion likely to be increased at midline who did not know about testing of tubewell water for arsenic identification and the test results. This might be because of lack of awareness raising activities and lack of facilities for arsenic testing in the study area or both. Knowledge on the affect of arsenic in public health is important for raising awareness for safe water. It would be more effective for the people of that area if awareness raising activities could be increased on arsenic free safe water and mitigation options.

TABLE 7 STATUS OF RESPONSES ON THE RESULTS OF TESTING OF TUBEWELL WATER FOR ARSENIC CONTAMINATION

Status	Baseline	Midline	P value
Arsenic free tubewells (%)	58.0	59.8	<0.001
Arsenic contaminated tubewells (%)	41.8	39.7	
Don't know about the results of testing (%)	0.2	0.6	
n	1656	1581	

CONCLUSION

This study reveals that the household members still drink water from arsenic-contaminated tubewells. Proportion of respondents who did not know about arsenic test and test results of tubewell water increased in the midline. This might be because of lack of awareness or lack of facilities for arsenic testing in the study area where more than 95% of women were responsible for collecting water from tubewells. As proportion of unmarked tubewells was high both at baseline and midline though study area was a highly risk for drinking tubewell water, it is necessary to motivate people for marking their tubewells based on results of arsenic testing. Information, education and communication campaigns should be strengthened to raise awareness and thereby testing and marking of tubewells will be enhanced. Besides, availability of arsenic-free safe water needs to be urgently ensured to prevent health hazard.

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