Compendium of Research Activities on Arsenic and Sanitation

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Policy Support Unit (PSU)
Local Government Division
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Acronyms and Abbreviations

ACF	Action Contre La Faim
AIRPs	Arsenic Iron Removal Plants
AOP	Advanced Oxidation Process
AORs	Adjusted Odds Ratios
ARF	Arsenic Removal Filter
ARI	Acute Respiratory Infections
ARTs	Arsenic Removal Technologies
As	Arsenic
AsMat	As and Health Consequences in Matlab
AT	Appropriate Technologies
B-ALP	Bone-Specific Alkaline Phosphatase
BAs	Blood Arsenic
BCSIR	Bangladesh Council of Scientific and Industrial Research
BD	Bengal Delta
BDS	Bangladesh Drinking Water Standard
BETV-SAM	Bangladesh Environmental Technology Verification-Support to Arsenic Mitigation
BINA	Bangladesh Institute of Nuclear Agriculture
BMI	Body Mass Index
BMRC	Bangladesh Medical Research Council
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
BTC	Breakthrough Curve
Ca	Calcium
CAD	Coronary Artery Disease
CARE	Contamination Assessment and Remediation of the Environment
CBO	Community Based Organization
CCCD	Centre for Control of Chronic Diseases
CCD	Center for Communicable Diseases
Cd	Cadmium
CERAR	Centre for Environmental Risk Assessment and Remediation
Cl	Chlorine
CI	Confidence Interval
CIMT	Carotid-artery Intima Media Thickness
CIs	Confidence Intervals
CLTS	Community Led Total Sanitation
Co	Cobalt
CO2	Carbon-di-oxide
COD	Chemical Oxygen Demand
Cr	Chromium
CSOs	Civil Society Organizations
Cu	Copper
CVD	Cardiovascular Disease
DAM	Dhaka Ahsania Mission
DBH	Dopamine-β-hydroxylase

DCH	Dhaka Community Hospital
DMA	Dimethylarsinic Acid
DOC	Dissolved Organic Carbon
DoE	Department of Environment
DPHE	Department of Public Health Engineering
DTW	Deep Tubewell
DW	Dry Weight
DW	Dugwells
EAIT	Engineering, Architecture and Information Technology
ECOSAN	Eco- Sanitation
EQ	Econo-Quick
FAN	Freshwater Action Network
FANSA	Freshwater Action Network South Asia
FAO	Food and Agricultural Organization
FFQ	Food Frequency Questionnaire
FT-IR	Fourier Transform Infrared
FY	Fiscal Year
GDP	Gross Domestic Product
GSH	Glutathione
HCl	Hydro-cloric Acid
HEALS	Health Effects of Arsenic Longitudinal Study
HLP	Horizontal Learning Program
HNO3	Nitric Acid
HR	Hazard Ratio
HRs	Hazard Ratios
ICDDR,B	International Centre for Diarrheal Disease Research, Bangladesh
IgG	Immunoglobulin G
IL-7	Interleukin-7
IMCH	International Maternal and Child Health
IOCS	Iron-Oxide Coated Sand
Ipth	Intact Parathyroid Hormone
IQ	Intelligence Quotient
KUET	Khulna University of Engineering and Technology
LGIs	Local Government Institutions
LRTI	Lower Respiratory Tract Infection
Ltf	Lactoferrin
MDG	Millenium Development Goal
MICS	Multiple Indicator Cluster Survey
MMA	Mono Methyl Arsonic Acid
MO	Moringaoleifera
MOH & FW	Ministry of Health and Family Welfare
MRT	Molecular Recognition Technology
MT	Methyltransferase
MUAC	Mid Upper Arm Circumference
NCSNP	NGO & Civil Society Networking Project
NGO	Non-government Organization

Ni	Nickel
NO2	Nitrogen-di-oxide
NO3	Nitric Oxide
OCETA	Ontario Centre for Environmental Technology Advancement
ODF	Open Defecation Free
ORs	Odds Ratios
PEHUP	Promoting Environmental Health for the Urban Poor
PMID	Participatory Management Initiative for Development
PO4	Phosphate
PPD	Purified protein derivative
PRA	Participatory Rural Appraisal
PSF	Pond Sand Filter
PSO	Private Sector Operators
PSTs	Problem Solving Tests
PTDI	Provisional tolerable daily intake
PVC	Perforated Polyvinyl Chloride
QOL	Quality of Life
RANAS	Risk, Attitudes, Norms, Abilities and Self-regulation
RCC	Renal Cell Cancers
RR	Relative Risk
RWH	Rainwater Harvester
RWHS	Rain Water Harvesting Systems
SAC	School-Age Children
SAH	S-adenosylhomocysteine
SAM	S-adenosylmethionine
SC	Social Competence
SES	Socioeconomic Status
SMC	School Management Committee
SNPs	Single Nucleotide Polymorphisms
SOES	School of Environmental Studies
SPE	Solid Phase Extraction
SPSS	Statistical Package for the Social Sciences
SRDI	Soil Resource Development Institute
SSS	Sustainable Sanitation System
SSTSB	Scaling Up and Sustainability of Total Sanitation in Bangladesh
STW	Shallow Tubewell
SUVA	Specific Ultra Violet Adsorption
SWDs	Surface Water Sevices
SWOT	Strength Weakness Opportunity Threats
SWS	Safe Water Supply
TCC	Transitional Cell Cancers
TCLP	Toxicity Characteristic Leaching Procedure
TDI-iAs	Total Daily Intake of Inorganic As
TG	Technological Governance
Th	Thorium
TI	Thymic Index

TN	Tin
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TW	Tubewell
UAs	Urinary Arsenic
U-As	Urinary Concentrations of Arsenic Metabolites
UDDTs	Urine Diversion Dehydration Toilets
UN	United Nation
UNICEF	United Nations International Children's Emergency Fund
URB	U-Chicago Research Bangladesh
USA	United States of America
VDCs	Provision of Effective Village Development Committees
VEGF	Vascular Endothelial Growth Factor
Vit-D	Vitamin D
VWC	Village WASH Committee
WAs	Water Arsenic
WASH	Water, Sanitation and Hygiene
WATSAN	Water and Sanitation
WHO	World Health Organization
WSP	Water and Sanitation Program
WSP	Water Safely Plan
WSSCC	Water Supply and Sanitation Collaborative Council
WTP	Willingness To Pay
WTW	Willingness To Walk
WW	Wet Weight
XAFS	X-ray Absorption Fine Structure
XRF	X-Ray Fluorescence
XRPD	X-Ray Powder Diffraction
Zn	Zinc

Chapter 1

1.1 Introduction

Safe water & Sanitation are essential and fundamental needs for the development of public health. The Mission of the Bangladesh Government is to ensure that all people have access to safe water & sanitation services at an affordable cost. Bangladesh had achieved a very impressive 98% coverage in water supply. But in the early 90s detection of Arsenic in shallow ground water, the primary source of municipal water supply, had significant adverse impact leading to lowering of the covereage to around 70%. With effective mitigation the covereage has been improved to over 80%.

Local Government Division; Ministry of Local Government, Rural Development and Cooperatives (MoLGRD&C) has developed the Sector Development Plan (FY 2011-25) for the Water and Sanitation Sector in Bangladesh. The SDP is a ground-breaking initiative to sketch a bottom-up road map to achieve the goal of providing safe drinking water and sanitation for all. It has addressed various issues related to sector financing, planning and coordination, monitoring and evaluation. It analyzes the issues of donor harmonization, adaptation of sector-wide approaches for WSS, highlighted the need of enhancing the Research and Development activities to support innovative technological solutions.

In the SDP specific recommendations were made as regard to arsenic mitigation with emphasis on conducting research such as safe disposal of arsenic -rich sludge and in-situ arsenic removal and development of locally manufactured arsenic test kits. Since the detection of arsenic in the ground water, different organizations have taken various initiatives in arsenic mitigation and to ensure safe water supply and sanitation which is still going on. In order to proceed further to support research and study it is necessary to determine what kind of research activities are conducted by different academic, research institutions and other organizations and to develop a way forward on the types of research activities that could be conducted.

As regard to sanitation, referring to SDP it could be mentioned that Bangladesh is presently on the first few steps of the sanitation ladder. It is now time to move further up the ladder by paying more attention to improve the sanitation technology options through converting unhygienic latrines and latrines with slab only (without water seal, lid or flap) to hygienic ones. Simultaneously, the prevalent open defecation must be stopped and further use of higher level technology options, such as septic tanks and double pit latrines, be encouraged. A burning issue is appropriate technologies for the hard-to-reach areas, which remain under very low sanitation coverage. Focused programs and research and development (R&D) activities are needed for the urban poor. It is heartening to know that a UNDP report published in late 2014 indicated that open defecation in Bangladesh has been reduced to around 3% of the population involved in this practice. It is expected that the practice will be totally eliminated well within the year 2020.

Arsenic situation analysis by JICA and DPHE gave a scenario of arsenic contamination up to 2009. Later many organizations implemented different type of projects and conducted different types of research/studies in the field of arsenic. Although the project implementation, research/studies in the field of sanitation is not as rigorous as in the case of arsenic it was, however, necessary to prepare an inventory to determine future needs.

In the SDP emphasis is also given on research and development on issues like appropriate sewerage systems for cities and towns, appropriate sanitation technologies for flood prone, high water table and hilly areas, high density urban slums, and sanitation options for higher level technologies for rural areas, decentralized wastewater treatment; and groundwater contamination due to onsite sanitation, arsenic or other pollutants.

In this backdrop Policy Support Unit (PSU) of the MoLGRD&C had initiated to 'Develop Compendium of Research Activities on Arsenic and Sanitation' to make an inventory of research activities that were conducted with regard to arsenic and sanitation since 2009.

1.2 Objectives

The overall objective of the study is to develop a compendium which would be helpful for researchers, policy makers and implementating agencies to determine the way forward in safe water supply hygienic sanitation.

The specific objectives of this consultancy are to -

1) Prepare inventory of research activities on arsenic issues since 2009 conducted by different organizations and institutions.

2) Prepare inventory of research activities related to sanitation conducted by different organizations and institutions since 2009.

3) To provide specific recommendations to address the current need and future challenges as regard to arsenic and sanitation.

This will enable the sector professionals to move forward for planning of further research.

1.3 Approach and Methodology

This section provides brief description of the methodology used for data collection which includes research methods adopted, instruments used for data collection, sampling procedures and field level data collection. Limitations have also been discussed.

In order to gather information for achieving the objectives of the study a data collection questionnaire was used. A draft questionnaire was developed with assistance from PSU Staff which was pre-tested with the help of the enumerators and then finalized.

Resource persons were selected from relevant agencies who are actively involved in the WSS sector. They included professionals from Government Departments, Autonomous Agencies, NGO's, CBO's, Universities and donor agencies.

As proposed in the technical proposal 3 enumerators were recruited for smooth implementation of the assignment. One of them was designated as the supervisor. After recruitmrnt, a 1-day training was imparted on them. During the training the draft questionnaire was thoroughly discussed with them and was fine tunned in the light of the discussions. The questionnaire was then finalized in the consultation with the PSU Staff.

For data collection a comprehensive list of organizations/individuals dealing with research and development in arsenic and sanitation were prepared based on secondary information and they were contacted. The enumerators carried out the interview of the resource persons at the organization level. The field work was started on 1 September and completed on 30 November 2014.

1.4 Limitation of the study

It was difficult for the enumerators to meet and collect information from the respondents in one session as they themselves had to collect information before talking to the enumerators. Initially most of the respondents were not very willing to meet the enumerators without a formal letter from the PSU. Also many of the respondents had to get clearance from their higher authorities before being interviewed. To overcome this, PSU was requested to write to the chief executives of the prospective organizations, specially the donor/ international agencies (like World Bank, UNICEF, EU etc) and major players in the field (like DPHE, WaterAid, BRAC, BCSIR, ITN, Universities etc) to designate contact persons to provide the needed information. PSU had kindly issued/mailed such letters to the respective organizations and supplied copies of the same to the Consultant.

With this support and other multi-dimensional efforts including website search a large volume of information on arsenic and sanitation research have been collected. The present report is based on the compilation of that information.

Chapter 2

Compendium on Arsenic

2.1. Risk Reduction of Non Communicable Diseases in Jessore District (April, 2013 to April, 2016)

Contact Person
Name (Principle Researcher): Tarun Kanti Hore
Designation: Program Manager
Telephone: 0421.68663
Mobile: 01711.811462
Email: tarunhore@hotmail.com

Objective of the Project

- To nurture health-consciousness through health education among residents in the target area;
- To improve the quality of, and access to, health services for NCD control;
- To develop a model for NCD risk reduction through multi-sector partnership.

2.2. Promoting Environmental Health for the Urban Poor (PEHUP) Project (November, 2011 to October, 2016)

Contact Person
Name: Kazi Wahiduzzaman
Designation: Chief Executive
Telephone: 041.720155, 041.810855
Mobile: 01711.422678
Email: nabolok@khulna.bangla.net
nabolok@nabolokbd.org

Objective of the Project

The overall goal is to contribute to the national goal and MDG related to environmental health and improve human well-being and dignity of the urban poor through ensuring access to safe drinking water, improved sanitation and adoption of desired hygiene practice.

2.3. Field Assessment of Arsenic-bearing Waste Treatment Options (September, 2013 to August, 2015)

Contact Person
Name: Dr. Shamim Uddin
Designation: Co-Investigator
Telephone: 02.9894493
Mobile : 01711.965944
Email: shamimuddinraj@gmail.com
Chief Researcher:
Name: Dr. AhammadulKabir
Designation: Principal Investigator
Telephone: N/A
Mobile: 01711.074775
Email: ahammadul.kabir@gmail.com

Objective of the Project/Research

- To analyze arsenic waste solids from two types of arsenic removal systems currently operating in Bangladesh;
- To evaluate alternative waste treatment options in the field;
- To quantify the arsenic transforming potential of microbial communities in disposal environment;
- To strengthen the capacity of the Asia Arsenic Network through the research work for performing similar researches and monitoring drinking water quality.

Duration of Research Activities September, 2013 to August, 2015

2.4. Assessing Urinary Arsenic Metabolites in Diabetic and Non-Diabetic Subjects in Bangladesh

Contact Person
Name: ANM Fajlul Hadi Sabbir
Designation: Executive Director
Telephone: 0631.61816
Mobile:01711.961317
Email: sabbirbff@gmail.com

Objective of the Project/Research
-Awareness Raising;
-Arsenicosis Patient Treatment.

2.5. Evolution of households' responses to the groundwater arsenic crisis in Bangladesh: information on environmental health risks can have increasing behavioral impact over time (2014)

Balasubramanya S[1], Pfaff A[2], Bennear L[3] et.al

[1]International Water Management Institute, 127 Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka.

[2]Duke University, Sanford School of Public Policy, Box 90239, Durham, NC 27708, USA.

[3]Nicholas School of the Environment, Box 90328, Duke University, Durham, NC 27708, USA.

Abstract

A national campaign of well testing through 2003 enabled households in rural Bangladesh to switch, at least for drinking, from high-arsenic wells to neighboring lower-arsenic wells. We study the well-switching dynamics over time by re-interviewing, in 2008, a randomly selected subset of households in the Araihazar region who had been interviewed in 2005. Contrary to concerns that the impact of arsenic information on switching behavior would erode over time, we find that not only was 2003-2005 switching highly persistent but also new switching by 2008 doubled the share of households at unsafe wells who had switched. The passage of time also had a cost: 22% of households did not recall test results by 2008. The loss of arsenic knowledge led to staying at unsafe wells and switching from safe wells. Our results support ongoing well testing for arsenic to reinforce this beneficial information.

Keywords: Bangladesh; arsenic; groundwater; health; information; risk; test; water

2.6. Associations of total arsenic in drinking water, hair and nails with serum vascular endothelial growth factor in arsenic-endemic individuals in Bangladesh (2014)

Rahman M[1], Mamun AA[2], Karim MR[3] et.al

[1]Department of Biochemistry and Molecular Biology, Rajshahi University, Rajshahi 6205, Bangladesh.

[2]Department of Biochemistry and Molecular Biology, Rajshahi University, Rajshahi 6205, Bangladesh.

[3]Laboratory of Molecular Nutrition and Toxicology, Faculty of Pharmaceutical Sciences, Tokushima Bunri University, Tokushima 770-8514, Japan.

Abstract

Arsenic exposure is associated with cancer and vascular diseases. Angiogenesis is an important step for the pathological development of cancer and vascular diseases. Vascular endothelial growth factor (VEGF) is a specific marker for angiogenesis. However, human study showing the association between arsenic exposure and serum VEGF levels has not yet been documented. This study was aimed to investigate the association between arsenic exposure and serum VEGF levels in the arsenic-endemic individuals in Bangladesh. A total of 260 individuals were recruited for this study. Arsenic exposure levels were measured by ICP-MS and VEGF levels were quantified using VEGF immunoassay kit. The study subjects were stratified into tertile (low, medium and high) groups based on the arsenic in water, hair and nails. Serum VEGF levels were correlated with water (r_s=0.363, $p<0.001$), hair (r_s=0.205, $p<0.01$) and nail (r_s=0.190, $p<0.01$) arsenic. Further, VEGF levels showed dose-response relationships with water, hair and nail arsenic. Mean VEGF levels in ≤10 μgL-1, 10.1-50 μgL-1 and >50μgL-1 groups were 91.84, 129.54, and 169.86pgmL-1, respectively, however, significant ($p<0.01$) difference in VEGF levels was only found in >50μgL-1 versus ≤10μgL-1 groups. Significant associations of arsenic exposure with VEGF levels were found even after adjusting with relevant covariates. Therefore, these results provide evidence that arsenic exposure has a pro-angiogenic effect on humans, which may be implicated in arsenic-induced tumorigenesis and vascular diseases.

Keywords: Angiogenesis; Arsenic; Bangladesh; Cancer; Vascular endothelial growth factor

2.7. Sediment color tool for targeting arsenic-safe aquifers for the installation of shallow drinking water tubewells (2014)

Hossain M[1], Bhattacharya P[2], Frape SK[3] et.al

[1]KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, Teknikringen 76, SE-100 44 Stockholm, Sweden; NGO-Forum for Public Health, 4-6/Block-E, Lalmatia, Dhaka 1207, Bangladesh.

[2]KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology, Teknikringen 76, SE-100 44 Stockholm, Sweden.

[3]Department of Earth and Environmental Sciences, University o0f Waterloo, Waterloo, ON N2L 3G1, Canada.

Abstract

In rural Bangladesh, drinking water supply mostly comes from shallow hand tubewells installed manually by the local drillers, the main driving force in tubewell installation. This study was aimed at developing a sediment color tool on the basis of local driller's perception of sediment color, arsenic (As) concentration of tubewell waters and respective color of aquifer sediments. Laboratory analysis of 521 groundwater samples collected from 144 wells during 2009 to 2011 indicate that As concentrations in groundwater were generally higher in the black colored sediments with an average of 239 μg/L. All 39 wells producing water from red sediments provide safe water following the Bangladesh drinking water standard for As (50 μg/L) where mean and median values were less than the WHO guideline value of 10 μg/L. Observations for off-white sediments were also quite similar. White sediments were rare and seemed to be less important for well installations at shallow depths. A total of 2240 sediment samples were collected at intervals of 1.5m down to depths of 100 m at 15 locations spread over a 410 km(2) area in Matlab, Bangladesh and compared with the Munsell Color Chart with the purpose of direct comparison of sediment color in a consistent manner. All samples were assigned with Munsell Color and Munsell Code, which eventually led to identify 60 color shade varieties which were narrowed to four colors (black, white, off-white and red) as perceived and used by the local drillers. During the process of color grouping, participatory approach was considered taking the opinions of local drillers, technicians, and geologists into account. This simplified sediment color tool can be used conveniently during shallow tubewell installation and thus shows the potential for educating local drillers to target safe aquifers on the basis of the color characteristics of the sediments.

Keywords: Arsenic; Bangladesh; Local driller; Sediment color tool; Sustainable mitigation; Tubewell

2.8. Arsenic exposure and cell-mediated immunity in pre-school children in rural Bangladesh (2014)

Ahmed S[1], Moore SE[2], Kippler M[3] et.al

[1]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden Centre for Vaccine Sciences, International Centre for Diarrheal Disease Research, Bangladesh (ICDDR,B), Dhaka, Bangladesh.

[2]MRC International Nutrition Group, London School of Hygiene and Tropical Medicine, London, UK, and MRC Keneba, The Gambia.

[3]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden.

Abstract

Prenatal arsenic exposure has been associated with reduced thymic index and increased morbidity in infants, indicating arsenic-related impaired immune function. We aimed at elucidating potential effects of pre- and postnatal arsenic exposure on cell-mediated immune function in pre-school aged children. Children born in a prospective mother-child cohort in rural Bangladesh were followed up at 4.5 years of age (n = 577). Arsenic exposure was assessed by concentrations of arsenic metabolites (U-As) in child urine and maternal urine during pregnancy, using high-performance liquid chromatography online with inductively coupled plasma mass spectrometry. For assessment of delayed type hypersensitivity response, an intradermal injection of purified protein derivative (PPD) was given to Bacillus Calmette-Guerin vaccinated children. The diameter (mm) of induration was measured after 48-72 h. Plasma concentrations of 27 cytokines were analyzed by a multiplex cytokine assay. Children's concurrent, but

not prenatal, arsenic exposure was associated with a weaker response to the injected PPD. The risk ratio (RR) of not responding to PPD (induration <5 mm) was 1.37 (95% confidence interval (CI): 1.07, 1.74) in children in the highest quartile of U-As (range 126-1228 μg/l), compared with the lowest (range 12-34 μg/l). The p for trend across the quartiles was 0.003. The association was stronger in undernourished children. Children's U-As in tertiles was inversely associated with two out of 27 cytokines only, i.e., IL-2 and TNF-α, both Th1 cytokines (in the highest tertile, regression coefficients (95% CI): -1.57 (-2.56, -0.57) and -4.53 (-8.62, -0.42), respectively), but not with Th2 cytokines. These associations were particularly strong in children with recent infections. In conclusion, elevated childhood arsenic exposure appeared to reduce cell-mediated immunity, possibly linked to reduced concentrations of Th1 cytokines.

Keywords: Arsenic exposure; cell-mediated immunity; delayed type hypersensitivity; immunotoxicity

2.9. Arsenic exposure in early pregnancy alters genome-wide DNA methylation in cord blood, particularly in boys (2014)

Broberg K[1], Ahmed S[1], Engström K[2] et.al

[1]1Institute of Environmental Medicine, Unit of Metals and Health, Karolinska Institutet, Stockholm, Sweden.

[2]2Department of Laboratory Medicine, Section of Occupational and Environmental Medicine, Lund University, Lund, Sweden.

Abstract

Early-life inorganic arsenic exposure influences not only child health and development but also health in later life. The adverse effects of arsenic may be mediated by epigenetic mechanisms, as there are indications that arsenic causes altered DNA methylation of cancer-related genes. The objective was to assess effects of arsenic on genome-wide DNA methylation in newborns. We studied 127 mothers and cord blood of their infants. Arsenic exposure in early and late pregnancy was assessed by concentrations of arsenic metabolites in maternal urine, measured by high performance liquid chromatography-inductively coupled plasma mass spectrometry. Genome-wide 5-methylcytosine methylation in mononuclear cells from cord blood was analyzed by Infinium HumanMethylation450K BeadChip. Urinary arsenic in early gestation was associated with cord blood DNA methylation (Kolmogorov-Smirnov test, P-value<10-15), with more pronounced effects in boys than in girls. In boys, 372 (74%) of the 500 top CpG sites showed lower methylation with increasing arsenic exposure (r S -values>-0.62), but in girls only 207 (41%) showed inverse correlation (r S -values>-0.54). Three CpG sites in boys (cg15255455, cg13659051 and cg17646418), but none in girls, were significantly correlated with arsenic after adjustment for multiple comparisons. The associations between arsenic and DNA methylation were robust in multivariable-adjusted linear regression models. Much weaker associations were observed with arsenic exposure in late compared with early gestation. Pathway analysis showed overrepresentation of affected cancer-related genes in boys, but not in girls. In conclusion, early prenatal arsenic exposure appears to decrease DNA methylation in boys. Associations between early exposure and DNA methylation might reflect interference with de novo DNA methylation.

Keywords: Inorganic arsenic exposure, early pregnancy, genome.

2.10. Enhancing arsenic mitigation in Bangladesh: Findings from institutional, psychological, and technical investigations (2014)

Richard Johnston[a], Stephan J. Hug[b], Jennifer Inauen[c]

[a]Eawag—Swiss Federal Institute of Aquatic Science and Technology, Sandec, Department of Water and Sanitation in Developing Countries, Switzerland

[b]Eawag—Swiss Federal Institute of Aquatic Science and Technology, Department of Water Resources and Drinking Water, Switzerland

[c]University of Zurich, Department of Psychology, Switzerland

Abstract

As part of a trans-disciplinary research project, a series of surveys and interventions were conducted in different arsenic-affected regions of rural Bangladesh. Surveys of institutional stakeholders identified deep tubewells and piped water systems as the most preferred options, and the same preferences were found in household surveys of populations at risk. Psychological surveys revealed that these two technologies were well-supported by potential users, with self-efficacy and social norms being the principal factors driving behavior change. The principal drawbacks of deep tubewells are that installation costs are too high for most families to own private wells, and that for various socio-cultural-religious reasons, people are not willing to walk long distances to access communal tubewells. In addition, water sector planners have reservations about greater exploitation of the deep aquifer, out of concern for current or future geogenic contamination. Groundwater models and field studies have shown that in the great majority of the affected areas, the risk of arsenic contamination of deep groundwater is small; salinity, iron, and manganese are more likely to pose problems. These constituents can in some cases be avoided by exploiting an intermediate depth aquifer of good chemical quality, which is hydraulically and geochemically separate from the arsenic-contaminated shallow aquifer. Deep tubewells represent a technically sound option throughout much of the arsenic-affected regions, and future mitigation programs should build on and accelerate construction of deep tubewells. Utilization of deep tubewells, however, could be improved by increasing the tubewell density (which requires stronger financial support) to reduce travel times, by considering water quality in a holistic way, and by accompanying tubewell installation with motivational interventions based on psychological factors. By combining findings from technical and social sciences, the efficiency and success of arsenic mitigation in general – and installation of deep tubewells in particular – can be significantly enhanced.

Keywords: Arsenic; Groundwater; Tubewell; Bangladesh; Behavior change; Institutional analysis.

2.11. Arsenic mitigation in Bangladesh: An analysis of institutional stakeholders' opinions (2014)

Nasreen Islam Khan [a, b], Hong Yanga

[a] Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland
[b] Fenner School of Environment and Society, The Australian National University, Canberra, ACT 0200, Australia

Abstract

While Bangladesh made significant achievements in safe water coverage via installation of shallow tubewells (STWs) nationwide, this success was shattered by the discovery of arsenic (As) in the STWs. The extent and severity of As groundwater contamination throughout Bangladesh and its detrimental effects on human health are well known and demand long-term sustainable mitigation. It is an immensely complex and expensive task to bring tens of millions of arsenic exposed people under safe water coverage. While various mitigation measures have been undertaken by various organizations, most have not achieved their expected outcomes due to technical, spatial and socio-economic challenges. Better understanding of these challenges by institutional stakeholders is crucial for sustainable arsenic mitigation in Bangladesh. In this study, institutional stakeholders' opinions on various aspects of As mitigation were elicited to identify their preferences for and reservations of specific mitigation measures. The current status of As mitigation activities and the factors influencing the success of As mitigation were also explored. Institutional weakness, lack of accountability and a latency period were the major factors hindering sustainable As mitigation. The results also suggested that the stakeholders' understanding of the As problem and their preferences for the different mitigation measures have a significant impact on the effectiveness of As mitigation. Mitigation of As contamination is a complex issue that requires a coordinated effort from various levels of stakeholders. The concept of "paying for water", which is currently potentially unknown in the rural areas of Bangladesh, also needs to be developed as this will create a stronger sense of user ownership of As safe water and thus better water management.

Keywords: Institutional; Stakeholder; Arsenic Mitigation; Deep tubewell (DTW); Willingness to pay (WTP); Willingness to walk (WTW)

2.12. Arsenic and lung disease mortality in Bangladeshi adults (2014)

Argos M[1], Parvez F, Rahman M et.al

[1]From the aDepartment of Health Studies, The University of Chicago, Chicago, IL; bDepartment of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, NY; cU-Chicago Research Bangladesh (URB), Ltd., Dhaka, Bangladesh; dPublic Health Sciences Division, International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh; eDepartment of Environmental Medicine, New York University School of Medicine, New York, NY; fDepartments of Medicine and Family Medicine, The University of Chicago, Chicago, IL; gDepartment of Medicine, University of North Carolina School of Medicine, Chapel Hill, NC; and hDepartments of Medicine and Human Genetics and Comprehensive Cancer Center, The University of Chicago, Chicago, IL.

Abstract

BACKGROUND: Chronic arsenic exposure through drinking water is a public health problem affecting millions of people worldwide, including at least 30 million in Bangladesh. We prospectively investigated the associations of arsenic exposure and arsenical skin lesion status with lung disease mortality in Bangladeshi adults.

METHODS: Data were collected from a population-based sample of 26,043 adults, with an average of 8.5 years of follow-up (220,157 total person-years). There were 156 nonmalignant lung disease deaths and 90 lung cancer deaths ascertained through October 2013. We used Cox proportional hazards models to estimate adjusted hazard ratios and 95% confidence intervals (CIs) for lung disease mortality.

RESULTS: Creatinine-adjusted urinary total arsenic was associated with nonmalignant lung disease mortality, with persons in the highest tertile of exposure having a 75% increased risk for mortality (95% CI = 1.15-2.66) compared with those in the lowest tertile of exposure. Persons with arsenical skin lesions were at increased risk of lung cancer mortality (hazard ratio = 4.53 [95% CI = 2.82-7.29]) compared with those without skin lesions.

CONCLUSIONS: This prospective investigation of lung disease mortality, using individual-level arsenic measures and skin lesion status, confirms a deleterious effect of ingested arsenic on mortality from lung disease. Further investigations should evaluate effects on the incidence of specific lung diseases, more fully characterize dose-response, and evaluate screening and biomedical interventions to prevent premature death among arsenic-exposed populations, particularly among those who may be most susceptible to arsenic toxicity.

Keywords: Lung disease mortality, arsenic, Chronic arsenic exposure.

2.13. Effectiveness of public rural water points in Bangladesh with special reference to arsenic mitigation (2014)

Peter Ravenscroft, Ahammadul Kabir, Syed Adnan Ibn Hakim et.al

UNICEF, BSL Office Complex, 1 Minto Road, Dhaka 1000, Bangladesh
Department of Public Health Engineering, DPHE Bhaban, Kakrail, Dhaka, Bangladesh

Abstract

A nationwide survey of 125,000 public rural waterpoints installed between 2007 and 2012 reveals major changes from the pre-arsenic era and expectations of the 2004 Arsenic Policy. Shallow tubewell (STW) use has greatly reduced and deep tubewells (DTWs) now dominate in arsenic-affected areas. Arsenic contamination is greatly reduced from baseline; 3.6% of DTWs, 7.6% of STWs and 5.5% of ringwells (RWs) exceed 50 µg/L. In some sub-districts contamination is worse than previously recognised. Faecal contamination affects 48% of devices, and is most severe in RWs and surface water devices (SWDs). Manganese exceeds 0.4 mg/L in 12% of DTWs, 51% of STWs and 40% of RWs. Iron exceeds 1 mg/L in 48% of devices. Sustained operation ranges from 91% in DTWs, 84% in STWs, 68% in RWs to 47–94% in SWDs. Falling water levels in shallow and deep aquifers require replacement of suction pumps. Addressing aesthetic, water quality and level issues will require major investment in piped water systems with Fe/Mn removal and chlorination. Technologies differ in household coverage (DTW > STW > RW) and use for drinking (DTW > RW > STW). With a modest increase in investment in relatively safe, popular and cost effective DTWs and better targeting, arsenic poisoning could be virtually eliminated in 5–10 years.

Keywords: Arsenic; Bangladesh; contamination; functionality; rural water supply;

2.14. Arsenic in drinking water in Bangladesh: factors affecting child health (2014)

Aziz SN[1], Aziz KM[2], Boyle KJ[3]

[1]Department of Economics, Moravian College, Bethlehem, PA , USA.

[2]Bangladesh Academy of Sciences, National Museum of Science and Technology Bhaban, Dhaka, Bangladesh.

[3]Department of Agricultural and Applied Economics, Virginia Tech , Blacksburg, VA , USA.

Abstract

The focus of this paper is to present an empirical model of factors affecting child health by observing actions households take to avoid exposure to arsenic in drinking water. Millions of Bangladeshis face multiple health hazards from high levels of arsenic in drinking water. Safe water sources are either expensive or difficult to access, affecting people's individuals' time available for work and ultimately affecting the health of household members. Since children are particularly susceptible and live with parents who are primary decision makers for sustenance, parental actions linking child health outcomes is used in the empirical model. Empirical results suggest that child health is significantly affected by the age and gender of the household water procurer. Adults with a high degree of concern for children's health risk from arsenic contamination, and who actively mitigate their arsenic contaminated water have a positive effect on child health.

Keywords: Bangladesh; arsenic in drinking water; child health; empirical model; environmental economics

2.15. Sealing Rice Field Boundaries in Bangladesh: A Pilot Study Demonstrating Reductions in Water Use, Arsenic Loading to Field Soils, and Methane Emissions from Irrigation Water (2014)

Rebecca B. Neumann*†, Lara E. Pracht †, Matthew L. Polizzotto ‡ et.al

† Department of Civil and Environmental Engineering, University of Washington, Seattle, Washington 98195, United States

‡ Department of Soil Science, North Carolina State University, Raleigh, North Carolina 27695, United States

Abstract

Irrigation of rice fields in Bangladesh with arsenic-contaminated and methane-rich groundwater loads arsenic into field soils and releases methane into the atmosphere. We tested the water-savings potential of sealing field bunds (raised boundaries around field edges) as a way to mitigate these negative outcomes. We found that, on average, bund sealing reduced seasonal water use by 52 ± 17% and decreased arsenic loading to field soils by 15 ± 4%; greater savings in both water use and arsenic loading were achieved in fields with larger perimeter-to-area ratios (i.e., smaller fields). Our study is the first to quantify emission of methane from irrigation water in Bangladesh, a currently unaccounted-for methane source. Irrigation water applied to unsealed fields at our site emits 18 to 31 g of methane per square-meter of field area per season, potentially doubling the atmospheric input of methane from rice cultivation. Bund sealing reduced the emission of methane from irrigation water by 4 to 19 g/m^2. While the studied outcomes of bund sealing are positive and compelling, widespread implementation of the technique should consider other factors, such as effect on yields, financial costs, and impact on the hydrologic system. We provide an initial and preliminary assessment of these implementation factors.

Keywords: Rice Field Boundaries, As loading, Methane Emissions, Irrigation.

2.16. Hydrogeological investigation for assessment of the sustainability of low-arsenic aquifers as a safe drinking water source in regions with high-arsenic groundwater in Matlab, southeastern Bangladesh (2014)

Mattias von Brömssena [b], Lars Markussen[b], Prosun Bhattacharya[a] et.al.

[a] KTH-International Groundwater Arsenic Research Group, Department of Sustainable Development, Environmental Science and Engineering, KTH Royal Institute of Technology Teknikringn 76, SE-100 44 Stockholm, Sweden

[b] Department of Soil and Water Environment, Ramböll Sweden AB, Box 4205, SE-102 65 Stockholm, Sweden

[c] Department of Geology, University of Dhaka, Curzon Hall Campus, Dhaka 1000, Bangladesh

Abstract

Exploitation of groundwater from shallow, high prolific Holocene sedimentary aquifers has been a main element for achieving safe drinking water and food security in Bangladesh. However, the presence of elevated levels of geogenic arsenic (As) in these aquifers has undermined this success. Except for targeting safe aquifers through installations of tubewells to greater depth, no mitigation option has been successfully implemented on a larger scale. The objective of this study has been to characterise the hydrostratigraphy, groundwater flow patterns, the hydraulic properties to assess the vulnerability of low-arsenic aquifers at Matlab, in south-eastern Bangladesh, one of the worst arsenic-affected areas of the country. Groundwater modelling, conventional pumping test using multilevel piezometers, hydraulic head monitoring in piezometer nests, 14C dating of groundwater and assessment of groundwater abstraction were used. A model comprising of three aquifers covering the top 250 m of the model domain showed the best fit for the calibration evaluation criteria. Irrigation wells in the Matlab area are mostly installed in clusters and account for most of the groundwater abstraction. Even though the hydraulic heads are affected locally by seasonal pumping, the aquifer system is fully recharged from the monsoonal replenishment. Groundwater simulations demonstrated the presence of deep regional flow systems with recharge areas in the eastern, hilly part of Bangladesh and shallow small local flow systems driven by local topography. Based on modelling results and 14C groundwater data, it can be concluded that the natural local flow systems reach a depth of 30 m b.g.l. in the study area. A downward vertical gradient of roughly 0.01 down to 200 m b.g.l. was observed and reproduced by calibrated models. The vertical gradient is mainly the result of the aquifer system and properties rather than abstraction rate, which is too limited at depth to make an imprint. Although irrigation wells substantially change local flow pattern, targeting low-As aquifers seems to be a suitable mitigation option for providing people with safe drinking water. However, installing additional irrigation- or high capacity production wells at the same depth is strongly discouraged as these could substantially change the groundwater flow pattern. The results from the present study and other similar studies can further contribute to develop a rational management and mitigation policy for the future use of the groundwater resources for drinking water supplies.

Keywords: Bangladesh; Arsenic; Groundwater; Flow-modelling; Drinking water source; Hydrogeology.

2.17. A dose-response study of arsenic exposure and markers of oxidative damage in Bangladesh (2014)

Harper KN[1], Liu X, Hall MN et.al

[1]From the Departments of Environmental Health Sciences (Dr Harper, Ms Ilievski, Ms Oka, Ms Calancie, Ms Slavkovich, Dr Graziano, and Dr Gamble), Biostatistics (Dr Liu and Ms Levy), and Epidemiology (Dr Hall), Mailman School of Public Health, Columbia University, New York, NY; Columbia University Arsenic Project in Bangladesh (Mr Siddique and Mr Alam), Dhaka, Bangladesh; Lamont-Doherty Earth Observatory (Dr Mey and Dr van Geen), Columbia University, Palisades, NY; and Kingsbridge Community College (Dr Mey), New York, NY.

Abstract

OBJECTIVE: To evaluate the dose-response relationship between arsenic (As) exposure and markers of oxidative damage in Bangladeshi adults.

METHODS: We recruited 378 participants drinking water from wells assigned to five water As exposure categories; the distribution of subjects was as follows: (1) less than 10 μg/L (n=76); (2) 10 to 100 μg/L (n=104); (3) 101 to 200 μg/L (n=86); (4) 201 to 300 μg/L (n=67); and (5) more than 300 μg/L (n=45). Arsenic concentrations were measured in well water, as well as in urine and blood. Urinary 8-oxo-2'-deoxyguanosine and plasma protein carbonyls were measured to assess oxidative damage.

RESULTS: None of our measures of As exposure were significantly associated with protein carbonyl or 8-oxo-2'-deoxyguanosine levels.

CONCLUSIONS: We found no evidence to support a significant relationship between long-term exposure to As-contaminated drinking water and biomarkers of oxidative damage among Bangladeshi adults.

Keywords: Oxidative damage, As exposure, protein carbonyl.

2.18. Household's willingness to pay for arsenic safe drinking water in Bangladesh (2014)

Khan NI[1], Brouwer R[2], Yang H[3] et.al

[1]Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Dübendorf, Switzerland; Fenner School of Environment and Society, Australian National University, Canberra, Australia.

[2]Department of Environmental Economics, Institute for Environmental Studies, Vrije Universiteit Amsterdam, The Netherlands.

[3]Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Dübendorf, Switzerland.

Abstract

This study examines willingness to pay (WTP) in Bangladesh for arsenic (As) safe drinking water across different As-risk zones, applying a double bound discrete choice value elicitation approach. The study aims to provide a robust estimate of the benefits of As safe drinking water supply, which is compared to the results from a similar study published almost 10 years ago using a single bound estimation procedure. Tests show that the double bound valuation design does not suffer from anchoring or incentive incompatibility effects. Health risk awareness levels are high and households are willing to pay

on average about 5 percent of their disposable average annual household income for As safe drinking water. Important factors influencing WTP include the bid amount to construct communal deep tubewell for As safe water supply, the risk zone where respondents live, household income, water consumption, awareness of water source contamination, whether household members are affected by As contamination, and whether they already take mitigation measures.

Keywords: Arsenic; Bangladesh; Contingent valuation; Drinking water; Health risks; Willingness to paysustainability.

2.19. Relationship between arsenic skin lesions and the age of natural menopause (2014)

Fakir Md Yunus,[1] Musarrat Jabeen Rahman,[2] Md Zahidul Alam[3] et.al

[1]BRAC Research and Evaluation Division, BRAC Centre, 75 Mohakhali, Dhaka 1212, Bangladesh

[2]ICDDR, B – Water, Sanitation and Hygiene Research Group, Center for Communicable Diseases (CCD), Moyeen Center, House-9b, Road-3, Gulshan-1, Dhaka 1212, Bangladesh

[3]Department of Biology, University of Texas at Arlington, 76010 Arlington, TX, USA

Abstract

BACKGROUND: Chronic exposure to arsenic is associated with neoplastic, cardiovascular, endocrine, neuro-developmental disorders and can have an adverse effect on women's reproductive health outcomes. This study examined the relationship between arsenic skin lesions (a hallmark sign of chronic arsenic poisoning) and age of natural menopause (final menopausal period) in populations with high levels of arsenic exposure in Bangladesh.

METHODS: We compared menopausal age in two groups of women--with and without arsenic skin lesions; and presence of arsenic skin lesions was used as an indicator for chronic arsenic exposure. In a cross-sectional study, a total of 210 participants were randomly identified from two ongoing studies--participants with arsenic skin lesions were identified from an ongoing clinical trial and participants with no arsenic skin lesions were identified from an ongoing cohort study. Mean age of menopause between these two groups were calculated and compared. Multivariable linear regression was used to estimate the relationship between the status of the arsenic skin lesions and age of natural menopause in women.

RESULTS: Women with arsenic skin lesions were 1.5 years younger ($p < 0.001$) at the time of menopause compared to those without arsenic skin lesions. After adjusting with contraceptive use, body mass index, urinary arsenic level and family history of premature menopause, the difference between the groups' age at menopause was 2.1 years earlier ($p < 0.001$) for respondents with arsenic skin lesions.

CONCLUSIONS: The study showed a statistically significant association between chronic exposure to arsenic and age at menopause. Heavily exposed women experienced menopause two years earlier than those with lower or no exposure.

Keywords: Arsenic skin lesions, Arsenic exposure, Age of Menopause, Reproductive period, Epidemiology.

2.20. Arsenic exposure increases maternal but not cord serum immunoglobulin G level in Bangladesh (2014)

Ser PH[1], Banu B, Jebunnesa F et.al

[1]University of Tokyo, Graduate School of Medicine.

Abstract

BACKGROUND: Thousands of pregnant women are exposed to arsenic (As), which has been shown to lead to a higher risk of maternal and infant morbidity. We hypothesized that As-induced modifications to the humoral immune system may be partly responsible, and examined the relationship between As and immunoglobulin G (IgG) levels.

METHODS: Pregnant women were recruited in As-contaminated rural areas in Bangladesh. Blood and urine samples, and questionnaire data were collected. We analyzed data from 202 pregnant women and a subset of 121 mother-infant pairs. Urinary-As was measured by inductively coupled plasma-mass spectrometry and adjusted with specific gravity (U-AsSG). Maternal (IgGmat) and cord (IgGcord) serum total IgG levels were measured by an immunoturbidity assay.

RESULTS: The geometric mean U-AsSG (N = 202) was 69 μg/L (range: 3.1-1356 μg/L). Urinary-AsSG level was significantly associated with IgGmat (N = 202) (r = 0.24; 95% confidence interval = 0.10-0.36; P < 0.001) and remained so after the inclusion of maternal-associated variables in a multiple-regression model (β = 1.26; 95% confidence interval = 0.47-2.05; P < 0.01). However, U-AsSG level was not significantly associated with IgGcord level (N = 121), while IgGmat and IgGcord levels were also not associated.

CONCLUSIONS: Maternal As exposure was positively associated with the IgGmat but not IgGcord level. An elevated IgGmat level may have implications as regards maternal morbidity and the placental transfer of specific IgGs. Further studies are required to better understand how As may affect maternal and child health by modifying the humoral immune system.

Keywords: Arsenic; immune system; immunoglobulin; infant; maternal exposure.

2.21. Folate and cobalamin modify associations between S-adenosylmethionine and methylated arsenic metabolites in arsenic-exposed Bangladeshi adults (2014)

Howe CG[1], Niedzwiecki MM, Hall MN et.al

[1]Departments of Environmental Health Sciences.

Abstract

Chronic exposure to inorganic arsenic (InAs) through drinking water is a major problem worldwide. InAs undergoes hepatic methylation to form mono- and dimethyl arsenical species (MMA and DMA, respectively), facilitating arsenic elimination. Both reactions are catalyzed by arsenic (+3 oxidation state) methyltransferase (AS3MT) using S-adenosylmethionine (SAM) as the methyl donor, yielding the methylated product and S-adenosylhomocysteine (SAH), a potent product-inhibitor of AS3MT. SAM biosynthesis depends on folate- and cobalamin-dependent one-carbon metabolism. With the use of samples from 353 participants in the Folate and Oxidative Stress Study, our objective was to test the hypotheses that blood SAM and SAH concentrations are associated with arsenic methylation and that these associations differ by folate and cobalamin nutritional status. Blood SAM and SAH were measured by HPLC. Arsenic metabolites in blood and urine were measured by HPLC coupled to dynamic reaction cell inductively coupled plasma MS. In linear regression analyses, SAH was not associated with any of the

arsenic metabolites. However, log(SAM) was negatively associated with log(% urinary InAs) (β: -0.11; 95% CI: -0.19, -0.02; P = 0.01), and folate and cobalamin nutritional status significantly modified associations between SAM and percentage of blood MMA (%bMMA) and percentage of blood DMA (%bDMA) (P = 0.02 and P = 0.01, respectively). In folate- and cobalamin-deficient individuals, log(SAM) was positively associated with %bMMA (β: 6.96; 95% CI: 1.86, 12.05; P < 0.01) and negatively associated with %bDMA (β: -6.19; 95% CI: -12.71, 0.32; P = 0.06). These findings suggest that when exposure to InAs is high, and methyl groups are limiting, SAM is used primarily for MMA synthesis rather than for DMA synthesis, contributing additional evidence that nutritional status may explain some of the interindividual differences in arsenic metabolism and, consequently, susceptibility to arsenic toxicity.

Keywords: Chronic exposure to inorganic arsenic, mono- and dimethyl arsenical species, folate and cobalamin nutritional status.

2.22. A prospective study of arm circumference and risk of death in Bangladesh (2014)

Chen Y[1], Ge W, Parvez F et.al

[1]Departments of Population Health and Environmental Medicine, New York University School of Medicine, New York, USA, Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York City, USA, Leon H Charney Division of Cardiology, Department of Medicine, New York University School of Medicine, New York, USA, Columbia University Arsenic Research Project, Dhaka, Bangladesh, Departments of Health Studies, Medicine and Human Genetics and Comprehensive Cancer Center, The University of Chicago, Chicago, IL, USA and Department of Biostatistics, Mailman School of Public Health, Columbia University, New York City, USA.

Abstract

BACKGROUND: Epidemiological studies have observed protective effects of mid-upper arm circumference (MUAC) against all-cause mortality mostly in Western populations. However, evidence on cause-specific mortality is limited.

METHODS: The sample included 19 575 adults from a population-based cohort study in rural Bangladesh, who were followed up for an average of 7.9 years for mortality. Cox proportional hazards regression was used to evaluate the effect of MUAC, as well as the joint effect of body mass index (BMI) and MUAC, on the risk of death from any cause, cancer and cardiovascular disease (CVD).

RESULTS: During 154 664 person-years of follow-up, 744 deaths including 312 deaths due to CVD and 125 deaths due to cancer were observed. There was a linear inverse relationship of MUAC with total and CVD mortality. Each 1-cm increase in MUAC was associated a reduced risk of death from any cause [hazard ratio (HR) = 0.85; 95% confidence interval (C), 0.81-0.89) and CVD (HR = 0.87; 95% CI, 0.80-0.94), after controlling for potential confounders. No apparent relationship between MUAC and the risk of death from cancer was observed. Among individuals with a low BMI (<18.5 kg/m2), a MUAC less than 24 cm was associated with increased risk for all-cause (HR = 1.81; 95% CI, 1.52-2.17) and CVD mortality (HR = 1.45; 95% CI, 1.11-1.91).

CONCLUSIONS: MUAC may play a critical role on all-cause and CVD mortality in lean Asians.

Keywords: Mid-upper arm circumference (MUAC); cardiovascular diseases; cohort study; epidemiology; mortality

2.23. A cross-sectional study of well water arsenic and child IQ in Maine schoolchildren (2014)

Wasserman GA[1], Liu X, Loiacono NJ et.al

[1]Department of Psychiatry, College of Physicians and Surgeons, Columbia University New York, NY, USA.

Abstract

BACKGROUND: In recent studies inBangladesh and elsewhere, exposure to arsenic (As) via drinking water is negatively associated with performance-related aspects of child intelligence (e.g., Perceptual Reasoning, Working Memory) after adjustment for social factors. Because findings are not easily generalizable to the US, we examine this relation in a US population.

METHODS: In 272 children in grades 3-5 from three Maine school districts, we examine associations between drinking water As (WAs) and intelligence (WISC-IV).

RESULTS: On average, children had resided in their current home for 7.3 years (approximately 75% of their lives). In unadjusted analyses, household well WAs is associated with decreased scores on most WISC-IV Indices. With adjustment for maternal IQ and education, HOME environment, school district and number of siblings, WAs remains significantly negatively associated with Full Scale IQ and Perceptual Reasoning, Working Memory and Verbal Comprehension scores. Compared to those with WAs < 5 μg/L, exposure to WAs ≥ 5 μg/L was associated with reductions of approximately 5-6 points in both Full Scale IQ ($p < 0.01$) and most Index scores (Perceptual Reasoning, Working Memory, Verbal Comprehension, all p's < 0.05). Both maternal IQ and education were associated with lower levels of WAs, possibly reflecting behaviors (e.g., water filters, residential choice) limiting exposure. Both WAs and maternal measures were associated with school district.

CONCLUSIONS: The magnitude of the association between WAs and child IQ raises the possibility that levels of WAs ≥ 5 μg/L, levels that are not uncommon in the United States, pose a threat to child development.

Keywords: Well water arsenic, child IQ.

2.24. A prospective cohort study of the association between drinking water arsenic exposure and self-reported maternal health symptoms during pregnancy in Bangladesh (2014)

Molly L Kile,[1] Ema G Rodrigues,[2] Maitreyi Mazumdar et.al

[1]Department of Public Health, College of Public Health and Human Sciences, Oregon State University, 15 Milam, Corvallis, OR 97331, USA

[2]Department of Environmental Health, Harvard School of Public Health, Boston, MA, USA

Abstract

Background: Arsenic, a common groundwater pollutant, is associated with adverse reproductive health but few studies have examined its effect on maternal health.

Methods: A prospective cohort was recruited in Bangladesh from 2008–2011 (N=1,458). At enrollment (<16 weeks gestational age [WGA]), arsenic was measured in personal drinking water using inductively-coupled plasma mass spectrometry. Questionnaires collected health data at enrollment, at 28 WGA, and

within one month of delivery. Adjusted odds ratios (aORs) and 95% confidence intervals (95% CI) for self-reported health symptoms were estimated for each arsenic quartile using logistic regression.

Results: Overall, the mean concentration of arsenic was 38 µg/L (Standard deviation, 92.7 µg/L). A total of 795 women reported one or more of the following symptoms during pregnancy (cold/flu/infection, nausea/vomiting, abdominal cramping, headache, vaginal bleeding, or swollen ankles). Compared to participants exposed to the lowest quartile of arsenic (≤0.9 µg/L), the aOR for reporting any symptom during pregnancy was 0.62 (95% CI=0.44-0.88) in the second quartile, 1.83 (95% CI=1.25-2.69) in the third quartile, and 2.11 (95% CI=1.42-3.13) in the fourth quartile where the mean arsenic concentration in each quartile was 1.5 µg/L, 12.0 µg/L and 144.7 µg/L, respectively. Upon examining individual symptoms, only nausea/vomiting and abdominal cramping showed consistent associations with arsenic exposure. The odds of self-reported nausea/vomiting was 0.98 (95% CI: 0.68, 1.41), 1.52 (95% CI: 1.05, 2.18), and 1.81 (95% CI: 1.26, 2.60) in the second, third and fourth quartile of arsenic relative to the lowest quartile after adjusting for age, body mass index, second-hand tobacco smoke exposure, educational status, parity, anemia, ferritin, medication usage, type of sanitation at home, and household income. A positive trend was also observed for abdominal cramping (P for trend <0.0001). A marginal negative association was observed between arsenic quartiles and odds of self-reported cold/flu/infection (P for trend=0.08). No association was observed between arsenic and self-reported headache (P for trend=0.19).

Conclusion: Moderate exposure to arsenic contaminated drinking water early in pregnancy was associated with increased odds of experiencing nausea/vomiting and abdominal cramping. Preventing exposure to arsenic contaminated drinking water during pregnancy could improve maternal health.

Keywords: Arsenic, Maternal health, Nausea, Vomiting, Cramping, Environmental health, Reproductive health.

2.25. Interaction of plasma glutathione redox and folate deficiency on arsenic methylation capacity in Bangladeshi adults (2014)

Niedzwiecki MM[1], Hall MN[2], Liu X[3] et.al

[1]Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, NY 10032, USA.

[2]Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, NY 10032, USA.

[3]Department of Biostatistics, Mailman School of Public Health, Columbia University, New York, NY 10032, USA.

Abstract

Inorganic arsenic(As) is metabolized through a series of methylation reactions catalyzed by arsenic(III)-methyltransferase (AS3MT), resulting in the generation of monomethylarsonic (MMAs) and dimethylarsinic acids (DMAs). AS3MT activity requires the presence of the methyl donor S-adenosylmethionine, a product of folate-dependent one-carbon metabolism, and a reductant. Although glutathione (GSH), the primary endogenous antioxidant, is not required for As methylation, GSH stimulates As methylation rates in vitro. However, the relationship between GSH redox and As methylation capacity in humans is unknown. We wished to test the hypothesis that a more oxidized plasma GSH redox status is associated with decreased As methylation capacity and examine whether

these associations are modified by folate nutritional status. Concentrations of plasma GSH and GSSG, plasma folate, total blood As (bAs), total urinary As (uAs), and uAs metabolites were assessed in a cross-sectional study of n=376 Bangladeshi adults who were chronically exposed to As in drinking water. We observed that a decreased plasma GSH/GSSG ratio (reflecting a more oxidized redox state) was significantly associated with increased urinary %MMA, decreased urinary %DMA, and increased total bAs in folate-deficient individuals (plasma folate ≤9.0nmol/L). Concentrations of plasma GSH and GSSG were independently associated with increased and decreased As methylation capacity, respectively. No significant associations were observed in folate-sufficient individuals, and interactions by folate status were statistically significant. Our findings suggest that GSH/GSSG redox regulation might contribute to the large interindividual variation in As methylation capacity observed in human populations.

Keywords: Arsenic; Arsenic methylation; Bangladesh; Folate; Free radicals; Glutathione; Glutathione disulfide; Oxidative stress; Redox

2.26. Biodegradable Organic Carbon in Sediments of an Arsenic-Contaminated Aquifer in Bangladesh (2014)

Rebecca B. Neumann*†, Lara E. Pracht †, Matthew L. Polizzotto ‡ et.al

† Department of Civil and Environmental Engineering, University of Washington, Seattle, Washington 98195, United States

‡ Department of Soil Science, North Carolina State University, Raleigh, North Carolina 27695, United States

Abstract

Laboratory incubations of sediment collected from an arsenic-contaminated aquifer in Bangladesh revealed a hitherto undocumented pool of biodegradable sedimentary organic carbon. Sampling, homogenizing, handling, and/or experimentation with the sediment released organic carbon, causing dissolved organic carbon (DOC) concentrations to reach ~150–250 mg/L when DOC was mixed with recharge water. The native sedimentary microbial community rapidly consumed the released carbon, producing methane, while no loss of DOC was observed in sterilized sediments. In both sterilized and native incubations, dissolved arsenic equilibrated with the sediment; arsenic concentrations initially dropped and then remained constant over the 180 day experiment. Collectively, these data suggest that *in situ* perturbations to the aquifer matrix could promote mobilization of bioavailable sedimentary organic carbon. Although this sedimentary organic carbon did not influence arsenic concentrations here, it represents a carbon source that could, in the presence of arsenic-bearing iron (hydr)oxides, fuel microbial reductive release of arsenic.

Keywords: Biodegradable Organic Carbon, Arsenic-Contaminated Aquifer**,** sediment, recharge water.

2.27. Dopamine-β-Hydroxylase Activity and Levels of Its Cofactors and Other Biochemical Parameters in the Serum of Arsenicosis Patients of Bangladesh (2014)

M. Khalilur Rahman,[1]M. Iqbal Choudhary,[2]M. Arif[1] et.al

[1]Department of Biochemistry and Molecular Biology, University of Dhaka, Dhaka-1000, Bangladesh;

[2]Dr. Panjwani Center for Molecular Medicine and Drug Research, International Center for Chemical and Biological Sciences, University of Karachi, Karachi 75270, Pakistan

Abstract

Dopamine-β-hydroxylase (DBH) is a neurotransmitter (catecholamine)-mediating enzyme, which catalyzes the formation of norepinephrine from dopamine. The levels of DBH activity, its coenzyme (ascorbic acid) and cofactor (Cu^{++}) and other biochemical parameters were measured in the serum of 32 arsenicosis patients of Bangladesh at three different age groups, namely, group 1 (10–18 years, 9 patients), group 2 (19–40 years, 14 patients) and group 3 (41–70 years, 9 patients) of the locality of Stadium Para of Meherpur district of Bangladesh. The values were compared with the same number of age-matched normal healthy individuals of the respective group. DBH activity was markedly decreased in the patients of group 1 as compared to that of the normal healthy people. The activities of DBH were decreased to lesser extents for the other two age groups. The total protein contents in the serum of arsenicosis patients were also significantly low as compared to that in the age-matched control groups. The levels of ascorbic acid and copper were found to be decreased in the serum of arsenicosis patients. The serum glucose levels were elevated in arsenicosis patients, as compared to that of the respective healthy controls. Other parameters, such as zinc and vitamin A levels were also decreased in the serum of arsenicosis patients. It was evident from the results of drinking of the arsenic contaminated water of shallow tube wells that the levels of DBH activity decreased significantly as compared to the control healthy persons. The levels of proteins, ascorbic acid, copper, zinc and vitamin A were decreased in the serum of people drinking the arsenic contaminated tube wells water as compared to that in the control healthy people with the exception that the levels of glucose were elevated in the serum of these patients. The pathophysiological significance of the results could be correlated with the decreased in proteins and that in DBH activities as DBH deficiency is characterized by lack of sympathetic noradrenergic function.The general physiologic findings of autonomic function indicate that complete DBH deficiency include minimal or absent plasma norepinephrine and epinephrine.

Keywords: Arsenicosis, Drinking-water, Dopamine-β-Hydroxylase, Norepinephrine, Serum

2.28. Poisoned Blood, Ghaa, and the Infected Body: Lay Understandings of Arsenicosis in Rural Bangladesh (2014)

Islam MS.

Abstract

This article draws on ethnographic data from rural Bangladesh to examine how community members affected by arsenicosis understand, explain, and experience this deadly illness. Biomedically, arsenicosis has been described as a disease caused by drinking arsenic-contaminated water, and it is manifested through physiological complications such as symmetric hyperkeratosis of the palms and soles, cancer of the skin, kidney and lungs, and diseases of the blood vessels. This paper goes beyond such biomedical discourse and illustrates how arsenicosis has been vernacularized as ghaa in practice. It focuses on lay world views, logic, local knowledge systems, and sociocultural factors that shape popular understandings of the disease. This article is thus a contribution to our understanding of how arsenicosis, apart from its biomedical and clinical manifestations, is understood and experienced by affected individuals living within the particular sociocultural and ecological constraints of rural Bangladesh.

Keywords: Bangladesh; arsenic-contaminated water; arsenicosis; lay health beliefs; public health.

2.29. Interaction between arsenic exposure from drinking water and genetic susceptibility in carotid intima-media thickness in Bangladesh (2014)

Wu F[1], Jasmine F[2], Kibriya MG[2] et.al

[1]Department of Population Health, New York University School of Medicine, New York, NY, USA; Department of Environmental Medicine, New York University School of Medicine, New York, NY, USA.

[2]Department of Health Studies, The University of Chicago, Chicago, IL, USA; The University of Chicago Comprehensive Cancer Center, Chicago, IL, USA.

Abstract

Epidemiologic studies that evaluated genetic susceptibility for the effects of arsenic exposure from drinking water on subclinical atherosclerosis are limited. We conducted a cross-sectional study of 1078 participants randomly selected from the Health Effects of Arsenic Longitudinal Study in Bangladesh to evaluate whether the association between arsenic exposure and carotid artery intima-media thickness (cIMT) differs by 207 single-nucleotide polymorphisms (SNPs) in 18 genes related to arsenic metabolism, oxidative stress, inflammation, and endothelial dysfunction. Although not statistically significant after correcting for multiple testing, nine SNPs in APOE, AS3MT, PNP, and TNF genes had a nominally statistically significant interaction with well-water arsenic in cIMT. For instance, the joint presence of a higher level of well-water arsenic (≥ 40.4 μg/L) and the GG genotype of AS3MT rs3740392 was associated with a difference of 40.9 μm (95% CI = 14.4, 67.5) in cIMT, much greater than the difference of cIMT associated with the genotype alone (β = -5.1 μm, 95% CI = -31.6, 21.3) or arsenic exposure alone (β = 7.2 μm, 95% CI = -3.1, 17.5). The pattern and magnitude of the interactions were similar when urinary arsenic was used as the exposure variable. Additionally, the at-risk genotypes of the AS3MT SNPs were positively related to the proportion of monomethylarsonic acid (MMA) in urine, which is indicative of arsenic methylation capacity. The findings provide novel evidence that genetic variants related to arsenic metabolism may play an important role in arsenic-induced subclinical atherosclerosis. Future replication studies in diverse populations are needed to confirm the findings.

Keywords: Arsenic; Bangladesh; Cardiovascular diseases; Carotid artery intima–media thickness; Drinking water; Single nucleotide polymorphism.

2.30. In situ treatment of arsenic-contaminated groundwater by air sparging (2014)

Brunsting JH[1], McBean EA[2]

[1]School of Engineering, University of Guelph, 50 Stone Road East, Guelph, Ontario N1G 2W1, Canada. Electronic address: j.h.brunsting@gmail.com.

[2]School of Engineering, University of Guelph, Canada Research Chair of Water Supply Security.

Abstract

Arsenic contamination of groundwater is a major problem in some areas of the world, particularly in West Bengal (India) and Bangladesh where it is caused by reducing conditions in the aquifer. In situ treatment, if it can be proven as operationally feasible, has the potential to capture some advantages over other treatment methods by being fairly simple, not using chemicals, and not necessitating disposal of arsenic-rich wastes. In this study, the potential for in situ treatment by injection of compressed air directly into the aquifer (i.e. air sparging) is assessed. An experimental apparatus was constructed to

simulate conditions of arsenic-rich groundwater under anaerobic conditions, and in situ treatment by air sparging was employed. Arsenic (up to 200 µg/L) was removed to a maximum of 79% (at a local point in the apparatus) using a solution with dissolved iron and arsenic only. A static "jar" test revealed arsenic removal by co-precipitation with iron at a molar ratio of approximately 2 (iron/arsenic). This is encouraging since groundwater with relatively high amounts of dissolved iron (as compared to arsenic) therefore has a large theoretical treatment capacity for arsenic. Iron oxidation was significantly retarded at pH values below neutral. In terms of operation, analysis of experimental results shows that periodic air sparging may be feasible.

Keywords: Air sparging; Arsenic; Bangladesh; Groundwater; In situ treatment

2.31. A prospective cohort study of stroke mortality and arsenic in drinking water in Bangladeshi adults (2014)

Mahfuzar Rahman, [#1,2]Nazmul Sohel,[#3]Mohammad Yunus[#1] et.al

[1]ICDDRB, 68 Shahid Tajuddin Ahmed Sarani, Mohakhali, Dhaka 1212, Bangladesh

[2]University of Chicago Research Bangladesh, House 338, Road 24, New DOHS, Mohakhali, Dhaka 1212, Bangladesh

[3]Department of Clinical Epidemiology and Biostatistics, McMaster University, 1280 Main Street West, Hamilton ON L8S 4K1, Ontario, Canada

Abstract

Background: Arsenic in drinking water causes increased coronary artery disease (CAD) and death from CAD, but its association with stroke is not known.

Methods: Prospective cohort study with arsenic exposure measured in well water at baseline. 61074 men and women aged 18 years or older on January 2003 were enrolled in 2003. The cohort was actively followed for an average of 7 years (421,754 person-years) through December 2010. Based on arsenic concentration the population was categorized in three groups and stroke mortality HR was compared to the referent. The risk of stroke mortality Hazard Ratio (HR) and 95% Confidence Interval was calculated in relation to arsenic exposure was estimated by Cox proportional hazard models with adjustment for potential confounders.

Results: A total of 1033 people died from stroke during the follow-up period, accounting for 23% of the total deaths. Multivariable adjusted HRs (95% confidence interval) for stroke for well water arsenic concentrations <10, 10-49, and ≥50 µg/L were 1.0 (reference), 1.20 (0.92 to 1.57), and 1.35 (1.04 to 1.75) respectively (P_{trend}=0.00058). For men, multivariable adjusted HRs (95%) for well water arsenic concentrations <10, 10-49, and ≥50 µg/L were 1.0 (reference), 1.12 (0.78 to 1.60), and 1.07 (0.75 to 1.51) respectively (P_{trend}=0.45) and for women 1.0 (reference),1.31 (0.87 to 1.98), and 1.72 (1.15 to 2.57) respectively (P_{trend}=0.00004).

Conclusion: The result suggests that arsenic exposure was associated with increased stroke mortality risk in this population, and was more significant in women compared to men.

Keywords: Disease, people, Hazard Ratio, stroke.

2.32. Association between betel quid chewing and carotid intima-media thickness in rural Bangladesh (2014)

McClintock TR[1], Parvez F, Wu F et.al

[1]Departments of Population Health and Environmental Medicine, New York University School of Medicine, New York, NY, USA, Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, NY, USA, U-Chicago Research Bangladesh, Dhaka, Bangladesh, Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, New York, USA, INSERM, UMR-S 707, Université Pierre et Marie Curie-Paris 6, Paris, France, École des Hautes Études en Santé Publique, Paris and Rennes, France and Departments of Health Studies, Medicine and Human Genetics and Comprehensive Cancer Center, University of Chicago, Chicago, IL, USA.

Abstract

BACKGROUND: Areca nut, more commonly known as betel nut, is the fourth most commonly used addictive substance in the world. Though recent evidence suggests it may play a role in the development of cardiovascular disease, no studies have investigated whether betel nut use is related to subclinical atherosclerosis.

METHODS: We evaluated the association between betel nut use and subclinical atherosclerosis in 1206 participants randomly sampled from the Health Effects of Arsenic Longitudinal Study (HEALS). Frequency and duration of betel nut use were assessed at baseline, and carotid IMT was measured on average 6.65 years after baseline.

RESULTS: A positive association was observed between duration and cumulative exposure (function of duration and frequency) of betel nut use and IMT, with above-median use for duration (7 or more years) and cumulative exposure (30 or more quid-years) corresponding to a 19.1 μm [95% confidence interval (CI): 5.3-32.8; $P \leq 0.01$] and 16.8 μm (95% CI: 2.9-30.8; $P < 0.05$) higher IMT in an adjusted model, respectively. This association was more pronounced in men [32.8 μm (95% CI: 10.0-55.7) and 30.9 μm (95% CI: 7.4-54.2)]. There was a synergy between cigarette smoking and above-median betel use such that the joint exposure was associated with a 42.4 μm (95% CI: 21.6-63.2; $P \leq 0.01$) difference in IMT.

CONCLUSION: Betel nut use at long duration or high cumulative exposure levels is associated with subclinical atherosclerosis as manifested through carotid IMT. This effect is especially pronounced among men and cigarette smokers.

Keywords: Areca nut; stroke mortality, Bangladesh; betel nut; cardiovascular disease; carotid intima-media thickness.

2.33. Review of remediation techniques for arsenic (As) contamination: a novel approach utilizing bio-organisms (2014)

Rahman S[1], Kim KH[2], Saha SK[3] et.al

[1]Department of Genetic Engineering and Biotechnology, Jessore University of Science and Technology, Jessore 7408, Bangladesh.

[2]Department of Civil & Environmental Engineering, Hanyang University, 222 Wangsimni-Ro, Seoul 133-791, Republic of Korea.

[3]Department of Animal Biotechnology, Konkuk University, Seoul, Republic of Korea.

Abstract

Arsenic (As) contamination has recently become a worldwide problem, as it is found to be widespread not only in drinking water but also in various foodstuffs. Because of the high toxicity, As contamination poses a serious risk to human health and ecological system. To cope with this problem, a great deal of effort have been made to account for the mechanisms of Asmineral formation and accumulation by some plants and aquatic organisms exposed to the high level of As. Hence, bio-remediation is now considered an effective and potent approach to breakdown As contamination. In this review, we provide up-to-date knowledge on how biological tools (such as plants for phytoremediation and to some extent microorganisms) can be used to help resolve the effects of As problems on the Earth's environment.

Keywords: Accumulation; Arsenic (As); Bio-organism; Bioremediation.

2.34. Association between arsenic exposure from drinking water and hematuria: results from the Health Effects of Arsenic Longitudinal Study (2014)

McClintock TR[1], Chen Y[2], Parvez F[3] et.al

[1]Department of Population Health, New York University School of Medicine, New York, NY, USA; Department of Environmental Medicine, New York University School of Medicine, New York, NY, USA; Department of Urology, New York University School of Medicine, New York, NY, USA.

[2]Department of Population Health, New York University School of Medicine, New York, NY, USA; Department of Environmental Medicine, New York University School of Medicine, New York, NY, USA.

[3]Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, NY, USA.

Abstract

Arsenic (As) exposure has been associated with both urologic malignancy and renal dysfunction; however, its association with hematuria is unknown. We evaluated the association between drinking water As exposure and hematuria in 7843 men enrolled in the Health Effects of Arsenic Longitudinal Study (HEALS). Cross-sectional analysis of baseline data was conducted with As exposure assessed in both well water and urinary As measurements, while hematuria was measured using urine dipstick. Prospective analyses with Cox proportional regression models were based on urinary As and dipstick measurements obtained biannually since baseline up to six years. At baseline, urinary As was significantly related to prevalence of hematuria (P-trend<0.01), with increasing quintiles of exposure corresponding with respective prevalence odds ratios of 1.00 (reference), 1.29 (95% CI: 1.04-1.59), 1.41 (95% CI: 1.15-1.74), 1.46 (95% CI: 1.19-1.79), and 1.56 (95% CI: 1.27-1.91). Compared to those with relatively little absolute urinary As change during follow-up (-10.40 to 41.17 μg/l), hazard ratios for hematuria were 0.99 (95% CI: 0.80-1.22) and 0.80 (95% CI: 0.65-0.99) for those whose urinary As decreased by >47.49 μg/l and 10.87 to 47.49 μg/l since last visit, respectively, and 1.17 (95% CI: 0.94-1.45) and 1.36 (95% CI: 1.10-1.66) for those with between-visit increases of 10.40 to 41.17 μg/l and >41.17 μg/l, respectively. These data indicate a positive association of As exposure with both prevalence and incidence of dipstick hematuria. This exposure effect appears modifiable by relatively short-term changes in drinking water As.

Keywords: Arsenic; Bangladesh; Environmental epidemiology; Hematuria; Mass screening; Urologic neoplasms

2.35. Comparison of two blanket surveys of arsenic in tubewells conducted 12 years apart in a 25 km(2) area of Bangladesh (2014)

Van Geen A[1], Ahmed EB[2], Pitcher L[3] et.al

[1]Lamont-Doherty Earth Observatory of Columbia University Palisades, NY, USA. Electronic address: avangeen@ldeo.columbia.edu.

[2]Geology Department, University of Dhaka, Dhaka, Bangladesh.

[3]Lamont-Doherty Earth Observatory of Columbia University Palisades, NY, USA.

Abstract

The arsenic (As) content of groundwater pumped from all tubewells within 61 contiguous villages of Araihazar, Bangladesh, was determined a first time in 2000-01 with laboratory measurements and a second time in 2012-13 using the ITS Arsenic Econo-Quick kit. The two surveys indicate that the total number of tubewells within the area almost doubled from 5560 to 10,879 over 12 years. The evolution of the distribution of well ages between the two surveys is consistent with a simple model that combines an annual increase of 42 wells/year in the rate of installations within the 61 villages starting in 1980 and a 7%/year rate of abandonment of wells as a function of well age. Colored placards were posted on each pumphead in 2012-13 on the basis of the kit results relative to the WHO guideline for As and the Bangladesh standard for As in drinking water: blue for As≤10 μg/L, green>10-50 μg/L, and red: >50 μg/L. According to quality-control samples collected from 502 tubewells for comparing the kit results with laboratory measurements, not a single well labeled blue in 2012-13 should have been labeled red and vice-versa. Field-kit testing in 2012-13 did not change the status of wells relative to the Bangladesh standard of 876 (87%) out of 1007 wells with a placard based on laboratory measurements in 2000-01 still attached to the pumphead. The high proportion of tubewells believed by households to be unsafe (66% out of 2041) that were still used for drinking and cooking in 2012-13 underlines the need for more widespread testing to identify low-As wells as an alternative source of drinking water.

Keywords: Arsenic; Bangladesh; Groundwater; Well testing

2.36. Retrofitting arsenic-iron removal plants in rural Bangladesh for performance enhancement (2014)

Ingrid M. Sorensen, Edward A. McBean and Mujibur Rahman

School of Engineering, University of Guelph, 50 Stone Rd., Guelph, ON, Canada N1G 2W1
Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

Abstract

As a result of naturally occurring arsenic in groundwater, it is estimated that 42–60 million people in Bangladesh are exposed to arsenic at concentrations greater than the World Health Organization (WHO) guideline of 10 μg/L. Arsenic-Iron Removal Plants (AIRPs) are capable of removing 50–90% of arsenic from groundwater, but are frequently unable to meet the WHO guideline. The effectiveness of three design modifications intended to improve the performance of AIRPs is described: (1) the addition of scrap or locally available iron to the filtration media, (2) raising the intake pipe that connects the two tanks of the AIRP, and (3) introducing baffles to the aeration tank. Total arsenic, iron, phosphate, and dissolved oxygen were measured to determine the impact of each modification. The addition of iron media showed an increase in arsenic removal up to 13%, while raising the pipe intake accounted for a

3% increase in arsenic removal. The installation of both modifications to the same AIRP is expected to reduce the lifetime body burden from drinking water by one-half. The addition of baffles to the aeration tank showed no evidence of improving the arsenic removal capabilities of the AIRP.

Keywords: AIRP; arsenic; Bangladesh; retrofit; water treatment

2.37. Toxic injustice in the Bangladesh water sector: a social inequities perspective on arsenic contamination (2014)

Crelis Rammelt[a,b,*], Zahed Masud[b,c], Jan Boes[b] and Fariba Masud[b]

[a]Institute of Environmental Studies, University of New South Wales, Australia

[b]Arsenic Mitigation and Research Foundation

[c]AITAM Welfare Hospital

Abstract

Arsenic contamination of groundwater in Bangladesh poses a major environmental health hazard to millions. The efforts of public health programmes to address the problem have often been short-lived and unevenly distributed. The crisis represents a failure of governance and a structural injustice of global dimensions. Rights-based approaches to development have been proposed to address such problems. This paper explores the implications of framing the arsenic problem in terms of social justice and human rights. It describes the efforts of the Arsenic Mitigation and Research Foundation to implement drinking water supplies and health support schemes with marginalised communities. The approach was never explicitly framed as rights-based, but focuses instead on social mobilisation and on securing fundamental human needs. We argue that this will be conducive to social justice, which in turn creates the necessary space for pursuing human rights claims.

Keywords: Arsenic contamination; Bangladesh; Drinking water; Human rights; Poverty and inequity; Public health; Social justice; Social mobilization

2.38. Distribution and abundance of arsenic in the soils and plants (2014)

Ismail M MRahman, Zinnat A. Begum, Seyed Y. Salehi-Lisar et.l

Abstract

Arsenic (As) has evoked concerns related to the environmental and human health issues for decades. In recent years, the concern has been relocated to the front position as more of the world's population relies on groundwater as a source of clean drinking water, which is reported to be contaminated due to the elevated level of arsenic. Arsenic, being a naturally-occurring element in the Earth's crust, has been commonly found as a trace constituent of rocks, soils, sediments, water, and biota. The natural or anthropogenic or both the activities can elevate arsenic concentrations in groundwater, soils, and sediments to toxic levels and consequently, in the plants. Arsenic exists in multiple oxidation states at earth surface conditions, while arsenite and arsenate are by far the most common As-species found in the environment. The surface processes such as precipitation, dissolution, adsorption, and desorption have been controlled by geochemical parameters, such as pH, Eh, ionic composition, and mineral type, and determine the mobility characteristics of arsenic and the abundance in any given location. The chapter will provide a critical review of the issues related to the distribution and abundance of arsenic in the soils and plants.

Keywords: Population, groundwater, abundance.

2.39. Phytoremediation of Arsenic, Chromium, Lead and Cadmium contaminated Soil by Jute, Kenaf and Mesta (2014)

M.U. Nizam

[1]PhD Fellow, Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh

Abstract

Arsenic (As), Chromium (Cr), Lead (Pb) and Cadmium (Cd) are toxic heavy metals in soils. These are toxic to plants, animals and humans. Remediation of As, Cr, Pb and Cd contaminated soil by jute, kenaf and mesta was studied. Results of germination and solution culture experiments showed significant reduction of germination, root and shoot growth, fresh and dry biomass production of crop seedlings due to elevated levels of As, Cr and Cd. Kenaf (cv. HC-95 & HC-3) and mesta (cv. Samu-93) showed tolerance up to 160 mg L^{-1} for each of Pb, Cr, Cd and 50 mg L^{-1} for As. At higher concentrations of As, Cr and Cd, the seedlings of *deshi* and *tossa* jute were died just after seed sprouting. At early growing stage, HC-95 and HC-3 kenaf and Samu-93 mesta grown in nutrient solutions showed 100% seedling survibility up to 15 mg As L^{-1}, 160 mg Pb L^{-1}, 15 mg Cr L^{-1} and 10 mg Cd L^{-1}, but the survibility of jute varieties (CVE-3 & BJC-7370) were the minimum. All the varieties accumulated considerable amounts of As, Cr, Pb and Cd at early growing stage and the concentrations were much higher in root than in shoot. The concentrations and uptake of As, Cr, Pb and Cd by shoot and root significantly increased with the increasing addition. In contaminated soil, the kenaf and mesta varieties had higher biomass production and took off more As, Cr, Pb and Cd than jute varieties. Absorption of As, Cr, Pb and Cd by shoot was significantly higher than that of root both in contaminated and uncontaminated soils. Higher was the contents of these metals in soil higher was their absorption and vice - versa. From the contaminated soil, the highest amounts of As (66.22 mg As pot $^{-1}$), Cr (52.96 mg Cr pot $^{-1}$), Pb (415.53 mg Pb pot $^{-1}$) and Cd (11.64 mg Cd pot $^{-1}$) were absorbed by kenaf HC-3; followed by 48.24 mg As pot $^{-1}$, 42.55 mg Cr pot $^{-1}$, 415.53 mg Pb pot $^{-1}$ and 9.19 mg Cd pot $^{-1}$ by kenaf HC-95. In terms of higher biomass production and As, Cr, Pb and Cd absorption, kenaf varieties HC-3 and HC-95 showed higher potentiality in the contaminated soil. Overall, As, Cr, Pb and Cd tolerance and absorption potentialities of the varieties were HC-3 kenaf > HC-95 kenaf > Samu-93 mesta > CVE-3 jute > BJC -7370 jute. The varieties of kenaf (HC-3 & HC-95), mesta (Samu-93) and jute (CVE-3 & BJC-7370) were found not only effective for remediation of As, Cr, Pb and Cd contamination of soils, and also effective for the removal of Fe, Mn, Cu and Zn from the contaminated soils. In the contaminated soil, the higher absorption of macro (P, S, K, Ca & Mg) and micro nutrients (Zn, Cu, Fe & Mn) influenced the absorption of As, Cr, Pb and Cd by plants.

2.40. Evaluation of Moringaoleifera Carbon for the As(III) Removal from Contaminated Groundwater (2014)

Suman Barua[1], Ismail M. M. Rahman[1], M. Nazimuddin[2], and Hiroshi Hasegawa[3]

[1]Department of Applied and Environmental Chemistry, Faculty of Science, University of Chittagong, Chittagong 4331, Bangladesh

[2]Department of Chemistry, Faculty of Science, University of Chittagong, Chittagong 4331, Bangladesh

[3]Institute of Science and Engineering, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan

Abstract

Removal of trivalent arsenic from contaminated groundwater was studied using steam activated carbon prepared from the leaf, seed and pod of Moringaoleifera (MO) plant of the indigenous-cultivar of Bangladesh. Batch adsorption experiments were performed as a function of contact time, adsorbent doses and variants. The removal efficiency of the MO-leaf-carbon and MO-seed-carbon was substantial, while it was trivial for MO-pod-carbon. The pseudo-first- and second-order and intra-particle diffusion equations were used to evaluate the sorption mechanism of the MO carbon options. The MO is a common plant variety of the arsenic-affected Bengal delta. Therefore, it can be exploited as a cheaper resource of carbonaceous adsorbent for the economical removal of arsenic from the water.

Keywords: Arsenic, Carbon, economical removal of As, Moringaoleifera, leaf, seed, pod, arsenic, water treatment.

2.41. Effects of Arsenic on the Germination and Primary Growth Parameters of Kenaf, Mesta and Jute (2013)

[1] M. U. Nizam, [2] M. W. Zaman, [3] M. Jahiruddin, [4] M. M. Rahman and [5] M. S. Islam

[1]PhD Fellow, Department of Agricultural Chemistry, BAU, and Assistant Professor, Department of Agricultural Chemistry, Patuakhali Science and Technology University.

[2,4] Professor, Department of Agricultural Chemistry,

[3] Professor, Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

[5] Upazila Agriculture Officer (LR), DAE.

Abstract

Arsenic (As) is toxic element. It is toxic to plants, animals and humans. Plant tolerance to As varies from species to species, variety to variety and even in the growing stages of the plants.

The present study was carried out in the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh to evaluate the effects of As on the germination and primary growth parameters of kenaf (*Hibiscus cannabinus* L. cv. HC-95 & HC-3), mesta (*Hibiscus sabdariffa* L. cv. Samu-93), *deshi* jute (*Corchorus capsularis* L. cv. CVE-3, BJC-7370 & CVL-1) and *tossa* jute (*Corchorus olitorius* L. cv. O-72, O-9897, OM-1&O-795) in As contaminated medium. Six levels (0, 10, 20, 30, 40, 50 mg As L^{-1}) of As were applied. Each level was triplicated following CRD. Results showed that increasing levels of As significantly decreased the germination percentage; root and shoot growth; and dry biomass of seedlings. The varieties of kenaf and mesta were able to germinate and tolerate up-to 50 mg As L^{-1}. On the other hand, almost all the varieties of *deshi* and *tossa* jute germinated and tolerated only up-to 30 mg As L^{-1}. While experimentation, visible morphological deformities like twisting, curling and growth stunting of shoots, black discoloration and rottening of roots of the seedlings appeared with higher (30 - 50 mg As L^{-1}) concentrations of As. Considering all the parameters, the varieties of kenaf (cv. HC -95 & HC-3) and mesta (cv. Samu-93) were found more tolerant to As toxicity at germination phase.

Key words: Arsenic, Kenaf, Mesta, Jute, Germination, Root and Shoot growth.

2.42. A consecutive study on arsenic exposure and intelligence quotient (IQ) of children in Bangladesh (2013)

Nahar MN[1], Inaoka T, Fujimura M.

[1]The United Graduate School of Agricultural Sciences, Kagoshima University Allied to the Faculty of Agriculture, Saga University, 1 Honjo-machi, Saga City, Saga, 840-8502, Japan.

Abstract

OBJECTIVE: In a recent cross-sectional investigation, we reported the intellectual function of adolescents (aged 14 and 15 years) in Bangladesh who had been exposed to arsenic (As). Here, we report a consecutive investigation on the intelligence quotient (IQ) of 408 children who are living in the Sonargoan Thana of Bangladesh (two age groups: 9 and 10 years; 4 and 5 years) were exposed to high levels of As in the groundwater.

METHODS: Urine and water samples were collected to assess As exposure. The IQ of the children was estimated using the Raven's Standard Progressive Matrices and the Kaufman Brief Intelligence Test. Information on parents' socioeconomic status (SES) was collected as confounding factors.

RESULTS: The results indicate that As exposure was responsible for a lower IQ. The concentration of urinary As ([As]u) was associated with reduced intellectual function in a dose-response manner. A stronger association was found between reduced intellectual function (IQ) and [As]u than the level of As in the drinking water [As]w. There was no association between verbal IQ scores and [As]u of children in early childhood (aged 4 and 5 years).

CONCLUSION**:** Based on these results, we conclude that current levels of As in the urine ([As]u), which we considered to reflect recent exposure to As from all possible sources, including groundwater, food, among others, were negatively associated to the IQ of the children tested, and that this adverse effect of As may also gradually accumulate over time among the poor.

Keywords: As exposure, IQ.

2.43. Association of low to moderate levels of arsenic exposure with risk of type 2 diabetes in Bangladesh (2013)

Pan WC, Seow WJ, Kile ML et.al

Abstract

Chronic exposure to high levels of arsenic in drinking water is associated with increased risk of type 2 diabetes mellitus (T2DM), but the association between lower levels of arsenic and T2DM is more controversial. Therefore, this study evaluated the association between low to moderate arsenic exposure and T2DM. In 2009-2011, we conducted a study of 957 Bangladeshi adults who participated in a case-control study of skin lesions in 2001-2003. The odds ratio of T2DM was evaluated in relationship to arsenic exposure measured in drinking water and in subjects' toenails (in 2001-2003) prior to the diagnosis of T2DM (in 2009-2011). Compared with those exposed to the lowest quartile of arsenic in water (≤ 1.7 μg/L), the adjusted odds ratio for T2DM was 1.92 (95% confidence interval (CI): 0.82, 4.35) for those in the second quartile, 3.07 (95% CI: 1.38, 6.85) for those in the third quartile, and 4.51 (95% CI: 2.01, 10.09) for those in the fourth quartile. The relative excess risk of T2DM was 4.78 for individuals who smoked and 8.93 for people who had a body mass index (weight (kg)/height (m)(2)) greater than

25. These findings suggest that exposure to modest levels of arsenic in drinking water was associated with increased risk of T2DM in Bangladesh. Being overweight or smoking was also associated with increased risk of T2DM.

Keywords: Bangladesh; additive interaction; arsenic; diabetes; overweight; smoking

2.44. Arsenic Exposure Affects Plasma Insulin-Like Growth Factor 1 (IGF-1) in Children in Rural Bangladesh (2013)

Sultan Ahmed,[1,2]Rokeya Sultana Rekha,[1]Khalid Bin Ahsan[1] et.al

[1]Centre for Vaccine Sciences, International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), Dhaka, Bangladesh

[2]Institute of Environmental Medicine (IMM), Karolinska Institutet, Stockholm, Sweden

Abstract

Background

Exposure to inorganic arsenic (As) through drinking water during pregnancy is associated with lower birth size and child growth. The aim of the study was to assess the effects of As exposure on child growth parameters to evaluate causal associations.

Methodology/Findings

Children born in a longitudinal mother-child cohort in rural Bangladesh were studied at 4.5 years (n=640) as well as at birth (n=134). Exposure to arsenic was assessed by concurrent and prenatal (maternal) urinary concentrations of arsenic metabolites (U-As). Associations with plasma concentrations of insulin-like growth factor 1 (IGF-1), calcium (Ca), vitamin D (Vit-D), bone-specific alkaline phosphatase (B-ALP), intact parathyroid hormone (iPTH), and phosphate (PO_4) were evaluated by linear regression analysis, adjusted for socioeconomic factor, parity and child sex. Child U-As (per 10 µg/L) was significantly inversely associated with concurrent plasma IGF-1 (β=-0.27; 95% confidence interval: -0.50, -0.0042) at 4.5 years. The effect was more obvious in girls (β=-0.29; -0.59, 0.021) than in boys, and particularly in girls with adequate height (β=-0.491; -0.97, -0.02) or weight (β=-0.47; 0.97, 0.01). Maternal U-As was inversely associated with child IGF-1 at birth (r=-0.254, P=0.003), but not at 4.5 years. There was a tendency of positive association between U-As and plasma PO_4 in stunted boys (β=0.27; 0.089, 0.46). When stratified by % monomethylarsonic acid (MMA, arsenic metabolite) (median split at 9.7%), a much stronger inverse association between U-As and IGF-1 in the girls (β=-0.41; -0.77, -0.03) was obtained above the median split.

Conclusion

The results suggest that As-related growth impairment in children is mediated, at least partly, through suppressed IGF-1 levels.

Keywords: Arsenic Exposure, Plasma Insulin-Like Growth Factor 1.

2.45. Arsenic contamination in groundwater and its effects on adolescent intelligence and social competence in Bangladesh with special reference to daily drinking/cooking water intake (2013)

Nahar MN[1], Inaoka T, Fujimura M et.al

[1]The United Graduate School of Agricultural Sciences, Kagoshima University Allied to Faculty of Agriculture, Saga University, 1 Honjo-machi, Saga, Saga, 840-8502, Japan.

Environ Health Prev Med. 2014 Mar;19(2):159. Tasnim, Sayra [corrected to Tasmin, Saira].

Abstract

OBJECTIVE: The present study aims to investigate the relationship between arsenic (As) exposure and intelligence quotient (IQ) or social competence (SC) of Bangladeshi adolescents (aged 14 or 15 years) in Sonargaon thana.

METHODS: Information about socioeconomic status (SES) was collected as confounding factors. To evaluate the relative contribution of As sources to total As intake, the As concentrations in urine and drinking/cooking water, and the amount of water added in cooking, were assessed on site using a food frequency questionnaire (FFQ).

RESULTS: The results confirmed that As exposure was essential to lower adolescent IQ or SC because they were negatively associated with As exposure after controlling for SES (particularly household income). Except for cooking water, the amount of drinking water varied with season and appeared to be the major As source because the As concentration in water was generally correlated with the As concentration in urine, and they were related to lower IQ or SC (even after controlling for SES). The FFQ survey revealed that rice was consumed the most frequently (more than once daily), followed by daal (bean) soup and nonleafy vegetables, but fish, meat, and eggs were consumed approximately once a week. Water intake per meal from cooked rice was estimated to be 616 mL/person, followed by bean soup (258 mL/person) and cooked vegetables (82 mL/person).

CONCLUSIONS: Our results suggest that water used for cooking might be an important source of As, and the cooking process can affect the amount of As in cooked food.

Keywords: Intelligence quotient, social competence, As exposure.

2.46. Urinary and Dietary Analysis of 18,470 Bangladeshis Reveal a Correlation of Rice Consumption with Arsenic Exposure and Toxicity (2013)

Stephanie Melkonian,[1]Maria Argos,[1]Megan N. Hall[2] et.al

[1]Department of Health Studies, The University of Chicago, Chicago, Illinois, United States of America

[2]Department of Epidemiology, Mailman School of Public Health, Columbia University, New York, New York, United States of America

Abstract

Background: We utilized data from the Health Effects of Arsenic Longitudinal Study (HEALS) in Araihazar, Bangladesh, to evaluate the association of steamed rice consumption with urinary total arsenic concentration and arsenical skin lesions in the overall study cohort (N=18,470) and in a subset with available urinary arsenic metabolite data (N=4,517).

Methods: General linear models with standardized beta coefficients were used to estimate associations between steamed rice consumption and urinary total arsenic concentration and urinary arsenic metabolites. Logistic regression models were used to estimate prevalence odds ratios (ORs) and their 95% confidence intervals (CIs) for the associations between rice intake and prevalent skin lesions at baseline. Discrete time hazard models were used to estimate discrete time (HRs) ratios and their 95% CIs for the associations between rice intake and incident skin lesions.

Results: Steamed rice consumption was positively associated with creatinine-adjusted urinary total arsenic (β=0.041, 95% CI: 0.032-0.051) and urinary total arsenic with statistical adjustment for creatinine in the model (β=0.043, 95% CI: 0.032-0.053). Additionally, we observed a significant trend in skin lesion prevalence (P-trend=0.007) and a moderate trend in skin lesion incidence (P-trend=0.07) associated with increased intake of steamed rice.

Conclusions: This study suggests that rice intake may be a source of arsenic exposure beyond drinking water.

Keywords: Arsenic Exposure, Rice Consumption, Urinary and Dietary Analysis.

2.47. Consumption of arsenic and other elements from vegetables and drinking water from an arsenic-contaminated area of Bangladesh (2013)

Rahman MM[1], Asaduzzaman M, Naidu R

[1]Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Mawson Lakes Campus, Mawson Lakes, South Australia, SA 5095, Australia; Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC-CARE), P.O. Box 486, Salisbury South, SA 5106, Australia.

Abstract

The study assesses the daily consumption by adults of arsenic (As) and other elements in drinking water and home-grown vegetables in a severely As-contaminated area of Bangladesh. Most of the examined elements in drinking water were below the World Health Organization (WHO) guideline values except As. The median concentrations of As, cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), Mn, nickel (Ni), and zinc (Zn) in vegetables were 90 μg kg(-1), 111 μg kg(-1), 0.80 mg kg(-1), 168 μg kg(-1), 13 mg kg(-1), 2.1 mg kg(-1), 65 mg kg(-1), 1.7 mg kg(-1), and 50 mg kg(-1), respectively. Daily intakes of As, Cd, Cr, Co, Cu, Pb, manganese (Mn), Ni, and Zn from vegetables and drinking water for adults were 839 μg, 2.9 μg, 20.8 μg, 5.5 μg, 0.35 mg, 56.4 μg, 2.0mg, 49.1 μg, and 1.3mg, respectively. The health risks from consuming vegetables were estimated by comparing these figures with the WHO/FAO provisional tolerable weekly or daily intake (PTWI or PTDI). Vegetables alone contribute 0.05 μg of As and 0.008 mg of Cu per kg of body weight (bw) daily; 0.42 μg of Cd, 8.77 mg of Pb, and 0.03 mg of Zn per kg bw weekly. Other food sources and particularly dietary staple rice need to be evaluated to determine the exact health risks from such foods.

Keywords: Arsenic; Garden soil; Groundwater; Health risk; Vegetables

2.48. Status of Remediation of Arsenic Contamination of Groundwater in Bangladesh (2013)

M. Feroze Ahmed, T. Ahmed
BUET, Dhaka, Bangladesh

Abstract

Arsenic contamination of groundwater in Bangladesh has severely affected the groundwater-based drinking water supply system, and its effect on irrigation and agroenvironment is under evaluation. Bangladesh is heavily (approximately 71%) dependent on groundwater for irrigation. Hence, the effect of arsenic in irrigation water on soil, crops, and finally in the food chain is a concern. The content of this chapter is limited to arsenic remediation by provision of arsenic-safe drinking water for the exposed population in Bangladesh. Since the magnitude of the problem was understood, priority was given to installation of arsenic-safe alternative water supply options in the affected areas but the progress was very slow. In this context, the policy and implementation plan for arsenic remediation, alternative water supply options adopted, progress achieved, and limitations of technologies deployed have been discussed. A strategic outline for arsenic remediation developed on the basis of experience gained through implementation of arsenic mitigation programs has been presented in this chapter.

Keywords: Aquifer; Arsenic contamination; Disease burden; Groundwater; Pond sand filter; Rainwater harvesting; Remediation; Treatment technology; Tubewells; Water safety plan.

2.49. Follow-up Study on Arsenic Test and Exposure to Drinking Arsenic Contaminated Tubewell Water (2013)

Nepal C Dey, Sifat E Rabbi

Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

This study evaluated the changes in the status of arsenic test and exposure to drinking arsenic contaminated tubewell water in BRAC Water, Sanitation and Hygiene programme (WASH I) intervention during 2006-2011. Three consecutive surveys conducted in 11 arsenic-prone *upazila*s (sub-districts) from the first phase of BRAC WASH I programme. Data were collected from 6,600 households, 600 from each *upazila* in each survey. However, by physical verification in the sampled households, 3,410 tubewells were found at baseline (2007), 3,453 at midline (2009) and 4,374 at end-line (2011) surveys. Chi-square and T-tests compared the differences between indicator values, and binary logistic regression identified the determinants of outcome variable. Analysis revealed that proportion of red marked tubewells decreased from baseline to end-line whereas the proportion of green marked tubewells increased in end-line among all economic groups ($p<0.001$). The proportion of unmarked tubewells significantly decreased from baseline to end-line. Besides, the percentage of arsenic tested tubewell decreased from baseline to midline and to end-line where proportion of higher testing showed in the case of shared than own tubewell. Moreover, the proportion of arsenic contaminated own tubewell associated with poor and non-poor households and shared tubewell associated with ultra poor decreased significantly in end-line. Drinking arsenic contaminated water increased from midline to end-line in ultra poor group whereas decreased in poor and non-poor. Analysis revealed that females were more exposed to drinking arsenic contaminated water then male followed by household head's occupation as agriculture, and other occupation includes household activities, unemployed student, etc. significantly associated with drinking arsenic contaminated water. With the increase of education level the tendency of drinking

arsenic contaminated water decreased. The respondents having access to media, e.g. television and radio showed significantly lower odds ratio with reference to no media access category for drinking arsenic contaminated water. The age of household heads (30-45 years) were comparatively less exposed to arsenic contaminated drinking water as they were aware of it. Information and communication should be strengthened to encourage people in testing and marking tubewell.

Key words: Arsenic, Tubewell, WASH, Bangladesh

2.50. Bayesian Spatial Design of Optimal Deep Tubewell Locations in Matlab, Bangladesh (2013)

Warren JL[1], Perez-Heydrich C[2], Yunus M[3]

[1]Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7420.

[2]Department of Biostatistics, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7420 ; Carolina Population Center, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7420.

[3]International Centre for Diarrhoeal Disease Research, GPO Box 128, Dhaka 1000, Bangladesh.

Abstract

We introduce a method for statistically identifying the optimal locations of deep tubewells (dtws) to be installed in Matlab, Bangladesh. Dtw installations serve to mitigate exposure to naturally occurring arsenic found at groundwater depths less than 200 meters, a serious environmental health threat for the population of Bangladesh. We introduce an objective function, which incorporates both arsenic level and nearest town population size, to identify optimal locations for dtw placement. Assuming complete knowledge of the arsenic surface, we then demonstrate how minimizing the objective function over a domain favors dtws placed in areas with high arsenic values and close to largely populated regions. Given only a partial realization of the arsenic surface over a domain, we use a Bayesian spatial statistical model to predict the full arsenic surface and estimate the optimal dtw locations. The uncertainty associated with these estimated locations is correctly characterized as well. The new method is applied to a dataset from a village in Matlab and the estimated optimal locations are analyzed along with their respective 95% credible regions.

Keywords: Approximate likelihood; Environmental health; Markov chain Monte Carlo

2.51. Arsenic transport in irrigation water across rice-field soils in Bangladesh (2013)

Polizzotto ML[1], Lineberger EM, Matteson AR et.al

[1]Department of Soil Science, North Carolina State University, 101 Derieux St, Campus Box 7619, Raleigh, NC 26795, USA.

Abstract

Experiments were conducted to analyze processes impacting arsenic transport in irrigation water flowing over bare rice-field soils in Bangladesh. Dissolved concentrations of As, Fe, P, and Si varied over space and time, according to whether irrigation water was flowing or static. Initially, under flowing conditions, arsenic concentrations in irrigation water were below well-water levels and showed little spatial variability across fields. As flowing-water levels rose, arsenic concentrations were elevated at

field inlets and decreased with distance across fields, but under subsequent static conditions, concentrations dropped and were less variable. Laboratory experiments revealed that over half of the initial well-water arsenic was removed from solution by oxidative interaction with other water-column components. Introduction of small quantities of soil further decreased arsenic concentrations in solution. At higher soil-solution ratios, however, soil contributed arsenic to solution via abiotic and biotic desorption. Collectively, these results suggest careful design is required for land-based arsenic-removal schemes.

Keywords: Arsenic transport, irrigation water.

2.52. Arsenic in drinking water and renal cancers in rural Bangladesh (2013)

Mostafa MG[1], Cherry N.

[1]National Institute of Cancer Research and Hospital, Dhaka, Bangladesh.

Abstract

OBJECTIVES: Data on the role of arsenic in renal cancer are suggestive but inconclusive. The present analysis aimed to determine whether renal cancers were more likely in Bangladeshi villagers exposed to high arsenic concentration in well water and, if so, whether this excess was limited to transitional cell cancers (TCC) or occurred also for renal cell cancers (RCC).

METHODS: Histology/cytology results from renal biopsies carried out at a single clinic in Dhaka, Bangladesh, from January 2008 to October 2011 were classified into four groups: RCC, TCC, other malignancy and benign. Patients aged ≥18 years using hand-pumped well water were identified by questionnaire, blind to diagnosis. Arsenic concentration was estimated from British Geological Survey reports for administrative area (thana) of residence. In a case-referent design (with benign results as referents), ORs were calculated by multilevel logistic regression adjusted for confounding. Time since well installation and smoking were examined by stratification.

RESULTS: Among 1489 cases included, 896 were RCC, 90 TCC and 503 benign. Arsenic concentration was estimated for 301 thanas with 63% of cases and 40% referents with arsenic concentration ≥50 µg/L ($p<0.001$). Risk increased monotonically with arsenic concentration ≥50 µg/L for both cell types (RCC and TCC). Risk estimates were greater in thana with early well installation where risk was increased for RCC in exposure stratum 10<50 µg/L (OR=2.47 95% CI 1.52 to 4.01). Stratification by 'ever smoked' confirmed the presence of risk in non-smokers.

CONCLUSIONS: The relationship between arsenic concentration and both RCC and TCC suggests that arsenic is a causal factor in renal cancer.

Keywords: Arsenic, renal cancer, RCC, TCC.

2.53. Developing and testing theory-based and evidence-based interventions to promote switching to arsenic-safe wells in Bangladesh (2013)

Inauen J[1], Mosler HJ.

[1]University of Konstanz, Germany.

Abstract

Millions of people in Bangladesh drink arsenic-contaminated water despite increased awareness of consequences to health. Theory-based and evidence-based interventions are likely to have greater impact on people switching to existing arsenic-safe wells than providing information alone. To test this assumption, we first developed interventions based on an empirical test of the Risk, Attitudes, Norms, Abilities and Self-regulation (RANAS) model of behaviour change. In the second part of this study, a cluster-randomised controlled trial revealed that in accordance with our hypotheses, information alone showed smaller increases in switching to arsenic-safe wells than information with reminders or information with reminders and implementation intentions.

Keywords: Arsenic, arsenic-contaminated water, arsenic-safe wells.

2.54. Studies on thb technology of arsenic removal from arsenic contaminated ground water (2013)

A J M Tahuran Negerl, Md. Abul Hossainl, Sufia Parveent et.al

ISSN 2224-1698 Jagannat University Journal of Science, Volume-2, Number-II
I Institute of Glass and Ceramic Research and Testing, Bangladesh Council of Scientific and Industrial Research, Dhaka, Bangladesh

Abstract

Removal of arsenic is notv possible through adsorption-coprecipitation-filtration .from arsenic contaminated shallotv tube-well water. This technology was effective to produce arsenic safe water from well waters having water paranxeters regarding arsenic, iron and pltospltate at concentrationo .fu pto 750 ppb, I 0 ppm and 08 ppnt respectively.A bout 99 percent arsenic can be rentoved by using CI/As mass ratio greater than 23 and Fe/As mass ratio greater tlmn 80 and to get arsenic safe water through this technology. This technology could mitigate tite amount of iron, phosplmte,N O2, NO3, TDS, colour and turbidity of the well water and increasest nanganesel,i nc', sulphate and chlorine to tlrc eJfluent. Tlrc e.ffiuent analysis data were analyzed statistically using MINITA Bl4 statistical software. Results revealed that tlrc data appears to be randomly distributed around a mean yalue. The mean effluent arsenic concentration is less thttn 50ppb with 95Vo confidence level. And the probability of this case is thot the null lqpothesis (mean= 50ppb) could be rejected.

Keywords: Arsenic, adsorption-coprecipitcLtion-Jiltration, water parameters, Ntill Hypothesis, TTC and E-coli

2.55. Development of low cost Arsenic and Iron removal unit for potable water (2013)

Tariqul Islam, Prof. Dr. Zainul Abedin, Md. Zillur Rahman

Department of Farm Structure and Environmental Engineering
Bangladesh Agricultural University, Mymensingh

Abstract

This study elucidates an attempt to develop a low cost Arsenic and Iron removal unit for potable water. The safe limit of Arsenic is 0.01 mg/l recognized byWHO and the safe limit of Arsenic at Bangladesh is 0.05 mg/l. the Iron content in water should be less than 0.3 mg/l. The process of reducing Arsenic and Iron from water has been experimented by developing a unit in the Department of Farm Structure at Bangladesh Agricultural University, Mymensingh. In order to test the performance of the developed unit, arsenic contaminated water with three different concentrations like 0.05, 0.3 and 0.25 mg/l were prepared in the laboratory by mixing chemical arsenic. The samples were passed into the developed unit and the respective output concentrations were found to be 0.05, 0.02, 0.015 mg/l. The input and output concentrations of Arsenic were tested in the chemical testing laboratory under the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Iron contaminated water was collected from three selected tube wells of different halls and nearest place of Bangladesh Agricultural University in Mymensingh. The collected samples were also passed into the developed unit with three input concentrations like 0.77, 0.519, 0.503 mg/l and the respective output concentrations were found to be 0.20, 0.15, 0.11 mg/l. Also the concentrations of Iron were tested in the BINA, Mymensingh. The developed unit can be satisfactorily used for receiving 50 litres of potable water per day with removal efficiency of 90-94% for Arsenic and 71-78% for Iron. The manufacturing cost of the removal unit is about Tk. 900 which is cheaper than the others available unit in the market. This price of the unit is affordable to the rural people at farmer's level.

Keywords: safe limits, BINA, laboratory, input, output, concentrations, cost.

2.56. Predicting water consumption habits for seven arsenic-safe water options in Bangladesh (2013)

Inauen J[1], Tobias R, Mosler HJ.

[1]Environmental and Health Psychology, Department of Environmental Social Sciences, Eawag: Swiss Federal Institute of Aquatic Science & Technology, Überlandstrasse 133, Dübendorf, 8600, Switzerland.

Abstract

BACKGROUND: In Bangladesh, 20 million people are at the risk of developing arsenicosis because of excessive arsenic intake. Despite increased awareness, many of the implemented arsenic-safe water options are not being sufficiently used by the population. This study investigated the role of social-cognitive factors in explaining the habitual use of arsenic-safe water options.

METHODS: Eight hundred seventy-two randomly selected households in six arsenic-affected districts of rural Bangladesh, which had access to an arsenic-safe water option, were interviewed using structured face-to-face interviews in November 2009. Habitual use of arsenic-safe water options, severity, vulnerability, affective and instrumental attitudes, injunctive and descriptive norms, self-efficacy, and coping planning were measured. The data were analyzed using multiple linear regressions.

RESULTS: Linear regression revealed that self-efficacy (B = 0.42, SE = .03, p < .001), the instrumental attitude towards the safe water option (B = 0.24, SE = .04, p < .001), the affective attitude towards contaminated tube wells (B = -0.04, SE = .02, p = .024), vulnerability (B = -0.20, SE = .02, p < .001), as well as injunctive (B = 0.08, SE = 0.04, p = .049) and descriptive norms (B = 0.34, SE = .03, p < .001) primarily explained the habitual use of arsenic-safe water options (R2 = 0.688). This model proved highly generalizable to all seven arsenic-safe water options investigated, even though habitual use of single options were predicted on the basis of parameters estimated without these options.

CONCLUSIONS: This general model for the habitual use of arsenic-safe water options may prove useful to predict other water consumption habits. Behavior-change interventions are derived from the model to promote the habitual use of arsenic-safe water options.

Keywords: water consumption habits, arsenic-safe water options.

2.57. Increased Childhood Mortality and Arsenic in Drinking Water in Matlab, Bangladesh: A Population-Based Cohort Study (2013)

Mahfuzar Rahman, Nazmul Sohel, Mohammad Yunus et.al

Abstract

Background: Arsenic in drinking water was associated with increased risk of all-cause, cancer, and cardiovascular death in adults. However, the extent to which exposure is related to all-cause and deaths from cancer and cardiovascular condition in young age is unknown. Therefore, we prospectively assessed whether long-term and recent arsenic exposures are associated with all-cause and cancer and cardiovascular mortalities in Bangladeshi childhood population.

Methods and Findings: We assembled a cohort of 58406 children aged 5–18 years from the Health and Demographic Surveillance System of icddrb in Bangladesh and followed during 2003–2010. There were 185 non-accidental deaths registered in-about 0.4 million person-years of observation. We calculated hazard ratios for cause-specific death in relation to exposure at baseline (μg/L), time-weighted lifetime average (μg/L) and cumulative concentration (μg-years/L). After adjusting covariates, hazard ratios (HRs) for all-cause childhood deaths comparing lifetime average exposure 10–50.0, 50.1–150.0, 150.1–300.0 and ≥300.1μg/L were 1.37 (95% confidence interval [CI], 0.74–2.57), 1.44 (95% CI, 0.88–2.38), 1.22 (95% CI, 0.75–1.98) and 1.88 (95% CI, 1.14–3.10) respectively. Significant increased risk was also observed for baseline (P for trend = 0.023) and cumulative exposure categories (P for trend = 0.036). Girls had higher mortality risk compared to boys (HR for girls 1.79, 1.21, 1.64, 2.31; HR for boys 0.52, 0.53, 1.14, 0.99) in relation to baseline exposure. For all cancers and cardiovascular deaths combined, multivariable adjusted HRs amounted to 1.53 (95% CI 0.51–4.57); 1.29 (95% CI 0.43–3.87); 2.18 (95%CI 1.15–4.16) for 10.0–50.0, 50.1–150.0, and ≥150.1, comparing lowest exposure as reference (P for trend = 0.009). Adolescents had higher mortality risk compared to children (HRs = 1.53, 95% CI 1.03–2.28 vs. HRs = 1.30, 95% CI 0.78–2.17).

Conclusions: Arsenic exposure was associated with substantial increased risk of deaths at young age from all-cause, and cancers and cardiovascular conditions. Girls and adolescents (12–18 years) had higher risk compared to boys and child.

Keywords: Risk, cancer, children, death.

2.58. Risk of arsenic exposure from drinking water and dietary components: implications for risk management in rural Bengal (2013)

Halder D[1], Bhowmick S, Biswas A et.al

[1]KTH-International Groundwater Arsenic Research Group, Department of Land and Water Resources Engineering, KTH Royal Institute of Technology, Teknikringen 76, SE-100 44 Stockholm, Sweden.

Abstract

This study investigates the risk of arsenic (As) exposure to the communities in rural Bengal, even when they have been supplied with as safe drinking water. The estimates of exposure via dietary and drinking water routes show that, when people are consuming water with an As concentration of less than 10 μg L(-1), the total daily intake of inorganic As (TDI-iAs) exceeds the previous provisional tolerable daily intake (PTDI) value of 2.1 μg day(-1) kg(-1) BW, recommended by the World Health Organization (WHO) in 35% of the cases due to consumption of rice. When the level of As concentration in drinking water is above 10 μg L(-1), the TDI-iAs exceeds the previous PTDI for all the participants. These results imply that, when rice consumption is a significant contributor to the TDI-iAs, supplying water with an As concentration at the current national drinking water standard for India and Bangladesh would place many people above the safety threshold of PTDI. We also found that the consumption of vegetables in rural Bengal does not pose a significant health threat to the population independently. This study suggests that any effort to mitigate the As exposure of the villagers in Bengal must consider the risk of As exposure from rice consumption together with drinking water.

Keywords: As exposure, PTDI, health threat.

2.59. Acceptance and use of eight arsenic-safe drinking water options in Bangladesh (2013)

Inauen J[1], Hossain MM, Johnston RB, Mosler HJ

Eawag: Swiss Federal Institute of Aquatic Science & Technology, Department of System Analysis, Integrated Assessment and Modelling, Dübendorf, Switzerland.
J. Christopher States, Editor
[1]Eawag: Swiss Federal Institute of Aquatic Science & Technology, Department of System Analysis, Integrated Assessment and Modelling, Dübendorf, Switzerland
[2]Eawag: Swiss Federal Institute of Aquatic Science & Technology, Department of Water and Sanitation in Developing Countries (Sandec), Dübendorf, Switzerland
University of Louisville, United States of America

Abstract

Arsenic contamination of drinking water is a serious public health threat. In Bangladesh, eight major safe water options provide an alternative to contaminated shallow tubewells: piped water supply, deep tubewells, pond sand filters, community arsenic-removal, household arsenic removal, dug wells, well-sharing, and rainwater harvesting. However, it is uncertain how well these options are accepted and used by the at-risk population. Based on the RANAS model (risk, attitudes, norms, ability, and self-regulation) this study aimed to identify the acceptance and use of available safe water options. Cross-sectional face-to-face interviews were used to survey 1,268 households in Bangladesh in November 2009 (n=872), and December 2010 (n=396). The questionnaire assessed water consumption, acceptance factors from the RANAS model, and socioeconomic factors. Although all respondents had

access to at least one arsenic-safe drinking water option, only 62.1% of participants were currently using these alternatives. The most regularly used options were household arsenic removal filters (92.9%) and piped water supply (85.6%). However, the former result may be positively biased due to high refusal rates of household filter owners. The least used option was household rainwater harvesting (36.6%). Those who reported not using an arsenic-safe source differed in terms of numerous acceptance factors from those who reported using arsenic-safe sources: non-users were characterized by greater vulnerability; showed less preference for the taste and temperature of alternative sources; found collecting safe water quite time-consuming; had lower levels of social norms, self-efficacy, and coping planning; and demonstrated lower levels of commitment to collecting safe water. Acceptance was particularly high for piped water supplies and deep tubewells, whereas dug wells and well-sharing were the least accepted sources. Intervention strategies were derived from the results in order to increase the acceptance and use of each arsenic-safe water option.

Keywords: Arsenic contamination, water options, tubewells, arsenic safe source.

2.60. Decontamination of Spent Iron-Oxide Coated Sand from Filters Used in Arsenic Removal (2013)

Ismail M. M. Rahman, a, b, * Zinnat A. Begum, a HikaruSawai et.al

a Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan

B Department of Applied and Environmental Chemistry, University of Chittagong, Chittagong 4331, Bangladesh

Abstract

Sand filters devised with iron-rich adsorbents are extensively promoted and deployed inthe arsenic-prone south and south-east Asian countries (e.g. Bangladesh). The approachoffers superior performance in removing arsenic while the spent sludge from the sand filtersis an issue of concern due to the possibility of toxic releases after being discarded. In thiswork, a new technique is proposed for the treatment of spent iron-oxide coated sand (IOCS)from filters used in arsenic removal. Chelant-washing of the arsenic-loaded IOCS iscombined with the solid phase extraction treatment to accomplish the objective. The uniquepoint of the proposed process is the cost-effective scheme, which includes the option ofrecycling of the washing solvent beside the decontamination of the spent arsenic-rich sludge.

Keywords: Arsenic removal; Sand filter; Iron-oxide coated sand (IOCS); Spent sludge; Chelant washing

2.61. Design of a Low-cost Purification System for the Removal of Arsenic 85 Design of A Low-cost Purification System for the Removal of Arsenic from Tubewell water in Bangladesh and India (2013)

Phillip Thomas Crisp, Ahmedul Hye Chowdhury
Contributors: The Pennsylvania State University CiteSeerX Archives

Abstract

A low-cost purification system has been designed which incorporates air/light oxidation, a sediment trap and a bed of adsorbent chemicals in a brick-tank which can be placed next to a tube well. The brick-tank (5.5 m long, 2.0 m wide and 1.5-2.0 m high) comprises a reservoir for arsenic-contaminated water, a tap for flow control, spreader troughs from which water drips (in order to expose a large water surface to

air), a series of baffles which forces water repeatedly to the surface (in order to expose it to air and light), a series of sediment traps (to remove arsenic-contaminated iron hydroxide, calcium carbonate and other sparingly soluble salts), an adsorbent bed to remove remaining arsenic species, a water lock so that the system cannot run dry, and a reservoir for purified water. Baffles are low brick walls with every second half-brick removed in the base row of every second wall. Sediment traps are layers of crushed brick with particles of increasing size (2 to 10 mm), placed at the bottom of the baffles. Layers of crushed brick of decreasing particle size are placed above and below the adsorbent bed in order to prevent mechanical disturbance during the percolation.

Keywords: purification system, adsorbent chemicals, water drips, Baffle.

2.62. Contamination of drinking-water by arsenic in Bangladesh: a public health emergency (2013)

Allan Smith Elena, Allan H. Smith, Elena O. Lingas, Mahfuzar Rahman
Contributors: The Pennsylvania State University CiteSeerX Archives

Abstract

This paper describes the history of the discovery of arsenic in drinking-water in Bangladesh and recommends intervention strategies. Tube-wells were installed to provide "pure water" to prevent morbidity and mortality from gastrointestinal disease. The water from the millions of tube-wells that were installed was not tested for arsenic contamination. Studies in other countries where the population has had long-term exposure to arsenic in groundwater indicate that 1 in 10 people who drink water containing 500 mg of arsenic per litre may ultimately die from cancers caused by arsenic, including lung, bladder and skin cancers. The rapid allocation of funding and prompt expansion of current interventions to address this contamination should be facilitated. The fundamental intervention is the identification and provision of arsenic-free drinking water. Arsenic is rapidly excreted in urine, and for early or mild cases, no specific treatment is required. Community education and participation are essential to ensure that interventions are successful; these should be coupled with follow-up monitoring to confirm that exposure has ended. Taken together with the discovery of arsenic in groundwater in other countries, the experience in Bangladesh shows that groundwater sources throughout the world that are used for drinking-water should be tested for arsenic

Keywords: Bangladesh, arsenic poisoning, prevention and control, arsenic poisoning, therapy

2.63. Arsenic Contamination in Bangladesh: Contemporary Alarm and Future Strategy (2013)

Md. Anwarul Abedin, Rajib Shaw
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan

Abstract

For thousands of years, groundwater has served as a unique and reliable source of potable water in developed as well as developing countries. But, at the end of the twentieth century, groundwater contamination of arsenic in Bangladesh is a serious national problem. Sixty-one districts out of sixty-four districts currently have been affected by arsenic contamination and up to 77 million people in Bangladesh have been exposed to toxic levels of arsenic from drinking water. To save the lives of millions in Bangladesh: a great challenge for the Government of Bangladesh is to provide safe drinking water for the urban and rural population. Hence, this chapter provides an insight into the historical background to the problem of safe drinking water in Bangladesh from surface water, groundwater, and

rainwater sources. It includes special reference to the occurrences, nature and extent and causes of arsenic contamination in groundwater aquifers of Bangladesh, which has emerged as a major crisis of the present decade. In addition, this chapter put its special attention on social problems due to the presence of arsenic in the drinking water, its impact on human health, agriculture, food chain and environment, Government and other organizations initiatives against arsenic contamination and the present status of technological achievement of arsenic removal at individual and community level in Bangladesh and finally this chapter serves as a ground for the common readers including researchers, policy makers, practitioners and academia.

Keywords: Potable water, toxic levels of arsenic, contamination of arsenic.

2.64. Arsenic contaminated groundwater and its treatment options in Bangladesh (2012)

Jiang JQ[1], Ashekuzzaman SM, Jiang A et.al

[1]School of Engineering and Built Environment, Glasgow Caledonian University, Glasgow, Scotland G4 0BA, UK.

Abstract

Arsenic (As) causes health concerns due to its significant toxicity and worldwide presence in drinking water and groundwater. The major sources of As pollution may be natural process such as dissolution of As-containing minerals and anthropogenic activities such as percolation of water from mines, etc. The maximum contaminant level for total As in potable water has been established as 10 µg/L. Among the countries facing As contamination problems, Bangladesh is the most affected. Up to 77 million people in Bangladesh have been exposed to toxic levels of arsenic from drinking water. Therefore, it has become an urgent need to provide As-free drinking water in rural households throughout Bangladesh. This paper provides a comprehensive overview on the recent data on arsenic contamination status, its sources and reasons of mobilization and the exposure pathways in Bangladesh. Very little literature has focused on the removal of As from groundwaters in developing countries and thus this paper aims to review the As removal technologies and be a useful resource for researchers or policy makers to help identify and investigate useful treatment options. While a number of technological developments in arsenic removal have taken place, we must consider variations in sources and quality characteristics of As polluted water and differences in the socio-economic and literacy conditions of people, and then aim at improving effectiveness in arsenic removal, reducing the cost of the system, making the technology user friendly, overcoming maintenance problems and resolving sludge management issues.

Keywords: Arsenic pollution, groundwater, toxic levels of arsenic, treatment options.

2.65. Arsenic in tube well water in Bangladesh: health and economic impacts and implications for arsenic mitigation (2012)

[a]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, United States of America.
[b]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland.

Abstract

A national drinking water quality survey conducted in 2009 furnished data that were used to make an updated estimate of chronic arsenic exposure in Bangladesh. About 20 million and 45 million people were found to be exposed to concentrations above the national standard of 50 µg/L and the World

Health Organization's guideline value of 10 µg/L, respectively. From the updated exposure data and all-cause mortality hazard ratios based on local epidemiological studies, it was estimated that arsenic exposures to concentrations > 50 µg/L and 10–50 µg/L account for an annual 24 000 and perhaps as many as 19 000 adult deaths in the country, respectively. Exposure varies widely in the 64 districts; among adults, arsenic-related deaths account for 0–15% of all deaths. An arsenic-related mortality rate of 1 in every 16 adult deaths could represent an economic burden of 13 billion United States dollars (US$) in lost productivity alone over the next 20 years. Arsenic mitigation should follow a two-tiered approach: (i) prioritizing provision of safe water to an estimated 5 million people exposed to > 200 µg/L arsenic, and (ii) building local arsenic testing capacity. The effectiveness of such an approach was demonstrated during the United Nations Children's Fund 2006–2011 country programme, which provided safe water to arsenic-contaminated areas at a cost of US$ 11 per capita. National scale-up of such an approach would cost a few hundred million US dollars but would improve the health and productivity of the population, especially in future generations.

Keywords: arsenic mitigation, tubewell, arsenic-related death, water guideline.

2.66. Pre- and Postnatal Arsenic Exposure and Body Size to 2 Years of Age: A Cohort Study in Rural Bangladesh (2012)

Kuntal K. Saha,[1,2] Annette Engström,[3] Jena Derakhshani Hamadani,[1] et.al

[1]International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh;

[2]International Food Policy Research Institute, Washington, DC, USA;

[3]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden; 4Division of Nutritional Sciences, Cornell University, Ithaca, New York, USA

Abstract

Background: Exposure to arsenic via drinking water has been associated with adverse pregnancy outcomes and infant morbidity and mortality. Little is known, however, about the effects of arsenic on child growth.

Objective: We assessed potential effects of early-life arsenic exposure on weight and length of children from birth to 2 years of age.

Methods: We followed 2,372 infants born in a population-based intervention trial in rural Bangladesh. Exposure was assessed by arsenic concentrations in urine (U-As) of mothers (gestational weeks 8 and 30) and children (18 months old). Child anthropometry was measured monthly in the first year and quarterly in the second. Linear regression models were used to examine associations of U-As (by quintiles) with child weight and length, adjusted for age, maternal body mass index, socioeconomic status, and sex (or stratified by sex).

Results: Median (10th–90th percentiles) U-As concentrations were about 80 (25–400) µg/L in the mothers and 34 (12–159) µg/L in the children. Inverse associations of maternal U-As with child's attained weight and length at 3–24 months were markedly attenuated after adjustment. However, associations of U-As at 18 months with weight and length at 18–24 months were more robust, particularly in girls. Compared with girls in the first quintile of U-As (< 16 µg/L), those in the fourth quintile (26–46 µg/L) were almost 300 g lighter and 0.7 cm shorter, and had adjusted odds ratios (95%

confidence interval) for underweight and stunting of 1.57 (1.02–2.40) and 1.58 (1.05–2.37), respectively, at 21 months.

Conclusions: Postnatal arsenic exposure was associated with lower body weight and length among girls, but not boys.

Keywords: Infant morbidity, arsenic exposure, Child anthropometry.

2.67. Evaluation of an Arsenic Test Kit for Rapid Well Screening in Bangladesh (2012)

Christine Marie George *†, Yan Zheng ‡, Joseph H. Graziano § et.al

† Department of International Health, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland 21205, United States
‡ UNICEF Bangladesh, Dhaka, Bangladesh
§ Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, New York, New York 10032, United States

Abstract

Exposure to arsenic in groundwater via drinking remains unabated for millions of villagers in Bangladesh. Since a blanket testing campaign using test kits almost a decade ago, millions of new wells have been installed but not tested; thus affordable testing is needed. The performance of the Arsenic Econo-Quick (EQ) kit was evaluated by blindly testing 123 wells in Bangladesh and comparing with laboratory measurements; 65 wells were tested twice. A subset of the same 123 wells was also tested using the Hach EZ kit in the field and the Digital Arsenator in the laboratory in Bangladesh. The EQ kit correctly determined the status of 110 (89%) and 113 (92%) out of 123 wells relative to the WHO guideline (10 μg/L) and the Bangladesh standard (50 μg/L), respectively. Relative to the WHO guideline, all misclassifications were underestimates for wells containing between >10 and 27 μg/L As. Relative to the Bangladesh As standard, over- and underestimates were evenly distributed. Given its short reaction time of 10 min relative to the Hach EZ and its lower cost compared to the Arsenator, the EQ kit appears to have several advantages for well testing in Bangladesh and elsewhere.

Keywords: Exposure to arsenic, test kits, Arsenic Econo-Quick (EQ) kit.

2.68. Impact of a Randomized Controlled Trial in Arsenic Risk Communication on Household Water-Source Choices in Bangladesh (2012)

Lori Bennear, Alessandro Tarozzi, Alexander Pfaff et.al

Lori Bennear: ude.ekud@raenneb.irol; Alessandro Tarozzi: ude.fpu@izzorat.ordnassela; Alexander Pfaff: ude.ekud@_afp.xela;

Abstract

We conducted a randomized controlled trial in rural Bangladesh to examine how household drinking-water choices were affected by two different messages about risk from naturally occurring groundwater arsenic. Households in both randomized treatment arms were informed about the arsenic level in their well and whether that level was above or below the Bangladesh standard for arsenic. Households in one

group of villages were encouraged to seek water from wells below the national standard. Households in the second group of villages received additional information explaining that lower-arsenic well water is always safer and these households were encouraged to seek water from wells with lower levels of arsenic, irrespective of the national standard. A simple model of household drinking-water choice indicates that the effect of the emphasis message is theoretically ambiguous. Empirically, we find that the richer message had a negative, but insignificant, effect on well-switching rates, but the estimates are sufficiently precise that we can rule out large positive effects. The main policy implication of this finding is that a one-time oral message conveying richer information on arsenic risks, while inexpensive and easily scalable, is unlikely to be successful in reducing exposure relative to the status-quo policy.

Keywords: Beliefs, Information, Health risk, Arsenic, Drinking water, Bangladesh

2.69. Design and development of Arsenic and Iron removal unit for drinking water (2012)

Tangina Akhter, Prof. Dr. Zainul Abedin, Md. Zillur Rahman

Department of Farm Structure, Bangladesh Agricultural University, Mymensingh

Abstract

This study elucidates an attempt to design and development of Arsenic and Iron removal unit for drinking water. The safe limits of Arsenic and Iron content in water should be within 0.05 mg/l and 0.20 mg/l respectively. The process of reducing Arsenic and Iron from water has been experimented by developing a unit in the Department of Farm Structure at Bangladesh Agricultural University, Mymensingh. In order to test the performance of the developing unit, arsenic contaminated water with four different concentrations like 0.05, 0.10, 0.15 and 0.20 mg/l were prepared in the laboratory and passed into the developed unit and the respective output concentrations were found to be 0.00,0.01, 0.025 and0.05 mg/l. the input and output concentrations of Arsenic were tested in the chemical testing laboratory under the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Iron contaminated water were collected from four selected tube wells of local Mymensingh and were also passed into the developed unit with four input concentrations like 0.18, 0.1532, 0.179 and 0.133 mg/l and the respective output concentrations were found to be 0.10, 0.1021, 0.11 and 0.09 mg/l. the concentrations of Iron were tested in the chemical testing laboratory under the Soil Resource Development Institute (SRDI), Dhaka, The developed unit has the capacity to remove Arsenic and Iron and help to eradicates hazardous problem of people.

Keywords: safe limits, BINA, laboratory, input, output, concentrations, SRDI.

2.70. A performance assessment of arsenic-iron removal plants in the Manikganj district of Bangladesh (2012)

Brennan R[1], McBean E.

[1]University of Guelph, 50 Stone Rd E., Guelph, ON, Canada N1G 2W1.

Abstract

In Bangladesh, arsenic contamination of groundwater, microbial contamination of surface water and seasonally variable rainfall make reliable access to acceptable quality drinking water a challenge. Arsenic-iron removal plants (AIRPs) are a relatively inexpensive way of removing arsenic from

groundwater for access to safer drinking water. This study evaluated the performance of 21 (of 105) AIRPs installed by a local non-governmental organization (Society for People's Action in Change and Equity) with financial assistance from the Australian High Commission, Dhaka, under the Direct Aid Program of the Australian Government. All AIRPs achieved the Bangladesh standard for arsenic in drinking water of 50 microg L(-1) and 17 achieved the World Health Organization guideline of 10 microg L(-1). The AIRPs removed 87% of influent arsenic, on average. After cleaning, poor arsenic and iron removal was observed for about 2 days due to inadequate residence time. Chemical processes that may influence AIRP performance are also discussed herein, including iron and arsenic oxidation, arsenic co-precipitation with iron, multiple iron additions, interference by organics, and iron crystallization. Effluent faecal coliform counts were generally low, though were slightly higher than influent counts. Overall, AIRPs were shown to possess considerable promise for use in areas with high natural iron where users are concerned about arsenic and/or iron in their drinking water.

Keywords: Arsenic-iron removal plants, World Health Organization guideline, residence time, faecal coliform counts.

2.71. Field Testing of Arsenic in Groundwater Samples of Bangladesh Using a Test Kit Based on Lyophilized Bioreporter Bacteria (2012)

Konrad Siegfried †, Carola Endes †, Abul Fateh Md. Khaled Bhuiyan ‡ et.al

†Helmholtz Centre for Environmental Research—UFZ, Department of Environmental Microbiology, Leipzig, Germany

‡ The ACME Specialized Pharmaceuticals Ltd., Dhulivita, Dhamrai, Dhaka, Bangladesh

Abstract

A test kit based on living, lyophilized bacterial bioreporters emitting bioluminescence as a response to arsenite and arsenate was applied during a field campaign in six villages across Bangladesh. Bioreporter field measurements of arsenic in groundwater from tube wells were in satisfying agreement with the results of spectroscopic analyses of the same samples conducted in the lab. The practicability of the bioreporter test in terms of logistics and material requirements, suitability for high sample throughput, and waste disposal was much better than that of two commercial chemical test kits that were included as references. The campaigns furthermore demonstrated large local heterogeneity of arsenic in groundwater, underscoring the use of well switching as an effective remedy to avoid high arsenic exposure.

Keywords: Test kit, lyophilized bacterial bioreporters, arsenic.

2.72. Application of a simple arsenic removal filter in a rural area of Bangladesh (2012)

Md Mahmudul Hasan, Md Shafiquzzaman, Jun Nakajima and Quazi Hamidul Bari

Department of Environmental Systems Engineering, Ritsumeikan University, 1-1-1 Nojihigashi, Kusatsu, Shiga 525-8577, Japan.

Department of Civil Engineering, Khulna University of Engineering and Technology (KUET), Khulna, Bangladesh

Abstract

A simple and low-cost household-based arsenic (As) removal filter (ARF) was tested under actual field conditions in a rural area of Bangladesh. The ARF consisted of a ceramic filter made of clay soil and rice bran collected on-site, iron netting and iron bacterial sludge liquor. Fifteen ARFs (14 shallow and one deep tubewells) were installed in three villages (five in each area) in the Khulna region (southwestern region of Bangladesh), and their performance was evaluated. More than 60% of ARFs produced effluent with As<50 μg/L (Bangladesh standard level). The effects of Fe and P on As removal were the same as in laboratory experiments. X-ray Absorption Fine Structure (XAFS) analysis showed the adsorption of primarily As(V), with lesser amounts of As(III). Continuous As removal performance was observed over 1 year of ARF use. By introducing a double ARF system, the As removal was significantly enhanced for the region with high As contamination levels. The ARF manufacturing cost was estimated to be US$4–5, which is low and affordable to the rural households of Bangladesh. The ARF, made of locally available materials, had a low cost and minimal maintenance and showed high user acceptance, satisfaction and sustained use.

Keywords: Arsenic removal filter; groundwater contamination; iron oxidation; rural area of Bangladesh; simple treatment

2.73. Arsenic in Eggs and Excreta of Laying Hens in Bangladesh: A Preliminary Study (2012)

Ghosh, Amalendu; Awal, M.A.; Majumder, Shankar et.al
ICDDR,B

Abstract

The aim of this study was to detect arsenic concentrations in feed, well-water for drinking, eggs, and excreta of laying hens in arsenic-prone areas of Bangladesh and to assess the effect of arsenic-containing feed and well-water on the accumulation of arsenic in eggs and excreta of the same subject. One egg from each laying hen (n=248) and its excreta, feed, and well-water for drinking were collected. Total arsenic concentrations were determined by atomic absorption spectrophotometer, coupled with hydride generator. Effects of arsenic-containing feed and drinking-water on the accumulation of arsenic in eggs and excreta were analyzed by multivariate regression model, using Stata software. Mean arsenic concentrations in drinkingwater, feed (dry weight [DW]), egg (wet weight [WW]), and excreta (DW) of hens were 77.3, 176.6, 19.2, and 1,439.9 ppb respectively. Significant ($p<0.01$) positive correlations were found between the arsenic contents in eggs and drinking-water ($r=0.602$), drinking-water and excreta ($r=0.716$), feed and excreta ($r=0.402$) as well as between the arsenic content in eggs and the age of the layer ($r=0.243$). On an average, 55% and 82% of the total variation in arsenic contents of eggs and excreta respectively could be attributed to the variation in the geographic area, age, feed type, and arsenic contents of drinking-water and feed. For each week's increase in age of hens, arsenic content in eggs increased by 0.94%. For every 1% elevation of arsenic in drinking-water, arsenic in eggs and excreta increased by 0.41% and 0.44% respectively whereas for a 1% rise of arsenic in feed, arsenic in eggs and excreta increased by 0.40% and 0.52% respectively. These results provide evidence that, although high arsenic level prevails in well-water for drinking in Bangladesh, the arsenic shows low biological transmission capability from body to eggs and, thus, the value was below the maximum tolerable limit for humans. However, arsenic in drinking-water and/or feed makes a significant contribution to the arsenic accumulations in eggs and excreta of laying hens.

Keywords: Arsenic; Drinking-water; Egg; Excreta; Feed; Laying hen; Bangladesh

2.74. Arsenic in the groundwater in Bangladesh: A geostatistical and epidemiological framework for estimating health effects and evaluating remedies (2012)

Winston H. Yu, Charles M. Harvey, Charles F. Harvey
Contributors: The Pennsylvania State University CiteSeerX Archives

Abstract

This paper examines the health crisis in Bangladesh due to dissolved arsenic in groundwater. First, we use geostatistical methods to construct a map of arsenic concentrations that divides Bangladesh into regions and estimate vertical concentration trends in these regions. Then, we use census data to estimate exposure distributions in the regions; we use epidemiological data from West Bengal and Taiwan to estimate dose response functions for arsenicosis and arsenic-induced cancers; and we combine the regional exposure distributions and the dose response models to estimate the health effects of groundwater arsenic in Bangladesh. We predict that long-term exposure to present arsenic concentrations will result in approximately 1,200,000 cases of hyperpigmentation, 600,000 cases of keratosis, 125,000 cases of skin cancer, and 3000 fatalities per year from internal cancers. Although these estimates are very uncertain, the method provides a framework for incorporating better data as it becomes available. Moreover, we examine the remedy of drilling deeper wells in selected regions of Bangladesh. By replacing 31% of the wells in the country with deeper wells the health effects of drinking groundwater arsenic could be reduced by approximately 70 % provided that arsenic concentrations in drinking water.

Keywords: Dissolved arsenic, geostatistical methods, arsenicosis, arsenic-induced cancers.

2.75. Research findings on arsenic issue: Experience of integrated community based arsenic mitigation project (2012)

Dr. Ahammadul Kabir, Susil Kumar Das
Asia Arsenic Network Dhaka, Bangladesh

Abstract

Recently in Bangladesh, arsenic pollution has been come into view as one of the grim public health concerns. Despite the fact that the country wide magnitude of the problem could not be assessed yet, it has however, been guessed that running between 18 million to 77 million people are at the risk of contracting arsenicosis as revealed by various national and international organizations. Over the past few years, the titles ‘arsenic bringing people slow death’. ‘Mass poisoning using ground water’, “poison water in Bangladesh’ – came into sight in various national and international news media which actually present the evidences regarding the on-going catastrophic natural disaster of ground water pollution in Bangladesh causing much concern both for the people and the Government.

Keywords: Integrated Community Based Arsenic Mitigation Project, screening, ground water pollution.

2.76. Arsenic in tube well water in Bangladesh: health and economic impacts and implications for arsenic mitigation (2012)

Sara V Flanagan [a], Richard B Johnston [b] & Yan Zheng [a]

[a]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, United States of America.
[b]Eawag, Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland.

Abstract

A national drinking water quality survey conducted in 2009 furnished data that were used to make an updated estimate of chronic arsenic exposure in Bangladesh. About 20 million and 45 million people were found to be exposed to concentrations above the national standard of 50 µg/L and the World Health Organization's guideline value of 10 µg/L, respectively. From the updated exposure data and all-cause mortality hazard ratios based on local epidemiological studies, it was estimated that arsenic exposures to concentrations > 50 µg/L and 10-50 µg/L account for an annual 24,000 and perhaps as many as 19,000 adult deaths in the country, respectively. Exposure varies widely in the 64 districts; among adults, arsenic-related deaths account for 0-15% of all deaths. An arsenic-related mortality rate of 1 in every 16 adult deaths could represent an economic burden of 13 billion United States dollars (US$) in lost productivity alone over the next 20 years. Arsenic mitigation should follow a two-tiered approach: (i) prioritizing provision of safe water to an estimated 5 million people exposed to > 200 µg/L arsenic, and (ii) building local arsenic testing capacity. The effectiveness of such an approach was demonstrated during the United Nations Children's Fund 2006-2011 country programme, which provided safe water to arsenic-contaminated areas at a cost of US$ 11 per capita. National scale-up of such an approach would cost a few hundred million US dollars but would improve the health and productivity of the population, especially in future generations.

Keywords: Adult Arsenic Arsenic: adverse effects Arsenic: analysis Arsenic Poisoning Arsenic Poisoning: economics Arsenic Poisoning: epidemiology Arsenic Poisoning: mortality Arsenic: standards Bangladesh Bangladesh: epidemiology Cardiovascular Diseases Cardiovascular Diseases: chemically induced Cardiovascular Diseases: mortality Cause of Death Dose-Response Relationship, Drug Drinking Water Drinking Water: adverse effects Drinking Water: analysis Drinking Water: standards Female Humans Infant Mortality Infant, Newborn Infection Infection: chemically induced Infection: mortality Maternal-Fetal Exchange Maternal-Fetal Exchange: drug effects Neoplasms Neoplasms: chemically induced Neoplasms: mortality Pregnancy Water Pollutants, Chemical Water Pollutants, Chemical: adverse effects Water Pollutants, Chemical: analysis Water Pollutants, Chemical: standards Water Wells Water Wells: analysis Water Wells: standards

2.77. Community managed Arsenic Removal Plant (2012)

Shafi qul Islam
Director Programs, Dhaka Ahsania Mission

Abstract

Arsenic had been detected in Bangladesh in late 90s and soon became the most priority concern among the development organization along with the government agencies. More than 15,000 patients were identified who were victim of the wide spread water borne toxicities ever seen in the region. A large scale survey across the country took place to detect the consequence of the arsenic and it was found that more than 20% of the country is affected from deadly range of arsenic concentration in tube well water. The vast areas in the Ganges Delta, especially South-Western districts were found to be the critical hot spots having 90% of their ground water, which once known to be safe, were contaminated with the deadly arsenic over acceptable limit of 50ppb.

Jessore and Satkhira, the south western districts in lower Ganges Delta are close to the border of India and just some kilometers away from where the poisoning was fi rst detected. In these districts, lives of the people are exposed to threat of high arsenic poisoning and many poor people have been badly suffering from arsenicosis. This has also created another socio cultural problem, as such, the people

suffering from arsenicosis of those areas are isolated and discriminated and people became reluctant to develop marital relationships with families whose members suffer from arsenicosis. This has caused serious anxiety for parents of unmarried adult children. The affected people are suffering from mental stress, inferiority complex and uncertainty about the future as there is no medical cure for the disease. Almost all of the arsenicosis patients are having constrained lives and women are more negatively affected than men.

In earlier 2000, many chemical and non chemical technologies were brought in to resolve the problem but in vain. Then, Dhaka Ahsania Mission (DAM) launched community managed solution to address the problem. Finally, SIDCO technology was preferred due to its performance and serving capacity. SIDCO Arsenic Removal Plant is a chemical technology developed by GmBH of Germany using granular ferric hydroxide. The structure of the plant is available in the country while it is manufactured locally in Dhaka and this was the only chemical technology approved by the government. The hourly production ofsmallest plant is 300L and it can remove arsenic up to an untraceable concentration. It also removesiron and improves taste of water. The key potential is the design of the plant which is simple to operatewith plug and play. The replacements are available in the market and SIDCO Company provides aftersales service as well as the environmentally safe management of arsenic waste.

Barsa Ganokendra, the local community organization became the receiver of the service. A separatecommittee was formed for the plant management which along with Ganokendra members worked toaware and motivates people on arsenic safe water and acceptance of the plant. The operation andmaintenance mechanism was finalized through series of community meetings and formulated theprocess of simple social business. Through the awareness raising and motivation, the communityspontaneously placed their willingness to pay for water and set a year bound rate for pitcher waterwithin their affordability. A female local entrepreneur from the same villagewas identified and trained to run the plant. Lack of awareness, absence ofstrong community organization, availability of electricity, availability of waterbearing aquifer to avoid fecal contamination and year round availability and finding suitable local entrepreneur are major challenges seen in these plants.However, the intrinsic potentiality of this initiative is the water demand andpeople's willingness to pay for arsenic free water that basically developeddue to nationwide campaign on arsenic.

Keywords: Patients, tube well, Ganges, arsenicosis, SIDCO.

2.78. Grassroots initiative to solve the safe water crisis (2012)

Shamim Arfeen
Executive Director, An Organisation for Socio-Economic Development

Abstract

The Southwest Coastal Region of Bangladesh is a part of the Ganges flood plain and has rich biodiversity and geographically a brackish water regime which has made it vulnerable to naturaldisasters. Human civilization and culture of the region has developed through the utilization of naturalresources. The development activities during the last four decades without considering its sensitiveecology and people's interest have resulted in massive degradation of environment-ecology and tidalwater management. Inhabitants of this region are victims of an enduring crisis of water resources fordrinking and domestic uses. The crisis has increased the incidence of water-borne diseases. Due tothe increased salinity of soil and water, local agriculture has drastically declined and cattle have almostdisappeared. Due to water scarcity, Dacope Upazila (sub-district, under the Khulna district) is one ofthe most vulnerable areas in this region. The local people, specially comprises of the poor and marginalpeople

without access to safe water, and who are highly vulnerable to diseases caused by lack of safewater. This leads to loss of income and unbearable expense for health services.

In this context, AOSED initiated a project titled Grassroots Initiative to Solve the Safe Water Crisisfrom 2007 till 2010. This project formed grassroots organizations 'Paani Audhikar Committee-PAC'(Water Rights Committee), conducted awareness & media campaign, identified local problems, needsand resources, developed effective communication with the different administrative strata and policyactors, conducted grassroots and policy advocacy; and repaired and constructed water points withpeoples' contribution and participations. The people's organization-PAC, Union Parishad and DPHEjointly work for maintenance and management of the water points ensuring the follow-up of the solutionat local level by local resources mobilization.

Post-project period, people have become organized and their knowledge and capacity to conservesafe water resources, conduct grassroots advocacy, local resources mobilization has enhanced andthey have developed a participatory management system of water points. Political parties and allies havebecome unanimous regarding the safe water issue. Legal action has been initiated by the government toprohibit leasing out of water bodies. Environment-unfriendly brackish water commercial shrimp culturehas been reduced by 80% in Dacope Upazila through joint initiative of community people and government.Department of Public Health Engineering (DPHE) with relevant Government organizations has becomemore sensitized regarding the safe water issue. The project has gained justifi cation for expanding intothe wider coastal region. And, organization staff gained experience of this kind of multilateral approachand became more confident.

Activities and implementing strategy of the solution can make a precedent for other sufferingcommunity to receive and implement this experience in their own context for sustainable solution of safewater crisis. Initially, the grassroots people had no experience of working with NGOs and contributingfor implementing any project but later on, they were convinced that their contribution will make them theowner of the benefi ts of the project. When people rise, no obstacles are too big to overcome. People ofDacope have proved that success can be achieved even out of the mouth of crisis. These successesare only the beginning because in the present context, when world leaders are struggling to reacha consensus about climate change, Dacope has started to make some headway in the struggle forensuring the right to fresh, pure and safe drinking water for a better humanitarian world.

Keyword: Ganges, biodiversity, grassroots, people, Dacope, DPHE, safe drinking, health

2.79. Improvement of Health Damage and Poverty by Arsenic Contamination in AbhaynagarUpazila, Jessore District, Bangladesh (April, 2010 to March, 2012)

Contact Person
Name: Sachie Tsushima
Designation: Country Manager
Telephone: 02.9894493
Mobile : 01713.002269
Email: tsushima@citech-bd.com

Project Director/Principle Researcher:
Name: Professor Masakazu Tani
Designation: Project Manager
Email:mt18916@gmail.com

Objective of the Project/Research

Strengthening the capacity of villagers, doctors, health workers and government to develop the safety-net measure to alleviate health damage and Poverty due to arsenic contamination.

Major Findings

Early Detection of Arsenicosis is Essential and Rehabilitation of Poor Severe Arsenicosis is Needed to be Considered by using Existing Government safety-net.

2.80. Increase in Diarrheal Disease Associated with Arsenic Mitigation in Bangladesh (2011)

Jianyong Wu[1], Yasuyuki Akita Jahangir Alam[1], Marc L. Serre[1] et.al

[1]Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, United States of America

Abstract

Background: Millions of households throughout Bangladesh have been exposed to high levels of arsenic (As) causing various deadly diseases by drinking groundwater from shallow tubewells for the past 30 years. Well testing has been the most effective form of mitigation because it has induced massive switching from tubewells that are high (>50 µg/L) in As to neighboring wells that are low in As. A recent study has shown, however, that shallow low-As wells are more likely to be contaminated with the fecal indicator E. coli than shallow high-As wells, suggesting that well switching might lead to an increase in diarrheal disease.

Methods: Approximately 60,000 episodes of childhood diarrhea were collected monthly by community health workers between 2000 and 2006 in 142 villages of Matlab, Bangladesh. In this cross-sectional study, associations between childhood diarrhea and As levels in tubewell water were evaluated using logistic regression models.

Results: Adjusting for wealth, population density, and flood control by multivariate logistic regression, the model indicates an 11% (95% confidence intervals (CIs) of 4–19%) increase in the likelihood of diarrhea in children drinking from shallow wells with 10–50 µg/L As compared to shallow wells with >50 µg/L As. The same model indicates a 26% (95%CI: 9–42%) increase in diarrhea for children drinking from shallow wells with ≤10 µg/L As compared to shallow wells with >50 µg/L As.

Conclusion: Children drinking water from shallow low As wells had a higher prevalence of diarrhea than children drinking water from high As wells. This suggests that the health benefits of reducing As exposure may to some extent be countered by an increase in childhood diarrhea.

Keywords: Shallow tubewells, childhood diarrhea, Arsenic Mitigation.

2.81. Field, Experimental, and Modeling Study of Arsenic Partitioning across a Redox Transition in a Bangladesh Aquifer (2011)

Hun Bok Jung †, Benjamin C. Bostick ‡, and Yan Zheng*†‡

† School of Earth and Environmental Sciences, Queens College, and Graduate School and University Center, City University of New York, Flushing, New York 11367, United States
‡ Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York 10964, United States

Abstract

To understand redox-dependent arsenic partitioning, we performed batch sorption and desorption experiments using aquifer sands subjected to chemical and mineralogical characterization. Sands collected from the redox transition zone between reducing groundwater and toxic river water at the Meghna riverbank with HCl extractable Fe(III)/Fe ratio ranging from 0.32 to 0.74 are representative of the redox conditions of aquifers common in nature. One brown suboxic sediment displayed a partitioning coefficient (K_d) of 7–8 L kg^{-1} at equilibrium with 100 μg L^{-1}As(III), while two gray reducing sediments showed K_d of 1–2 L kg^{-1}. Lactate amendment to aquifer sands containing 91 mg kg^{-1} P-extractable As resulted in the reduction of As and Fe with sediment Fe(III)/Fe decreasing from 0.54 to 0.44, and mobilized an equivalent of 64 mg kg^{-1} As over a month. Desorption of As from nonlactate-amended sediment was negligible with little change in sediment Fe(III)/Fe. This release of As is consistent with microbial reduction of Fe(III) oxyhydroxides and the resulting decrease in the number of surface sites on Fe(III) oxyhydroxides. Arsenic partitioning (K_d) in iron-rich, sulfur-poor aquifers with circumneutral pH is redox-dependent and can be estimated by HCl leachable sediment Fe(III)/Fe ratio with typical Fe concentrations.

Keywords: Aquifer, redox-dependent arsenic partitioning.

2.82. Characterization of arsenic leaching in paddy field soil (2011)

Md. Shafiul Azam[1], Md. Shafiquzzaman[2] and Jun Nakajima[2]

[1]Department of Civil Engineering,IUBAT, Dhaka, Bangladesh
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh
[2]Department of Environmental Systems Engineering Ritsumeikan University, Shiga, Japan.

Abstract:

This paper examines the arsenic leaching characteristics in the paddy field soils. Samples were collected from actual paddy field of Bangladesh which was irrigated by groundwater. Soil samples were tested by sequential extraction procedure (0.1N HCl and 0.1N NaOH) and pH leaching test. Results indicated that about 22-57% of the total arsenic in the samples were 0.1 N NaOH extractable arsenic which seemed to be strongly bound with amorphous iron hydroxides. Leached arsenic concentrations were high in high alkaline pH conditions. Comparing the extraction results with pH leaching test it was observed that leachedarsenic in low pH was from the 0.1N HCl extractable arsenic fractions which might be sorbed weakly on the soil surface. At high alkaline conditions (pH 13) the leached arsenic concentrations were as much as 6-10 times higher than at low pH (pH 1) which indicated that strongly bound arsenic would be leached at high alkaline and under low redox conditions.

Keywords: Acid-alkali extraction, arsenic contamination, soil arsenic leaching, redox potential, paddy soil

2.83. Arsenic migration to deep groundwater in Bangladesh influenced by adsorption and water demand (2011)

K.A. Radloff [1,2,] *Y. Zheng[2,3,] H.A. Michael[4] et.al

[1] Columbia University, New York, NY USA
[2] Lamont- Doherty Earth Observatory, Palisades, NY USA
[3] Queens College, New York, NY USA
[4] University of Delaware, Newark, DE USA

Abstract

Drinking shallow groundwater with naturally elevated concentrations of arsenic is causing widespread disease in many parts of South and Southeast Asia. In the Bengal Basin, growing reliance on deep (>150 m) groundwater has lowered exposure. In the most affected districts of Bangladesh, shallow groundwater concentrations average 100 to 370 μg L−1, while deep groundwater is typically < 10 μgL−1. Groundwater flow simulations have suggested that, even when deep pumping is restricted to domestic use, deep groundwater in some areas of the Bengal Basin is at risk of contamination. However, these simulations have neglected the impedance of As migration by adsorption to aquifer sediments. Here we quantify for the first time As adsorption on deeper sediments in situ by replicating the intrusion of shallow groundwater through injection of 1,000 L of deep groundwater modified with 200μg L−1 of As into a deeper aquifer. Arsenic concentrations in the injected water were reduced by 70% due to adsorption within a single day. Basin-scale modelling indicates that while As adsorption extends the sustainable use of deep groundwater, some areas remain vulnerable; these areas can be prioritized for management and monitoring.

Keywords: Arsenic migration, deep groundwater, deeper sediments.

2.84. Dynamics of arsenic adsorption in the targeted arsenic-safe aquifers in Matlab, south-eastern Bangladesh: Insight from experimental studies (2011)

Clare Robinson a, b, Mattias von Brömssen c, d, Prosun Bhattacharya c et.al

a Department of Civil and Environmental Engineering, University of Western Ontario, London, Canada N6A 5B9
b NGO Forum for Drinking Water Supply and Sanitation, Lalmatia, Dhaka 1207, Bangladesh
c KTH-International Groundwater Arsenic Research Group, Department of Land and Water Resources Engineering, Royal Institute of Technology, SE-100 44 Stockholm, Sweden
d Ramböll Sweden AB, Box 4205, SE-102 65 Stockholm, Sweden

Abstract

Targeting shallow low-As aquifers based on sediment colour may be a viable solution for supplying As-safe drinking water to rural communities in some regions of Bangladesh and West Bengal in India. The sustainability of this solution with regard to the long-term risk of As-safe oxidized aquifers becoming enriched with As needs to be assessed. This study focuses on the adsorption behavior of shallow oxidized sediments from Matlab Region, Bangladesh, and their capacity to attenuate As if cross-contamination of the oxidized aquifers occurs. Water quality analyses of samples collected from 20 tube-wells in the region indicate that while there may be some seasonal variability, the groundwater chemistry in the reduced and oxidized aquifers was relatively stable from 2004 to 2009. Although sediment extractions indicate a relatively low amount of As in the oxidized sediments, below 2.5 mg kg−1, batch isotherm experiments show that the sediments have a high capacity to adsorb As. Simulations using a surface complexation model that considers adsorption to amorphous Fe(III) oxide minerals only, under-predict the experimental isotherms. This suggests that a large proportion of the adsorption sites in the oxidized sediments may be associated with crystalline Fe(III) oxides, Mn(IV) and Al(III) oxides, and clay minerals. Replicate breakthrough column experiments conducted with lactose added to the influent solution demonstrate that the high adsorption capacity of the oxidized sediments may be reduced if water drawn down into the oxidized aquifers contains high levels of electron donors such as reactive dissolved organic C.

Keywords: As-safe oxidized aquifers, oxidized sediments.

2.85. Making Economic Sense for Arsenic Mitigation: A Case Study of Comilla District Bangladesh (2011)

Sara V. Flanagan, Yan Zheng
UNICEF, Bangladesh

Abstract

Naturally occurring Arsenic in the groundwater of Bangladesh is a significant public health problem for millions of people. Using new arsenic in drinking water survey data obtained during the 2009 Multiple Indicator Cluster Survey (MICS) and all-cause mortality hazard ratios recently established by the Health Effects of Arsenic Longitudinal Study (HEALS) based on arsenic exposure in a Bangladesh population, it is possible to estimate the population fraction of mortality attributable to arsenic in Bangladesh. The lost productivity due to this mortality burden as a fraction of Gross Domestic Product (GDP) can also be estimated.

Using the distribution of arsenic concentrations in the MICS drinking water survey of 2009 and the district populations from the Bangladesh Bureau of Statistics 2001 census (country total 124,272,764), the population exposed to concentrations greater than 50 µg/L is estimated to be 17.9 million. If using the projected total population of 150 million in 2009, the population exposed to greater than 50 µg/L would then be 21.6 million. With the HEALS mortality hazard ratios, the population fraction estimates of district-level mortality attributable to arsenic range between less than 1% to as high as 17.5%. Based on 2001 census population data, these fractions can be translated into almost 68,000 arsenic attributable deaths per year across the country and is likely to be higher. Thus, a conservative estimate of the portion of GDP to be lost from arsenic-attributable mortality over the next 20 years is between US$ 6.1-20.1 billion depending on discount rate selected.

When the cost analysis of lost productivity due to pre-mature death was similarly performed at sub-district level for a hard hit district Comilla where a large fraction of existing tube wells are contaminated with concentration reaching hundreds of µg/L, losses ranged from US$ 0.5 to 1.67 billion for a discount rate from 5% to 15% over 20 years. To provide 100% safe water coverage to the 2.9 million people in Comilla who are still in need of safe water options, the investment costs for water supply over the next 20 years ranges from US$ 49.2-85.4 million depending on the technology scenario and discount rate selected. Thus, the estimated economic losses due to arsenic exposure in drinking water at current levels are at least 10 times of the costs of providing complete safe water coverage to the exposed population in Comilla. Whereas cost is an important factor, selection of the most appropriate safe-water technology for an area will depend on hydro geochemical conditions, public health risks, and social acceptability by the community.

Keywords: Arsenic, Mitigation, MICS, mortality, economic loss.

2.86. Rice Field Geochemistry and Hydrology: An Explanation for Why Groundwater Irrigated Fields in Bangladesh are Net Sinks of Arsenic from Groundwater (2011)

Rebecca B. Neumann,[1,2] Allison P. St. Vincent,[1,3] Linda C. Roberts[4] et.al

[1] Parsons Laboratory, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139, USA

[2] Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138, USA

[3] Department of Civil and Environmental Engineering, Tufts University, Medford, MA 02155, USA

[4] Eawag, Swiss Federal Institute of Aquatic Science and Technology, Ueberlandstrasse 133, CH-8600 Dübendorf, Switzerland

Abstract

Irrigation of rice fields in Bangladesh with arsenic-contaminated groundwater transfers tens of cubic kilometers of water and thousands of tons of arsenic from aquifers to rice fields each year. Here we combine observations of infiltration patterns with measurements of porewater chemical composition from our field site in Munshiganj Bangladesh to characterize the mobility of arsenic in soils beneath rice fields. We find that very little arsenic delivered by irrigation returns to the aquifer, and that recharging water mobilizes little, if any, arsenic from rice field subsoils. Arsenic from irrigation water is deposited on surface soils and sequestered along flow paths that pass through bunds, the raised soil boundaries around fields. Additionally, timing of flow into bunds limits the transport of biologically available organic carbon from rice fields into the subsurface where it could stimulate reduction processes that mobilize arsenic from soils and sediments. Together, these results explain why groundwater irrigated rice fields act as net sinks of arsenic from groundwater.

Keywords: Irrigation, infiltration patterns, Geochemistry, Hydrology, Irrigation, Arsenic-contaminated groundwater.

2.87. Arsenic contamination in groundwater and its proposed remedial measures (2011)

[1]A. Akter; [2]M. H. Ali

[1]Department of Civil and Offshore Engineering, School of Built Environment, Heriot-Watt University, Edinburgh, Scotland, EH144 AS, UK and Department of Civil Engineering, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh

[2]Department of Civil Engineering, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh and Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor Darul Ta'zim, Malaysia

Abstract

Arsenic contamination occurs in groundwater of Bangladesh mainly from the alluvial and deltaic sediments. Arsenic contamination of groundwater in Bangladesh was first detected more than a decade ago and the `shallow tubewells' were reported as the main source of arsenic contaminated water. From the nutritional and metabolic points of view, arsenic is likely to adversely affect human health and nutrition. Up to now, several studies have been carried out on this context; however, inadequate knowledge on arsenic sources, mobilization and transport still remains as a constraint due to lack of data, information and technological advances. Thus, a review study has been undertaken on the sources of arsenic, its causes, mobilization, transport, effects on human health, arsenic test procedures and removal methods, in the context of groundwater contamination in Bangladesh, and finally sustainable remedial measures of arsenic have been proposed. This study suggests that laboratory facilities for testing of arsenic and effects of enhanced groundwater pumping, phosphate fertilizer etc., need to be updated, expanded and studied. This review work is significant to further knowledge improvement, as the topic is general and worldwide. It can be concluded that the integration of the proposed remedial measures with the national geographic information system interface database relating to arsenic for

analysis, production of hazard maps, and dissemination on television show for the planners, engineers, managers, field supervisors and affected people, can reach at the sustainable solution for mitigating arsenic and associated problems successfully in Bangladesh.

Keywords: Arsenic removal methods; Mobilization; Source; Transport

2.88. Fecal Contamination of Shallow Tubewells in Bangladesh Inversely Related to Arsenic (2011)

Alexander van Geen*†, Kazi Matin Ahmed ‡, Yasuyuki Akita § et.al

† Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York 10964, United States
‡ Department of Geology, University of Dhaka, Dhaka, Bangladesh
§ Department of Environmental Sciences and Engineering, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599, United States.

Abstract

The health risks of As exposure due to the installation of millions of shallow tubewells in the Bengal Basin are known, but fecal contamination of shallow aquifers has not systematically been examined. This could be a source of concern in densely populated areas with poor sanitation because the hydraulic travel time from surface water bodies to shallow wells that are low in As was previously shown to be considerably shorter than for shallow wells that are high in As. In this study, 125 tubewells 6–36 m deep were sampled in duplicate for 18 months to quantify the presence of the fecal indicator *Escherichia coli*. On any given month, *E. coli* was detected at levels exceeding 1 most probable number per 100 mL in 19–64% of all shallow tubewells, with a higher proportion typically following periods of heavy rainfall. The frequency of *E. coli* detection averaged over a year was found to increase with population surrounding a well and decrease with the As content of a well, most likely because of downward transport of *E. coli* associated with local recharge. The health implications of higher fecal contamination of shallow tubewells, to which millions of households in Bangladesh have switched in order to reduce their exposure to As, need to be evaluated.

Keywords: E. coli, fecal contamination, shallow tubewells.

2.89. Mineralogy and geochemistry of shallow sediments of Sonargaon, Bangladesh and implications for arsenic dynamics: Focusing on the role of organic matter (2011)

Ashraf Ali Seddiquea,[b] Harue Masuda[b], Muneki Mitamura[b] et.al

[a]Department of Petroleum and Mining Engineering, Jessore Science and Technology University, Jessore-7408, Bangladesh

[b]Department of Geosciences, Osaka City University, Sugimoto-cho 3-3-138, Sumiyoshi-ku, Osaka 558-8585, Japan

Abstract

Mineralogy and geochemistry of modern shallow sediments (up to 5 m thick) within the zone of water table fluctuations were studied to determine the likely sources and processes responsible for releasing As into groundwater. Samples were collected from different geological settings with varying groundwater As concentrations during dry (December 2005) and wet (September 2006) seasons at Sonargaon, Bangladesh. Stratigraphic sequences of the studied sediments showed three distinct

lithofacies, viz. clayey-silt, silty-clay, and silty-very fine sand, corresponding to fine-grained overbank associations. Total As concentrations of shallow sediments ranged from <1 to 16 mg/kg without a significant difference in the range of Asconcentrations between the seasons. Sequential chemical extraction analysis of As revealed that >80% of the As was fixed in insoluble and organic phases, while the amount of As in reducible and acid-soluble phases was very low (<20%) and varied inversely with total As content. Total As concentration varied with mica content (muscovite and biotite) and its related elements (Al, Mg and Fe), but not with total organic C, suggesting that biotite is the major host phase of As. Arsenic appears to be liberated from biotite and/or other As-bearing minerals via chemical weathering (i.e., hydration–decomposition), either from the near-surface sediments which are subject to seasonal cycling of the redox conditions, or from within the aquifer sediments. Once released, progressive diagenesis to form As-bearing organic matter may be responsible for controlling As distribution in the sediments and coexisting groundwater of the study area.

Keywords: Zone of water table, As content, biotite.

2.90. Sustainable safe water options in Bangladesh: Experiences from the Arsenic Project at Matlab (AsMat) (2011)

Md. Jakariya, Mizanur Rahman, A. M. R. Chowdhury et.al
The Pennsylvania State University CiteSeerX Archives

Abstract

The presence of elevated levels of naturally occurring arsenic in groundwater of Bangladesh has severely impaired the decade long effort of providing safe water to nearly 98% of its population and putting an estimated 35 million people-nearly one fourth of the total population –at risk. In order to address this problem, a project titled "Arsenic in tubewell (TW) water and health consequences in Matlab Upazila of Chandpur district (AsMat) " is being implemented jointly by ICDDR,B and BRAC. During this study.all the TWs in Matlab have been assigned unique identification numbers, with marked GPS coordinates, depth, and age. It is estimated that nearly 65 % of the about 13.000 TWs in Matlab have As concentrations above the Bangladesh drinking water standard (50 µg/L). In order to minimize arsenic exposure, a work to provide various alternate safe drinking water options to the exposed population has been initiated. As of March 2004, about 1,047 different alternate safe water options, such as Pond Sand Filter (PSF), Rainwater Harvester (RWH) and different filters to remove arsenic as well as pathogenic bacteria, were distributed among the targeted exposed population in Matlab. To ensure sustainable use, the provided options were assessed based on community acceptability, technical viability, and financial viability.

Keywords: Naturally occurred arsenic, Bangladesh drinking water standard, safe drinking water options.

2.91. A comparative study on dispersivity of arsenic among surma, sari and volaganj sand (2011)

Shriful Islam [a], M.S. Rahman [b], R.K. Das [c]
BRAC University Journal, vol. VIII, no. 1&2, 2011, pp. 23-30

[a]Department of Civil Engineering, IUBAT- International University of Business Agriculture and Technology, 4 Embankment Drive Road, Sector- 10, Uttara Model Town, Dhaka, Bangladesh

[b]Department of Civil Engineering and Environmental Engineering, Shahjalal University of Science & Technology, Sylhet, Bangladesh

[c]Janata Bank Limited, Dhaka, Bangladesh

Abstract

Transport mechanism of Arsenic (As) through the Surma, Sari and Volaganj sand is the prime concern of this study. Three column leaching tests were performed to find the dispersivity property of As. Numerous physical properties of these sand samples were determined and it shows Volaganj sand is most permeable. From the collected data experimental and theoretical breakthrough curve (BTC) were prepared and compared with each other. The value of dispersion coefficient and Index of dispersion were calculated. Dispersion coefficient (773.763cm2/min) and index of dispersion (844.3cm2/min) was higher for Surma sand. The leaching rate was found higher for higher pore water velocity of the Volaganj sand. The study also reveals that there is a significant difference between theoretical and experimental breakthrough curve. So not only convection/dispersion but also other rocesses such as adsorption, reaction with other compound are associated with the movement of arsenic through the sand medium.

Keywords: Soil pollution, arsenic movement, dispersion, breakthrough curve.

2.92. Assessment of dugwell as an alternative water supply options in arsenic affected areas of Bangladesh (2011)

Md. Akramul Alam, Md. Mujibur Rahman
BUET

Abstract

About 29 million people are either directly or indirectly exposed to arsenic contamination with varying degrees of risk due to extensive arsenic contamination of the groundwater in the alluvial aquifers of Bangladesh. Considering the urgency and gravity of the problem, alternative water supply options like dugwells (DW), deep tubewells (DTW), pond sand filters (PSF) and rain water harvesting systems (RWHS) are being installed in arsenic affected areas under arsenic mitigation programme. The study aimed at assessing the water quality in both dry and wet seasons, sanitary integrity, functionality, operation and maintenance and social acceptability of dugwells. The study was conducted on 11 dugwells of Charghat, Dohar and Gazaria. Microbial contaminations were found in 95 percent water samples of DWs. None of DW water sampled in this study had an arsenic concentration higher than the Bangladesh drinking water standard (BDS) of 50 µg/L but arsenic concentrations exceeding the WHO guideline value (WHOGV) of 10 µg/L were found in 35 percent of DWs water samples. Both iron and manganese were present in DW water of Dohar and Gazaria in excess of BDS. Water quality of DWs of Charghat in all respects was found better than DWs of Dohar and Gazaria. Users ' satisfaction and social acceptability of the DWs were found area specific depending on the quality and availability of water.

Keywords: Dugwell, arsenic contamination, Bangladesh drinking water standard.

2.93. Selenium: A Right Choice to Treat Arsenicosis in Bangladesh (2011)

Abdul Momin
101. Department of Dermatology, Dhaka Medical College, Dhaka, 1000, Bangladesh

Abstract

One half of the Bangladeshi population has been drinking arsenic contaminated water, drawn from the ground by tube-wells since 1993. More than 38,000 arsenicosis cases are reported. The present knowledge of the management of arsenicosis is limited, and specific treatment of chronic poisoning has not yet been identified.

With the approval of the ethical review board of the Bangladesh Medical Research Council (BMRC) double blind, randomized, placebo controlled trial with selenium intervention was carried out on 174 arsenicosis patients, irrespective of age and sex, for 12 months in a hyper-contaminated rural area of Bangladesh. In this study, melanosis decreased in 76% ($n = 67$, $p < 0.00$) of selenium treated patients and palmo-planter keratosis in 81% ($n = 67$, $p < 0.00$). For the selenium group arsenic content was decreased 38.2% ($p < 0.01$) in hair and 37.2% ($p < 0.00$) in nails. Overall symptoms improved 68% ($p < 0.00$) in the selenium treated group. There was no observed toxicity in a heart, kidney and liver function test. It was found that a dose of 100 µg of selenium as selenomethionine per day along with use of arsenic safe water for 12 months in chronic arsenic toxicity is a safe and effective treatment for arsenicosis.

Keywords: Arsenicosis, arsenic contaminated water, selenium.

2.94. Selective separation of arsenic species from aqueous solutions with immobilized macro cyclic material containing solid phase extraction columns (2011)

Ismail M.M. Rahmana, b, Zinnat A. Beguma, Masayoshi Nakanoa et.al

Graduate School of Natural Science and Technology, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan (I.M.M. Rahman). Tel./fax: +81 76 234 4792.

Abstract

A combination of solid phase extraction (SPE) columns was used for selective separation of water-soluble arsenic species: arsenite, arsenate, monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA). The SPE columns, namely AnaLig TE-01 (TE-01), AnaLig AN-01 Si (AN-01) and AnaLig As-01 PA (As-01), contain immobilized macrocyclic material as the sorbent and commonly known as molecular recognition technology (MRT) gel. The retention, extraction and recovery behavior of the MRT gel SPE columns were studied at pH 4–10. Fortified deionized water spiked with 100 µM of arsenic species were treated at the flow rate of 0.2 mL min–1. HNO3 (1.0 and 6.0 M) was used as eluent to recover the retained arsenic species from TE-01 and AN-01 SPE columns. Arsenic species retained in the As-01 column were eluted with HNO3 (0.1 M) followed by NaOH (2.0 M). Likely interference from the various coexisting ions (Na+, K+, Ca2+, Mg2+, Cl–, View the MathML sourceNO3-, CH3COO–, View the MathML sourcePO43-, View the MathML sourceSO42-, View the MathML sourceClO4-) (10 mM) were negligible. Quantitative separation of As(III), As(V), MMA and DMA was achieved based on the differences in extraction and recovery behavior of the MRT gel SPE columns with pH for different arsenic species. Complexation between arsenic species and MRT gel is the core phenomenon of the proposed technique as the complexation of MRT gels is expected to be stronger than the resin-based separation processes. MRT gel SPE columns are advantageous as compared with other reported SPE columns in terms of its performance with As(III). Effortless regeneration and unaltered separation performance of the sorbent materials for more than 100 loading and elution cycles are other sturdy characteristics to consider the MRT gel SPE columns for sensitive and selective arsenic species separation.

Keywords: Solid phase extraction; Molecular recognition technology gel; Water-soluble arsenic; Selective separation; pH

2.95. Arsenic in the environment: phytoremediation using aquatic macrophytes In: Handbook of Phytoremediation (2011)

M Azizur Rahman, M Mahfuzur Rahman, Ismail M M Rahman, H Hasegawa

Ivan A. Golubev. 573–589 Hauppauge, NY, USA: Nova Science Publishers, Inc. isbn: 978-1-61728-753-4.

Abstract

A large number of sites worldwide are contaminated by arsenic (As) as a result of human activities as well as from natural sources. Arsenic is a vital environmental and health concern due to its known chronic and epidemic toxicity. The main arsenic exposures to humans are through water pathway and food contamination originates from natural processes. Many of the available remediation technologies lost economic favor and public acceptance because of some unavoidable limitations of those technologies. Therefore, phytoremediation, a plant-based green technology, becomes an emerging and alternative technology that aims to extract or inactivate As in the environment. However, two approaches have been proposed in literature for the phytoremediation of arsenic: continuous or natural phytoremediation, and chemically enhanced phytoremediation. The first one is based on the use of natural hyperaccumulator plants having the ability to accumulate very high concentration of As in their shoots with exceptionally higher tolerance to As toxicity. On the other hand, As uptake in high biomass crop plants is increased using some chelating ligands in chemically enhanced phytoremediation technology.

Freshwater and seawater around the world have been contaminated by As from various anthropogenic activities and natural sources over time. Therefore, remediation of As-contaminated aquatic systems is important as it is for terrestrial system. Aquatic macrophytes could be used to remediate the aquatic system. The use of aquatic macrophytes or other floating plants in phytoremediation technology is commonly known as phytoextraction. This cleanup process involves biosorption and accumulation of As. Recently, aquatic macrophytes and some other small floating plants such as Spirodela polyrhiza L., Lemna spp., Azolla pinnata, Salvinia natans, Eichhornia crassipes have been investigated for the remediation of As-contaminated aquatic systems. Compared to the As-phytoremediation in terrestrial system, less work has been done in aquatic systems. In this chapter, process and prospect of As phytoremediation by aquatic macrophytes is discussed.

Keywords: Arsenic, phytoremediation, aquatic systems, anthropogenic activities, phytoremediation technology

2.96. Arsenic exposure and adverse health effects: A review of recent findings from arsenic and health studies in Matlab, Bangladesh (2011)

Mohammad Yunus, Nazmul Sohel, Samar Kumar Hore, Mahfuzar Rahman

Abstract

The recent discovery of large-scale arsenic (As) contamination of groundwater has raised much concern in Bangladesh. Reliable estimates of the magnitude of As exposure and related health problems have not been comprehensively investigated in Bangladesh. A large population-based study on As and health consequences in Matlab (AsMat) was done in Matlab field site where International Centre for Diarrhoeal Disease Research, Bangladesh has maintained a health and demographic surveillance system registering prospectively all vital events. Taking advantage of the health and demographic surveillance system and collecting data on detailed individual level As exposure using water and urine samples, AsMat investigated the morbidity and mortality associated with As exposure. Reviews of findings to date suggest the adverse effects of As exposure on the risk of skin lesions, high blood pressure, diabetes mellitus, chronic disease, and all-cause infant and adult disease mortality. Future studies of clinical endpoints will enhance our knowledge gaps and will give directions for disease prevention and mitigations.

Keywords: Adverse effects, Arsenic, Bangladesh Drinking water, Health

2.97. Alternative water supplies to replace arsenic polluted groundwater in Bangladesh (2011)

M. Jujuly, J. Uddin, A. Rahman

Abstract

Bangladesh faces a major challenge in supplying safe potable water to the most of her 160 million people. The drinking water in Bangladesh is largely sourced from handpump tubewells, which draw drinking water from shallow aquifer, which has been badly polluted with Arsenic in recent years. Although various methods have been proposed to solve this problem, an acceptable and sustainable solution is yet to be achieved. As an alternative, rainwater can be harvested and used to secure the safe potable water for Bangladesh. This paper proposes an alternative community-based rainwater-fed surface water supply scheme to provide fresh drinking water to the affected regions. It is argued that rainwater is a viable alternative fresh water source which can be preserved in a community owned purpose built surface water lake. A simple low-cost water treatment and distribution system can then be built to treat and supply the lake water. Various challenges for such an alternative water supply scheme are discussed in the paper.

Keywords: Arsenic, groundwater contamination, Rainwater harvesting, tubewells

2.98. Manganese Removal Status by Arsenic Removal Technologies Available in Bangladesh: Manganese Removal Treatment by Sodium Hypochlorite (2011)

S. Siraj*, A. I. Kazi, S. Ahmed, M. A. Akbor and A. Ahsan

Analytical Research Division, Bangladesh Council of Scientific and Industrial Research,
Dr. Qudrat-i-Khuda Road, Dhanmondi, Dhaka-1205, Bangladesh.
Available online at www.banglajol.info
Bangladesh J. Sci. Ind. Res. 46(3),291-296,

Abstract

In addition to arsenic, the groundwater in Bangladesh is often found to be contaminated with manganese whose permissible limit set by WHO being 400 ppb in drinking water. Since most arsenic removal technologies (ARTs) are designed to remove As and not to remove Mn, during field testing and verification of performance of ARTs under the Bangladesh Environmental Technology Verification-Support to Arsenic Mitigation (BETV-SAM) project of BCSIR, it has been found that only the Sono technology using Feo as arsenic removal medium which can also remove Mn to produce Mn safe drinking water but others such as Alcan, Read-F household, Sidko, Nelima, Shawdesh cannot. During field testing of these technologies under the BETV-SAMproject, it has been attempted to treat Mn by a traditional chlorine oxidation method to produce Mn safe drinking water. Concentrations of dissolved As (T), As (III), Fe, Mn and pH in the considered well water for manganese treatment were in ranges of 125 - 1247 ppb, 116 - 1127 ppb, 1.40 - 15.5 ppm, 505 - 2245 ppb and 7.0 to 7.5, respectively. The required chlorine dose and time for treatment of manganese in 20 L water have been found to be 6.2 - 12.4 ppm and 1 - 2 h, respectively.

Keyword: Arsenic, Manganese, ART, Verification, Chlorine, Iron.

2.99. Validation of analysis of arsenic in water samples using Wagtech Digital Arsenator (2011)

A Safarzadeh-Amiri a.*, P. Fowlie a, AI. Kazi b et.al
a. Ontario Centre for Environmental Technology Advancement, 2070 Hadwen Road, Mississallga, ON, Canada, L5K 2C9
b. Bangladesh Council of Scientific and Industrial Research, Dr. Khudrat-i-Khuda Road, DllQnmondi, Dhaka-120S, Bangladesh
Science of the Total Environment 409 (2011) 2662-2667

Abstract

Groundwater, the only source of potable water for millions of people in Bangladesh during dry season, is often contaminated with arsenic (As) *above* the allowable drinking water limit of 50 µg /L.Testing well water – with arsenic field test kits (ITKs) - and switching to safe-wells can effectively reduce exposure to As. ITKs are low cost, provide fast results, and are commercially available. There are between 10 and 11 million shallow tubewells in Bangladesh. Approximately, 5 million have been tested using ITKs. ITKs with color comparator rely on visual identification for generating qualitative results, which may not be highly reliable at the lower range because human eyes have low sensitivity in this range and sensitivity *varies* from person to person. The Wagtech Digital Arsenator does not suffer from this limitation and should, in theory, be able to generate quantitative, accurate, and reliable results. The instrument has a linear range of 0-100 µg /L, an accuracy of ± 20% for the 50 µg /L quality control standards, and a detection limit of about 4.4 µg/L. All Arsenators employed in this investigation also displayed high bias for 50 µg /L arsenic standard and were calibrated in order to improve measurement accuracy and reliability. Analyses of 179 raw and 92 treated well waters in the field and in two analytical laboratories were found to be highly correlated with the Spearman rank correlation coefficient of ≥0.800, indicating that Arsenator results are perhaps nearly as accurate and reliable as those from analytical laboratories.

Keywords: ITKs, Wagtech Digital Arsenator, range.

2.100. Socioeconomic Condition and Health Status of Chronic Arsenicosis Patients in Jessore, Bangladesh [CLOUD, International Journal of Advanced Nutritional and Health Science 2012, 1(1): 9-17].

Contact Person
Name: Sabia Sultana
Designation: Lecturer, Department of Anatomy, AddinSakina Medical College, Jessore, Bangladesh
Telephone: N/A
Mobile: 01718.051747
Email: sabia_23_s@yahoo.com

Project Director/Principal Researcher
Name: Quazi Zahangir Hossain
Designation: Adjunct Faculty
Telephone: N/A
Mobile: 01914.067504
Email: zahangirku@yahoo.com

Objective of the Project/Research

- To determine the prevalence of arsenicosis through drinking water.
  Project Duration: July to October, 2011

Major Findings

- The chronic effect is about 32% and the men (69.33%) were more susceptible to arsenicosis.
- The affected patients were identified: melanosis (94%), keratosis (33%), leucomelanosis (38%), respiratory problem (49%), loss of sensation (45%), bowen's (21.33%), oedema (9.33%), chronic non-healing ulcer (6.33%), lung cancer (2%), and gangrene (0.66%).

2.101. Arsenic in soil and irrigation water affects arsenic uptake by rice: complementary insights from field and pot studies (2010)

Dittmar J[1], Voegelin A, Maurer F et.al

[1]Institute of Biogeochemistry and Pollutant Dynamics, Department of Environmental Sciences, ETH Zurich, CHN F23.2, CH-8092 Zurich, Switzerland.

Abstract

Groundwater rich in arsenic (As) is extensively used for dry season boro rice cultivation in Bangladesh, leading to long-term As accumulation in soils. This may result in increasing levels of As in rice straw and grain, and eventually, in decreasing rice yields due to As phytotoxicity. In this study, we investigated the As contents of rice straw and grain over three consecutive harvest seasons (2005-2007) in a paddy field in Munshiganj, Bangladesh, which exhibits a documented gradient in soil As caused by annual irrigation with As-rich groundwater since the early 1990s. The field data revealed that straw and grain As concentrations were elevated in the field and highest near the irrigation water inlet, where As concentrations in both soil and irrigation water were highest. Additionally, a pot experiment with soils and rice seeds from the field site was carried out in which soil and irrigation water As were varied in a full factorial design. The results suggested that both soil As accumulated in previous years and As freshly introduced with irrigation water influence As uptake during rice growth. At similar soil As contents, plants grown in pots exhibited similar grain and straw As contents as plants grown in the field. This suggested that the results from pot experiments performed at higher soil Aslevels can be used to assess the effect of continuing soil As accumulation on As content and yield of rice. On the basis of a recently published scenario of long-term As accumulation at the study site, we estimate that, under unchanged irrigation practice, average grain As concentrations will increase from currently ~0.15 mg As kg(-1) to 0.25-0.58 mg As kg(-1) by the year 2050. This translates to a 1.5-3.8 times higher As intake by the local population via rice, possibly exceeding the provisional tolerable As intake value defined by FAO/WHO.

Keywords: As accumulation, pot study, As concentration.

2.102. Arsenic Dynamics in Porewater of an Intermittently Irrigated Paddy Field in Bangladesh (2010)

Linda C. Roberts*[†‡], Stephan J. Hug*[†], Andreas Voegelin[†] et.al

*[†‡] Eawag, Swiss Federal Institute of Aquatic Science and Technology, Ueberlandstrasse 133, CH-8600 Duebendorf, Switzerland, Institute of Biogeochemistry and Pollutant Dynamics, [†] Department of Environmental Sciences, ETH Zurich, CH-8092 Zurich, Switzerland.

Abstract

In Bangladesh, irrigation of dry season rice (*boro*) with arsenic-contaminated groundwater is leading to increase As levels in soils and rice, and to concerns about As-induced yield reduction. Arsenic concentrations and speciation in soil porewater are strongly influenced by redox conditions, and thus by water management during rice growth. We studied the dynamics of As, Fe, P, Si, and other elements in porewater of a paddy field near Sreenagar (Munshiganj), irrigated according to local practice, in which flooding was intermittent. During early rice growth, As porewater concentrations reached up to 500 μg L^{-1} and were dominated by As^{III}, but As release was constrained to the lower portion of the soil above the plow pan. In the later part of the season, soil conditions were oxic throughout the depth range relevant to rice roots and porewater concentrations only intermittently increased to ~150 μg L^{-1} As^{V} following irrigation events. Our findings suggest that intermittent irrigation, currently advocated in Bangladesh for water-saving purposes, may be a promising means of reducing As input to paddy soils and rice plant exposure to As.

Keywords: Arsenic Dynamics, Porewater, Intermittently Irrigated Paddy field.

2.103. Arsenic Exposure in Pregnancy Increases the Risk of Lower Respiratory Tract Infection and Diarrhea during Infancy in Bangladesh (2010)

Anisur Rahman1,2, Marie Vahter3, Eva-Charlotte Ekström2 et.al

1 International Centre for Diarrhoeal Disease Research, Bangladesh, Dhaka, Bangladesh,
2 International Maternal and Child Health, Department of Women's and Children's Health, Uppsala University, Uppsala, Sweden

Abstract

Background: Previous studies have reported associations between prenatal arsenic exposure and increased risk of infant mortality. An increase in infectious diseases has been proposed as the underlying cause of these associations, but there is no epidemiologic research to support the hypothesis.

Objective: We evaluated the association between arsenic exposure in pregnancy and morbidity during infancy.

Methods: This prospective population-based cohort study included 1,552 live-born infants of women enrolled during 2002–2004 in Matlab, Bangladesh. Arsenic exposure was assessed by the concentrations of metabolites of inorganic arsenic in maternal urine samples collected at gestational weeks 8 and 30. Information on symptoms of lower respiratory tract infection (LRTI) and diarrhea in infants was collected by 7-day recalls at monthly home visits.

Results: In total, 115,850 person-days of observation were contributed by the infants during a 12-month follow-up period. The estimated risk of LRTI and severe LRTI increased by 69% [adjusted relative risk (RR) = 1.69; 95% confidence interval (CI), 1.36–2.09)] and 54% (RR = 1.54; 95% CI, 1.21–1.97), respectively, for infants of mothers with urinary arsenic concentrations in the highest quintile (average of arsenic concentrations measured in early and late gestation, 262–977 μg/L) relative to those with exposure in the lowest quintile (< 39 μg/L). The corresponding figure for diarrhea was 20% (RR = 1.20; 95% CI, 1.01–1.43).

Conclusions: Arsenic exposure during pregnancy was associated with increased morbidity in infectious diseases during infancy. Taken together with the previous evidence of adverse effects on health, the findings strongly emphasize the need to reduce arsenic exposure via drinking water.

Keywords: Arsenic, Bangladesh, diarrhea, infants, pregnancy, respiratory tract infection

2.104. Status of groundwater arsenic contamination in Bangladesh: A 14-year study report (2010)

Dipankar Chakrabortia, Mohammad Mahmudur Rahmana[b], Bhaskar Das[a] et.al

[a]School of Environmental Studies (SOES), Jadavpur University, Kolkata 700 032, India
[b]Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Mawson Lakes Campus, SA 5095, Australia

Abstract

Since 1996, 52,202 water samples from hand tubewells were analyzed for arsenic (As) by flow injection hydride generation atomic absorption spectrometry (FI-HG-AAS) from all 64 districts of Bangladesh; 27.2% and 42.1% of the tubewells had As above 50 and 10 μg/l, respectively; 7.5% contained As above 300 μg/l, the concentration predicting overt arsenical skin lesions. The groundwater of 50 districts contained As above the Bangladesh standard for As in drinking water (50 μg/l), and 59 districts had As above the WHO guideline value (10 μg/l). Water analyses from the four principal geomorphological regions of Bangladesh showed that hand tubewells of the Tableland and Hill tract regions are primarily free from As contamination, while the Flood plain and Deltaic region, including the Coastal region, are highly As-contaminated. Arsenic concentration was usually observed to decrease with increasing tubewell depth; however, 16% of tubewells deeper than 100 m, which is often considered to be a safe depth, contained As above 50 μg/l. In tubewells deeper than 350 m, As>50 μg/l has not been found. The estimated number of tubewells in 50 As-affected districts was 4.3 million. Based on the analysis of 52,202 hand tubewell water samples during the last 14 years, we estimate that around 36 million and 22 million people could be drinking As-contaminated water above 10 and 50 μg/l, respectively. However for roughly the last 5 years due to mitigation efforts by the government, non-governmental organizations and international aid agencies, many individuals living in these contaminated areas have been drinking As-safe water. From 50 contaminated districts with tubewell As concentrations >50 μg/l, 52% of sampled hand tubewells contained As <10 μg/l, and these tubewells could be utilized immediately as a source of safe water in these affected regions provided regular monitoring for temporal variation in As concentration. Even in the As-affected Flood plain, sampled tubewells from 22 thanas in 4 districts were almost entirely As-safe. In Bangladesh and West Bengal, India the crisis is not having too little water to satisfy our needs, it is the challenge of managing available water resources. The development of community-specific safe water sources coupled with local participation and education are required to slow the current effects of widespread As poisoning and to prevent this disaster from continuing to plague individuals in the future.

Keywords: Bangladesh; Arsenic; Hand tubewell; Groundwater; Deep tubewells; Geomorphological regions; Number of hand tubewells; Population at risk; Approach for mitigation

2.105. Spatial patterns of fetal loss and infant death in an arsenic-affected area in Bangladesh (2010)

Nazmul Sohel[1]*, Marie Vahter[2], Mohammad Ali[3] et.al

[1]Department of Women's and Children's Health, International Maternal and Child Health (IMCH), Uppsala University, Uppsala, Sweden.

[2]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden.
[3]International Vaccine Institute, Seoul, Korea.

Abstract

Background: Arsenic exposure in pregnancy is associated with adverse pregnancy outcome and infant mortality. Knowledge of the spatial characteristics of the outcomes and their possible link to arsenic exposure are important for planning effective mitigation activities. The aim of this study was to identify spatial and spatiotemporal clustering of fetal loss and infant death, and spatial relationships between high and low clusters of fetal loss and infant death rates and high and low clusters of arsenic concentrations in tube-well water used for drinking.

Methods: Pregnant women from Matlab, Bangladesh, who used tube-well water for drinking while pregnant between 1991 and 2000, were included in this study. In total 29,134 pregnancies were identified. A spatial scan test was used to identify unique non-random spatial and spatiotemporal clusters of fetal loss and infant death using a retrospective spatial and spatiotemporal permutation and Poisson probability models.

Results: Two significant clusters of fetal loss and infant death were identified and these clusters remained stable after adjustment for covariates. One cluster of higher rates of fetal loss and infant death was in the vicinity of the Meghna River, and the other cluster of lower rates was in the center of Matlab. The average concentration of arsenic in the water differed between these clusters (319µg/L for the high cluster and 174µg/L for the low cluster). The spatial patterns of arsenic concentrations in tube-well water were found to be linked with the adverse pregnancy outcome clusters. In the spatiotemporal analysis, only one high fetal loss and infant death cluster was identified in the same high cluster area obtained from purely spatial analysis. However, the cluster was no longer significant after adjustment for the covariates.

Conclusion: The finding of this study suggests that given the geographical variation in tube-well water contamination, higher fetal loss and infant deaths were observed in the areas of higher arsenic concentrations in groundwater. This illustrates a possible link between arsenic contamination in tube-well water and adverse pregnancy outcome. Thus, these areas should be considered a priority in arsenic mitigation programs.

Keywords: Infant mortality, Arsenic, fetal loss.

2.106. Comparative assessment of four alternative water supply options in arsenic affected areas of Bangladesh (2010)

Md. Akramul Alam[1], Md. Mujibur Rahman[2]

[1]Department of Civil Engineering, Dhaka University of Engineering and Technology, Gazipur 1700, Bangladesh
[2]Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

Abstract

Arsenic contamination in groundwater and its toxic effect on human health is a major public health problem in Bangladesh and it is emphasized in the national level to use alternative water sources for drinking water to mitigate the arsenic problem. To identify reasons of non-functioning and in order to develop a comparative information and better understanding of the options, assessment of alternative water supply options in both technical and social aspects are essential. The study was conducted on 11 Dug wells (DW) of Charghat, Dohar and Gazaria, 9 Deep hand tubewells (DTW) of Dohar and Gournadi, 17 Rain water harvesting systems (RWHS) of Charghat, Gournadi, Pathorghata and Ghior and 6 Pond sand filters (PSF) of Pathorghata and Gournadi. Microbial contamination were found in 95 percent water samples of DW, 7 percent of DTW, 43 percent of RWHS and 77 percent of PSF. None of DW water sampled in this study had an arsenic concentration higher than the Bangladesh drinking water standard (BDS) of 50 µg/L but arsenic concentrations exceeding the WHO guideline value (WHOGV) of 10 µg/L were found in 35 percent of DW water samples. Arsenic concentrations in DTW, RWHS and PSF water samples were found within BDS and WHOGV. Both iron and manganese were present in DW water of Dohar and Gazaria in excess of BDS. Manganese was present in DTW water of Dohar in excess of BDS. The concentrations of nitrate in DW, DTW, PSF and RWHS water samples were within BDS. Water quality of DWs of Charghat in all respects was found better than DWs of Dohar and Gazaria. Users' satisfaction and social acceptability of the DW, DTW, PSF and RWHS were found area specific depending on the quality and availability of water.

Keywords: Arsenic, Alternative water supply options, Dugwells, Deep hand tubewells, Pond sand filters, Rain water harvesting systems

2.107. Arsenic exposure from drinking water, and all-cause and chronic-disease mortalities in Bangladesh (HEALS): a prospective cohort study (2010)

Maria Argos MPH, Tara Kalra MPH, Paul J Rathouz PhD et.al

Abstract

Background: Millions of people worldwide are chronically exposed to arsenic through drinking water, including 35—77 million people in Bangladesh. The association between arsenic exposure and mortality rate has not been prospectively investigated by use of individual-level data. We therefore prospectively assessed whether chronic and recent changes in arsenic exposure are associated with all-cause and chronic-disease mortalities in a Bangladeshi population.

Methods: In the prospective cohort Health Effects of Arsenic Longitudinal Study (HEALS), trained physicians unaware of arsenic exposure interviewed in person and clinically assessed 11 746 population-based participants (aged 18—75 years) from Araihazar, Bangladesh. Participants were recruited from October, 2000, to May, 2002, and followed-up biennially. Data for mortality rates were available throughout February, 2009. We used Cox proportional hazards model to estimate hazard ratios (HRs) of mortality, with adjustment for potential confounders, at different doses of arsenic exposure.

Findings: 407 deaths were ascertained between October, 2000, and February, 2009. Multivariate adjusted HRs for all-cause mortality in a comparison of arsenic at concentrations of 10·1—50·0 µg/L, 50·1—150·0 µg/L, and 150·1—864·0 µg/L with at least 10·0 µg/L in well water were 1·34 (95% CI 0·99—1·82), 1·09 (0·81—1·47), and 1·68 (1·26—2·23), respectively. Results were similar with daily arsenic dose and total arsenic concentration in urine. Recent change in exposure, measurement of total arsenic concentrations in urine repeated biennially, did not have much effect on the mortality rate.

Interpretation: Chronic arsenic exposure through drinking water was associated with an increase in the mortality rate. Follow-up data from this cohort will be used to assess the long-term effects of arsenic exposure and how they might be affected by changes in exposure. However, solutions and resources are urgently needed to mitigate the resulting health effects of arsenic exposure.

Keywords: Arsenic exposure, Health Effects of Arsenic Longitudinal Study, hazards model, hazard ratio.

2.108. Personal, social, and situational factors influencing the consumption of drinking water from arsenic-safe deep tubewells in Bangladesh (2010)

Mosler HJ[1], Blöchliger OR, Inauen J.

[1]Eawag: Swiss Federal Institute of Aquatic Science and Technology, Ueberlandstrasse 133, P.O. Box 611, 8600 Duebendorf, Switzerland.

Abstract

Naturally occurring arsenic in groundwater in Bangladesh poses a well-known public health threat. The aim of the present study is to investigate fostering and hindering factors of people's use of deep tubewells that provide arsenic-safe drinking water, derived from the Protection Motivation Theory and the Theory of Planned Behavior. Structured personal interviews were conducted with 222 households in rural Sreenagar, Bangladesh. Multiple linear regressions were carried out to identify the most influential personal, social, and situational behavior determinants. Data revealed that social factors explained greater variance in the consumption of drinking water from deep tubewells than did situational and personal factors. In an overall regression, social factors played the biggest role. In particular, social norms seem to strongly influence deep tubewell use. But also self-efficacy and the perceived taste of shallow tubewell water proved influential. Concurrently considering other important factors, such as the most mentioned response cost (i.e., time needed to collect deep tubewell water), we propose a socially viable procedure for installing deep tubewells for the extended consumption of arsenic-safe drinking water by the Bangladeshi population.

Keywords: Deep tubewells, arsenic, arsenic-safe drinking water.

2.109. Arsenic accumulation in a paddy field in Bangladesh: seasonal dynamics and trends over a three-year monitoring period (2010)

Dittmar J[1], Voegelin A, Roberts LC et.al

[1]Institute of Biogeochemistry and Pollutant Dynamics, Department of Environmental Sciences, ETH Zurich, CHN F23.2, CH-8092 Zurich, Switzerland.

Abstract

Shallow groundwater, often rich in arsenic (As), is widely used for irrigation of dry season boro rice in Bangladesh. In the long term, this may lead to increasing As contents in rice paddy soils, which threatens rice yields, food quality, and human health. The objective of this study was to quantify gains and losses of soil As in a rice paddy field during irrigation and monsoon flooding over a three-year period. Samples were collected twice a year on a 3D-sampling grid to account for the spatially heterogeneous As distribution within the soil. Gains and losses of soil As in different depth segments were calculated using a mass-balance approach. Annual As input with irrigation water was estimated as 4.4 +/- 0.4 kg ha(-1) a(-1). Within the top 40 cm of soil, the mean As accumulation over three years amounted to 2.4 +/- 0.4 kg ha(-1) a(-1), implying that on average 2.0 kg ha(-1) a(-1) were lost from the soil. Seasonal changes of soil As showed that 1.05 to 2.1 kg ha(-1) a(-1) were lost during monsoon flooding. The remaining As-loss (up

to 0.95 kg ha(-1) a(-1)) was attributed to downward flow with percolating irrigation water. Despite these losses, we estimate that total As within the top 40 cm of soil at our field site would further increase by a factor of 1.5 to 2 by the year 2050 under current cultivation practices.

Keywords: Arsenic accumulation, Shallow groundwater, rice yields, cultivation practices.

2.110. Subsurface iron and arsenic removal: low-cost technology for community-based water supply in Bangladesh (2010)

D. van Halem, S. G. J. Heijman, R. Johnston et.al

Faculty of Civil Engineering and Geosciences, Delft University of Technology, The Netherlands
The Netherlands Present address: King Abdullah University of Science and Technology, Saudi Arabia. Department of Water and Sanitation in Developing Countries (Sandec), Eawag: Swiss Federal Institute of Aquatic Science and Technology, Switzerland (formerly: UNICEF Bangladesh)

Abstract

The principle of subsurface or in situ iron and arsenic removal is that aerated water is periodically injected into an anoxic aquifer through a tube well, displacing groundwater containing Fe(II). An oxidation zone is created around the tube well where Fe(II) is oxidised. The freshly formed iron hydroxide surfaces provide new sorption sites for soluble Fe(II) and arsenic. The system's efficiency is determined based on the ratio between abstracted volume with reduced iron/arsenic concentrations (V) and the injected volume (Vi). In the field study presented in this paper, the small-scale application of this technology was investigated in rural Bangladesh. It was found that at small injection volumes (<1 m3) iron removal was successful and became more effective with every successive cycle. For arsenic, however, the system did not prove to be very effective yet. Arsenic retardation was only limited and breakthrough of 10 mg/L (WHO guideline) was observed before V/Vi=1, which corresponds to arrival of groundwater at the well. Possible explanations for insufficient arsenic adsorption are the short contact times within the oxidation zone, and the presence of competing anions, like phosphate.

Keywords: Arsenic; Bangladesh; community-based; drinking water; iron; subsurface

2.111. Causes and distribution of arsenic contamination in Bangladesh: evidence from the literature (2010)

Planning Commission, Ministry of Planning, Shere-Bangla Nagor, Bangladesh.

Abstract

In attempting to eliminate disease caused by drinking polluted surface water, millions of tube-wells were drilled in Bangladesh. However, owing to arsenic in groundwater, the availability of safe drinking water has declined from earlier achievement of 97% to 51.2%. This article reviews the causes and distribution of arsenic concentration in rural Bangladesh from a wide variety of literature. Scientists have converged to two hypotheses for causes of arsenic in groundwater: the pyrite oxidation hypothesis and the oxy-hydroxide reduction hypothesis. There is a positive correlation between arsenic content in irrigated groundwater and arsenic contained in soils. There is a significant presence of arsenic in rice and leafy vegetables. Today, arsenic is causing toxicity to human health and creating major social problems. This finding implies that, had there been a precautionary measure taken when a new technology tube-well was being introduced, in the form of testing water for harmful metals, the risk that the rural population is facing now could have been drastically reduced. This lack of precautionary measure,

before starting a mass installation of tube-wells for drinking and irrigation should be seen as a “human error” and avoided in future water policy and planning.

Keywords: Arsenic; Bangladesh; Green revolution; Groundwater; Human error

2.112. Quality and suitability of harvested rainwater for drinking in Bangladesh (2010)

Md. Rezaul Karim
Department of Civil and Environmental Engineering, Yamaguchi University, 2-16-1 Tokiwadai, Ube 755-8611, Japan

Abstract

Several programs have been undertaken during the last few years to install rooftop rainwater harvesting systems as an alternative drinking water supply source both in the coastal and arsenic affected areas in Bangladesh. In this study, quality of the harvested rainwater used for drinking water supply was assessed. A total of 308 harvested rainwater samples were collected from the different storage reservoirs located both in coastal and arsenic affected areas and analysed for various physical, chemical and microbial indicators. Most of the physical and chemical water quality parameters were well below the Bangladesh Drinking Water Standard and WHO guideline values. However, the harvested rainwater was found microbiologically contaminated to some extent and the water is not suitable for consumption without treatment. For safe and sustainable rainwater harvesting, WHO guideline and water safely plan (WSP) can be adopted in Bangladesh.

Keywords: Drinking water; microbial indicators; rainwater harvesting; suitability; water quality

2.113. Arsenic and Cadmium in Food-chain in Bangladesh-An Exploratory Study (2010)

Khan, Shafiqul Islam; Ahmed, A.K. Mottashir; Yunus, Mohammad et.al

ICDDRB

Abstract

Arsenic contamination of tubewell water is a major public-health problem in Bangladesh. In the recent years, the use of shallow and deep tubewell water for irrigation and the use of excess amount of cheap fertilizers and pesticides containing cadmium pose a serious threat of contamination of arsenic and cadmium in food. In an exploratory study, arsenic and cadmium were measured in foods from Matlab, a rural area in Bangladesh, that is extensively affected by arsenic and the economy is agriculture-based. Raw and cooked food samples were collected from village homes (households, n=13) and analyzed to quantify concentrations of arsenic and cadmium using atomic absorption spectrophotometry. Washing rice with water before cooking reduced the concentration of arsenic in raw rice by 13-15%. Rice, when cooked with excess water discarded, showed a significant decrease in arsenic concentration compared to that cooked without discarding the water ($p<0.001$). In contrast, concentration of cadmium did not decrease in cooked rice after discarding water. Cooked rice with discarded water had significantly lower concentration of arsenic compared to raw rice ($p=0.002$). Raw rice had higher concentration of arsenic compared to raw vegetables ($p<0.001$); however, no such difference was found for cadmium. Compared to raw vegetables (e.g. arum), concentration of arsenic increased significantly ($p=0.024$) when cooked with arsenic-contaminated water. Thus, the practice of discarding excess water while cooking rice reduces the concentration of arsenic but not of cadmium in cooked rice. However, water generally not discarded when cooking vegetables to avoid loss of micronutrients consequently retains arsenic. The

results suggest that arsenic and cadmium have entered the food-chain of Bangladesh, and the cooking practices influence the concentration of arsenic but not of cadmium in cooked food.

Keywords: Arsenic; Arsenic contamination; Cadmium; Cooking process; Food; Bangladesh

2.114. Technical and Social Evaluation of Arsenic Mitigation in Rural Bangladesh (2010)

Shafiquzzaman, Md.; Azam, Md. Shafiul; Mishima, Iori & Nakajima, Jun

ICDDRB

Abstract

Technical and social performances of an arsenic-removal technology—the sono arsenic filter—in rural areas of Bangladesh were investigated. Results of arsenic field-test showed that filtered water met the Bangladesh standard (<50 μg/L) after two years of continuous use. A questionnaire was administrated among 198 sono arsenic filter-user and 230 non-user families. Seventy-two percent of filters (n=198) were working at the time of the survey. Another 28% of the filters were abandoned due to breakage. The abandonment percentage (28%) was lower than other mitigation options currently implemented in Bangladesh. Households were reluctant to repair the broken filters on their own. High cost, problems with maintenance of filters, weak sludge-disposal guidance, and slow flow rate were the other demerits of the filter. These results indicate that the implementation approaches of the sono arsenic filter suffered from lack of ownership and long-term sustainability. Continuous use of arsenic-contaminated tubewells by the non-user households demonstrated the lack of alternative water supply in the survey area. Willingness of households to pay (about 30%) and preference of household filter (50%) suggest the need to develop a low-cost household arsenic filter. Development of community-based organization would be also necessary to implement a long-term, sustainable plan for household-based technology.

Keywords: Arsenic; Arsenic contamination; Drinking-water; Evaluation studies; Social development; Sono arsenic filter; Sustainability; Water pollution; Bangladesh

2.115. The socio-economics of arsenic removal (2010)

Richard Bart Johnston[1], Suzanne Hanchett[2] & Mohidul Hoque Khan[3]

[1]Department of Water and Sanitation in Developing Countries, Swiss Federal Institute of Aquatic Science and Technology, Ueberlandstrasse 133, CH-8600 Dübendorf, Switzerland

[2]Planning Alternatives for Change LLC, PO Box 8952, University Station, Portland, Oregon 97207, USA

[3]Pathways Consulting Services Ltd, 3/12 Block-F, Lalmatia, Dhaka-1207, Bangladesh.

Abstract

Nearly an eighth of the population in Bangladesh relies on arsenic-contaminated drinking water. Arsenic-removal filters could help to reduce exposure, but their price is high for the poor and their maintenance is cumbersome. The contamination of drinking water with naturally occurring arsenic threatens the health of millions of people in southern Asia. The problem is particularly acute in Bangladesh, where 13% of the population relies on arsenic-contaminated water to live1.

Keywords: Arsenic, Bangladesh, arsenic-contaminated drinking water.

2.116. Anthropogenic influences on groundwater arsenic concentrations in Bangladesh (2010)

Rebecca B. Neumann1, Khandaker N. Ashfaque1, A. B. M. Badruzzaman2 et.al

Abstract

The origin of dissolved arsenic in the Ganges Delta has puzzled researchers ever since the report of widespread arsenic poisoning two decades ago. Today, microbially mediated oxidation of organic carbon is thought to drive the geochemical transformations that release arsenic from sediments, but the source of the organic carbon that fuels these processes remains controversial. At a typical site in Bangladesh, where groundwater-irrigated rice fields and constructed ponds are the main sources of groundwater recharge, we combine hydrologic and biogeochemical analyses to trace the origin of contaminated groundwater. Incubation experiments indicate that recharge from ponds contains biologically degradable organic carbon, whereas recharge from rice fields contains mainly recalcitrant organic carbon. Chemical and isotopic indicators as well as groundwater simulations suggest that recharge from ponds carries this degradable organic carbon into the shallow aquifer and that groundwater flow, drawn by irrigation pumping, transports pond water to the depth where dissolved arsenic concentrations are greatest. Results also indicate that arsenic concentrations are low in groundwater originating from rice fields. Furthermore, solute composition in arsenic-contaminated water is consistent with that predicted using geochemical models of pond-water–aquifer-sediment interactions. We therefore suggest that the construction of ponds has influenced aquifer biogeochemistry, and that patterns of arsenic contamination in the shallow aquifer result from variations in the source of water, and the complex three-dimensional patterns of groundwater flow.

Keywords: Anthropology, aquifer, geochemical transformations, arsenic concentrations.

2.117. Towards an Arsenic Safe Environment in Bangladesh (2010)

FAO, UNICEF, WHO and WSP

Abstract

It was though the Bangladesh had succeeded in offering safe drinking water to the vast majority of its population though tube wells with hand pumps by the early 1990s. However during the same decade this success was challenged by the discovery of widespread arsenic contamination exceeding the Bangladesh drinking water standard of 50 microgram per liter. Several screening campaigns have determined the extent and severity of arsenic contamination. Tens of millions of people were at risk reducing the safe water coverage of Bangladesh from nearly universal to about 80%. The government of Bangladesh together with stakeholders has undertaken a range of arsenic mitigation strategies guided by the national policy for Arsenic Mitigation issued in 2004, and the implementation plan for Arsenic Mitigation the public and the private sectors have made significant progress towards mitigation.

Keyword: Safe drinking water, arsenic, arsenic contamination, mitigation.

2.118. Integrated Community Based Arsenic Mitigation Project for Bangladesh, Report on Baseline Survey (2010)

Ahammadul Kabir (Ph.D.)
NGO Forum for Drinking Water Supply & Sanitation

Abstract

The Baseline Survey on Integrated Community Based Arsenic Mitigation Project (Phase-II), which was conducted in all 133 working villages of 61 unions under 35 upazila of 22 districts of the project, has revealed some arsenic problem related scenarios, demanding action and impact oriented activities which are adequately reflected in the project proposal. it needs to be noted that villages ware emergency villages according to the last national tube well screening and more then 80% of the tube wells of those villages were contaminated with arsenic and large number of patients exists.

Keywords: Integrated Community Based Arsenic Mitigation Project, screening.

2.119. Nutrition Guidance to Improve the Symptoms of Arsenicosis patients in Bangladesh (2010)

Md. Ashadul Latif
Asia Arsenic Network, Dhaka, Bangladesh

Abstract

Arsenicosis is often seen among people of poor strata. Field surveys in Samta village condacted between 1998 and 2000 indicated the relationship between health effect and household income after finding that "the poorer families had more cases of arsenic posoning". the result of a meal survey clearly showed that people who often eat protein-rech food such as met, fish, egg, etc. did not develop skin symptoms associated with arsenic toxicity while those people who seldom take such food items where prone to arsenicosis. obviously, the latter group of people is poor and simply cannot afford to buy meat or fish on daily basis. this report is to share the exprience and lessons learned in nutrition guidance for arsenicosis patients. the report is also value for those who are concerned with the current situation of people with health effect and poverty caused by arsenic contamination in tube well water.

Keywords: Arsenic, Water, Arseniccosis, Bangladesh.

2.120. Pre- and postnatal arsenic exposure and child development at 18 months of age: a cohort study in rural Bangladesh (2010)

Abstract

Exposure to arsenic through drinking water has been associated with impaired cognitive function in school-aged children in cross-sectional studies; however, there are few longitudinal studies and little information on effects of exposure in early life when the brain is generally most vulnerable.

Keywords: Children, longitudinal, vulnerable

2.121. Evaluation of processes controlling the geochemical constituents in deep groundwater in Bangladesh: Spatial variability on arsenic and boron enrichment (2010)

M. A. Halim, R. K. Majumder, S. A. Nessa et.al

Forty-six deep groundwater samples from highly arsenic affected areas in Bangladesh were analyzed in order to evaluate the processes controlling geochemical constituents in the deep aquifer system. Spatial trends of solutes, geochemical modeling and principal component analysis indicate that carbonate dissolution, silicate weathering and ion exchange control the major-ion chemistry. The groundwater is dominantly of Na-Cl type brackish water. Approximately 17% of the examined groundwaters exhibit As concentrations higher than the maximum acceptable limit of 10??g/L for drinking water. Strong correlation (R2=0.67) of Fe with dissolved organic carbon (DOC) and positive saturation index of siderite suggests that the reductive dissolution of Fe-oxyhydroxide in presence of organic matter is considered to be the dominant process to release high content of Fe (median 0.31mg/L) in the deep aquifer. In contrast, As is not correlated with Fe and DOC. Boron concentration in the 26% samples exceeds the standard limit of 500??g/L, for water intended for human consumption. Negative relationships of B/Cl ratio with Cl and boron with Na/Ca ratio demonstrate the boron in deep groundwater is accompanied by brackish water and cation exchange within the clayey sediments.

Keywords: Arsenic, Boron, Deep groundwater, Geochemical, constituents, Geochemical model, Principal, component, analysis

2.122. Results from the First-Round of Bangladesh Environmental Technology Verification - Support to Arsenic Mitigation (BETV-SAM) Field Test (2010)

Ali Sc-Amiri=', E. Morsheda-, A. I. Kazi b, S. Siraj" et.al
"Ontario Centre for Environmental Technology Advancement (OCETA), 2070 Hadwen Road, Unit 20IA, Mississauga, Ontario, Canada, L5K 2C9 and Bangladesh Council of Scientific and Industrial Research, Dr. Qudrat-I-Khoda Road, Dhanmondi, Dhaka, Bangladesh
Available online at www.banglajol.info

Abstract

The Bangladesh Environmental Technology Verification - Support to Arsenic Mitigation (BETV-SAM) program objectively assessed thirteen arsenic removal technologies (ARTs) that had been submitted for performance verification, and selected seven technologies for the field testing and performance verification. Each technology was deployed to five hydrogeologically distinct regions of Bangladesh and was tested on five wells (with replicate units installed and tested on two wells). Raw and treated water samples were collected at regular intervals and were analysed for arsenic and other water quality parameters. The data were analysed using standard statistical software and the performance of individual ARTs have been evaluated and compared with the proponent's claim. Two technologies (STAR & CIWP) performed well while five other technologies performed poorly and their claims were rejected. The results of the first-round of the BETV-SAM field testing and performance verification program presented and discussed in this paper, may be important from a technological design and development point of view.

Keywords: Arsenic removal technology, Field testing, Performance verification, Water quality parameters.

2.123. Integrated Initiative to Enrich the Living Environment through Safe Drinking Water Supply and sanitation (October, 2008 to September, 2010)

Contact Person
Name: Tofayel Ahmed
Designation: Deputy Country Representative
Telephone: 02.9899574
Mobile: 01715.499376
Email: tofaeljade@dhaka.net

Project Director/Principal Researcher
Name: Mr. Akira Sakai
Designation: Chairperson, JADE
Telephone: 02.9899574
Email: sakai_a@khaki.plala.or.jp

Objective of the Project/Research
- To Develop Knowledge, Attitude and Practice of the Community People on Safe Drinking Water and Improved Sanitation;
- To Provide Appropriate Safe Dirking Water Free from Arsenic;
- To Provide Improved Sanitation Facilities (EcoSan-toilet);
- To Enhance Capacity of Community People for Sustainable Management of Provided Water and Sanitation Option.

Major Findings
- Under privileged people get the arsenic free safe drinking water through PSF at their door steps. Particularly women have got relief from their physical and mental burden;
- Improved sanitation facilities by EcoSan-toilet have turned the village environment good;
- Villagers are accustomed to maintain the community options.

2.124. Implications of organic matter on arsenic mobilization into groundwater: Evidence from northwestern (Chapai-Nawabganj), central (Manikganj) and southeastern (Chandpur) Bangladesh (2009)

A.H.M. Selim Reza[a], Jiin-Shuh Jean[a], Ming-Kuo Lee[b] et.al

[a]Department of Earth Sciences, National Cheng Kung University, Tainan 70101, Taiwan
[b]Department of Geology and Geography, Auburn University, Auburn, AL, USA

Abstract

Boreholes (50 m depth) and piezometers (50 m depth) were drilled and installed for collecting As-rich sediments and groundwater in the Ganges, Brahmaputra, and Meghna flood plains for geochemical analyses. Forty-one groundwater samples were collected from the three areas for the analyses of

cations (Ca2+, Mg2+, K+, Na+), anions (Cl−, NO3−, SO42−), total organic carbon (TOC), and trace elements (As, Mn, Fe, Sr, Se, Ni, Co, Cu, Mo, Sb, Pb). X-ray powder diffraction (XRD) and X-ray fluorescence (XRF) were performed to characterize the major mineral and chemical contents of aquifer sediments. In all three study areas, results of XRF analysis clearly show that fine-grained sediments contain higher amounts of trace element because of their high surface area for adsorption. Relative fluorescent intensity of humic substances in groundwater samples ranges from 30 to 102 (mean 58 ± 20, n = 20), 54–195 (mean 105 ± 48, n = 10), and 27–243 (mean 79 ± 71, n = 11) in the Ganges, Brahmaputra and Meghna flood plains, respectively. Arsenic concentration in groundwater (20–50 m of depth) ranges from 3 to 315 μg/L (mean 62.4 ± 93.1 μg/L, n = 20), 16.4–73.7 μg/L (mean 28.5 ± 22.4 μg/L, n = 10) and 4.6–215.4 μg/L (mean 30.7 ± 62.1 μg/L, n = 11) in the Ganges, Brahmaputra and Meghna flood plains, respectively. Specific ultra violet adsorption (SUVA) values (less than 3 m−1 mg−1 L) indicate that the groundwater in the Ganges flood plain has relatively low percentage of aromatic organic carbon compared to those in the Brahmaputra and Meghna flood plains. Arsenic content in sediments ranges from 1 to 11 mg/kg (mean 3.5 ± 2.7 mg/kg, n = 17) in the three flood plains. Total organic carbon content is 0.5–3.7 g/kg (mean 1.9 ± 1.1 g/kg) in the Ganges flood plain, 0.5–2.1 g/kg (mean: 1.1 ± 0.7 g/kg) in the Brahmaputra flood plain and 0.3–4.4 g/kg (mean 1.9 ± 1.9 g/kg) in the Meghna flood plain. Arsenic is positively correlated with TOC (R2 = 0.50, 0.87, and 0.85) in sediments from the three areas. Fourier transform infrared (FT-IR) analysis of the sediments revealed that the functional groups of humic substances in three areas include amines, phenol, alkanes, and aromatic carbon. Arsenic and Fe speciation in sediments were determined using XANES and the results imply that As(V) and Fe(III) are the dominant species in most sediments. The results also imply that As (V) and Fe (III) in most of the sediment samples of the three areas are the dominant species. X-ray absorption fine structure (EXAFS) analysis shows that FeOOH is the main carrier of As in the sediments of three areas. In sediments, As is well correlated with Fe and Mn. However, there is no such correlation observed between As and Fe as well as As and Mn in groundwater, implying that mobilizations of Fe, Mn, and As are decoupled or their concentrations in groundwater have been affected by other geochemical processes following reductive dissolution of Fe or Mn-hydroxides. For example, dissolved Fe and Mn levels may be affected by precipitation of Fe- and Mn-carbonate minerals such as siderite, while liberated As remains in groundwater. The groundwaters of the Brahmaputra and Meghna flood plains contain higher humic substances in relative fluorescence intensity (or fluorescence index) and lower redox potential compared to the groundwater of Ganges flood plain. This leads to the release of arsenic and iron to groundwater of these three plains in considerable amounts, but their concentrations are distributed in spatial variations.

Keywords: Arsenic mobilization; Organic matter; Bangladesh; Ganges flood plain; Brahmaputra flood plain; Meghna flood plain

2.125. Environmental and Genetic Control of Arsenic Accumulation and Speciation in Rice Grain: Comparing a Range of Common Cultivars Grown in Contaminated Sites Across Bangladesh, China, and India (2009)

Gareth J. Norton*[†], Guilan Duan[‡], Tapash Dasgupta[§] et.al

*[†] Institute of Biological and Environmental Sciences, University of Aberdeen, Cruickshank Building, St Machar Drive, Aberdeen, AB24 3UU, U.K.

[‡] Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China.

[§] Institute of Agricultural Science, Calcutta University, 35 B.C. Road, Kolkata 700 019 West Bengal, India, Department of Soil Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

Abstract

The concentration of arsenic (As) in rice grains has been identified as a risk to human health. The high proportion of inorganic species of As (As_i) is of particular concern as it is a nonthreshold, class 1 human carcinogen. To be able to breed rice with low grain As, an understanding of genetic variation and the effect of different environments on genetic variation is needed. In this study, 13 cultivars grown at two field sites each in Bangladesh, India, and China are evaluated for grain As. There was a significant site, genotype, and site by genotype interaction for total grain As. Correlations were observed only between sites in Bangladesh and India, not between countries or within the Chinese sites. For seven cultivars the As was speciated which revealed significant effects of site, genotype, and site by genotype interaction for percentage As_i. Breeding low grain As cultivars that will have consistently low grain As and low As_i, over multiple environments using traditional breeding approaches may be difficult, although CT9993-5-10-1-M, Lemont, Azucena, and Te-qing in general had low grain As across the field sites.

Keywords: Arsenic, rice grains, genotype interaction.

2.126. Sampling and Analysis of Arsenic in Groundwater in West Bengal, India, and Bangladesh (2009)

Mohammad M. Rahman, Bhaskar Das, Dipankar Chakraborti*
School of Environmental Studies, Jadavpur University, Kolkata 700 032, West Bengal, India

Abstract

This chapter provides an understanding of the contamination situation in an area. The sampling could be hotspot sampling, blanket sampling, and total screening of samples. Collection and preservation of samples are as important as analysis. Sampling technique is very crucial for the determination of arsenic in water samples. The major concern for sampling and storage are to prevent contamination and minimize the loss of trace amounts of analyses for assessing the total concentration of any element. Several analytical methods are currently used for the determination of total arsenic in water samples. The widely used analytical methods for the determination of arsenic in water are colorimetric/spectrophotometric/silver-diethyldithiocar-bamate (Ag-DDTC) methods, atomic absorption spectrometry (hydride generation and graphite furnace) methods, and inductively coupled plasma mass spectrometry methods. Various clinical, epidemiological, and hydrogeological studies are shown in arsenic-affected areas of West Bengal to determine the magnitude of arsenic contamination and its health effects.

Keywords: Arsenic contamination, colorimetric/spectrophotometric/silver-diethyldithiocar-bamate, plasma mass spectrometry methods.

2.127. Identification of Low Inorganic and Total Grain Arsenic Rice Cultivars from Bangladesh (2009)

Gareth J. Norton*†, M. Rafiqul Islam‡, Claire M. Deacon† et.al

*† Institute of Biological and Environmental Sciences, University of Aberdeen, Cruickshank Building, St. Machar Drive, Aberdeen AB24 3UU, U.K.,

‡ Department of Soil Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh,

† Soil Science Department, Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, U.K

Abstract

For the world's population, rice consumption is a major source of inorganic arsenic (As), a nonthreshold class 1 carcinogen. Reducing the amount of total and inorganic As within the rice grain would reduce the exposure risk. In this study, grain As was measured in 76 cultivars consisting of Bangladeshi landraces, improved Bangladesh Rice Research Institute (BRRI) cultivars, and parents of permanent mapping populations grown in two field sites in Bangladesh, Faridpur and Sonargaon, irrigated with As-contaminated tubewell water. Grain As ranged from 0.16 to 0.74 mg kg^{-1} at Faridpur and from 0.07 to 0.28 mg kg^{-1} at Sonargaon. Highly significant cultivar differences were detected and a significant correlation (r = 0.802) in the grain As between the two field sites was observed, indicating stable genetic differences in As accumulation. The cultivars with the highest concentration of grain As were the Bangladeshi landraces. Landraces with red bran had significantly more grain As than the cultivars with brown bran. The percent of inorganic As decreased linearly with increasing total As, but genetic variation within this trend was identified. A number of local cultivars with low grain As were identified. Some tropical japonica cultivars with low grain As have the potential to be used in breeding programs and genetic studies aiming to identify genes which decrease grain As.

Keywords: Inorganic arsenic, exposure risk, tubewell water.

2.128. Quality of life and mental health status of arsenic-affected patients in a Bangladeshi population (2009)

Syed EH1, Poudel KC, Sakisaka K et.al

1 Department of Community and Global Health, Graduate School of Medicine, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.

Abstract

Contamination of groundwater by inorganic arsenic is one of the major public-health problems in Bangladesh. This cross-sectional study was conducted (a) to evaluate the quality of life (QOL) and mental health status of arsenic-affected patients and (b) to identify the factors associated with the QOL. Of 1,456 individuals, 521 (35.78%) were selected as case and control participants, using a systematic random-sampling method. The selection criteria for cases (n=259) included presence of at least one of the following: melanosis, leucomelanosis on at least 10% of the body, or keratosis on the hands or feet. Control (nonpatient) participants (n=262) were selected from the same villages by matching age (±5 years) and gender. The Bangladeshi version of the WHOQOL-BREF was used for assessing the QOL, and the self-reporting questionnaire (SRQ) was used for assessing the general mental health status. Data

were analyzed using Student's t-test and analysis of covariance (ANCOVA), and the WHOQOL-BREF and SRQ scores between the patients and the non-patients were compared. The mean scores of QOL were significantly lower in the patients than those in the non-patients of both the sexes. Moreover, the mental health status of the arsenic-affected patients (mean score for males=8.4 and females=10.3) showed greater disturbances than those of the non-patients (mean score for males=5.2 and females=6.1) of both the sexes. The results of multiple regression analysis revealed that the factors potentially contributing to the lower QOL scores included: being an arsenic-affected patient, having lower age, and having lower annual income. Based on the findings, it is concluded that the QOL and mental health status of the arsenic-affected patients were significantly lower than those of the non-patients in Bangladesh. Appropriate interventions are necessary to improve the well-being of the patients.

Keywords: Inorganic arsenic, contamination of ground water, arsenic-affected patients.

2.129. Effect of Arsenic Exposure during Pregnancy on Infant Development at 7 Months in Rural Matlab, Bangladesh (2009)

[1]Fahmida Tofail, [2]Marie Vahter, [1]Jena D. Hamadani et.al

[1]Child Development Unit, Clinical Sciences Division and Public Health Sciences Division, International Center for Diarrhoeal Disease Research, Dhaka, Bangladesh.
[2]Institute of Environmental Medicine, Karolinska Institutet, Stockholm, Sweden.

Abstract

Background: Exposure to arsenic-contaminated drinking water during pregnancy is associated with low birth weight and fetal loss, and there is concern that the infants' development may be affected.

Objective: We assessed the effects of in utero arsenic exposure during pregnancy on infants' problem-solving ability and motor development.

Methods: We conducted a large population-based study of nutritional supplementation with 4,436 pregnant women in Matlab, Bangladesh, an area of high-arsenic–contaminated tube wells. We measured arsenic concentration in spot urine specimens at 8 and 30 weeks of pregnancy. We assessed a subsample of 1,799 infants, born to these mothers, at 7 months of age on two problem-solving tests (PSTs), the motor scale of the Bayley Scales of Infant Development–II, and behavior ratings.

Result: Arsenic concentrations in maternal urine were high, with a median (interquartile range) of 81 μg/L (37–207 μg/L) at 8 weeks of gestation and of 84 μg/L (42–230 μg/L) at 30 weeks. Arsenic exposure was related to many poor socioeconomic conditions that also correlated with child development measures. Multiple regressions of children's motor and PST scores and behavior ratings, controlling for socioeconomic background variables, age, and sex, showed no significant effect of urinary arsenic concentration on any developmental outcome.

Conclusion: We detected no significant effect of arsenic exposure during pregnancy on infant development. However, it is possible that other effects are as yet unmeasured or that effects will become apparent at a later age.

Keywords: Arsenic, Bangladesh, diarrhea, infants, pregnancy.

2.130. Baseline Soil Variation Is a Major Factor in Arsenic Accumulation in Bengal Delta Paddy Rice (2009)

Ying Lu[†‡], Eureka E. Adomako[†], A. R. M. Solaiman[§] et.al

[†‡] School of Biological Sciences, University of Aberdeen, Cruickshank Building, St Machar Drive, Aberdeen, AB24 3UU, U.K.

[†] College of Natural Resources and Environment, South China Agricultural University, Guangzhou 510642, P.R. China.

[§] Bangabandu Sheikh Mujibur Rahman Agricultural University, Gazipur - 1706, Bangladesh, and Bangladesh Agricultural University, Mymensingh - 2202, Bangladesh.

Abstract

Factors responsible for paddy soil arsenic accumulation in the tubewell irrigated systems of the Bengal Delta were investigated. Baseline (i.e., nonirrigated) and paddy soils were collected from 30 field systems across Bangladesh. For each field, soil sampled at dry season (Boro) harvest, i.e., the crop cycle irrigated with tubewell water, was collected along a 90 m transect away from the tubewell irrigation source. Baseline soil arsenic levels ranged from 0.8 to 21. mg/kg, with lower values found on the Pliestocene Terrace around Gazipur (average, 1.6 ± 0.2 mg/kg), and higher levels found in Holecene sediment tracts of Jessore and Faridpur (average, 6.6 ± 1.0 mg/kg). Two independent approaches were used to assess the extent of arsenic build-up in irrigated paddy soils. First, arsenic build-up in paddy soil at the end of dry season production (irrigated − baseline soil arsenic) was regressed against number of years irrigated and tubewell arsenic concentration. Years of irrigation was not significant (P = 0.711), indicating no year-on-year arsenic build-up, whereas tubewell As concentration was significant (P = 0.008). The second approach was analysis of irrigated soils for 20 fields over 2 successive years. For nine of the fields there was a significant (P< 0.05) decrease in soil arsenic from year 1 to 2, one field had a significant increase, whereas there was no change for the remaining 10. Over the dry season irrigation cycle, soil arsenic built-up in soils at a rate dependent on irrigation tubewell water, 35* (tubewell water concentration in mg/kg, ≡ mg/L). Grain arsenic rises steeply at low soil/shoot arsenic levels, plateauing out at concentratations. Baseline soil arsenic at Faridpur sites corresponded to grain arsenic levels at the start of this saturation phase. Therefore, variation in baseline levels of soil arsenic leads to a large range in grain arsenic. Where sites have high baseline soil arsenic, further additional arsenic from irrigation water only leads to a gradual increase in grain arsenic concentration.

Keywords: Soil Variation, As accumulation, Bengal delta.

2.131. Arsenic levels in rice grain and assessment of daily dietary intake of arsenic from rice in arsenic-contaminated regions of Bangladesh—implications to groundwater irrigation (2009)

Mohammad Mahmudur Rahman[1,2], Gary Owens[1], Ravi Naidu[1,2]

[1]Centre for Environmental Risk Assessment and Remediation (CERAR), University of South Australia, Mawson Lakes Campus, Mawson Lakes, SA, 5095, Australia

[2]CRC for Contamination Assessment and Remediation of the Environment, University of South Australia, Mawson Lakes Campus, Mawson Lakes, SA, 5095, Australia

Abstract

Chronic exposure to arsenic (As) causes significant human health effects, including various cancers and skin disorders. Naturally elevated concentrations of As have been detected in the groundwater of Bangladesh. Dietary intake and drinking water are the major routes of As exposure for humans. The objectives of this study were to measure As concentrations in rice grain collected from households in As-affected villages of Bangladesh where groundwater is used for agricultural irrigation and to estimate the daily intake of As consumed by the villagers from rice. The median and mean total As contents in 214 rice grain samples were 131 and 143 μg/kg, respectively, with a range of 2–557 μg/kg (dry weight, dw). Arsenic concentrations in control rice samples imported from Pakistan and India and on sale in Australian supermarkets were significantly lower ($p < 0.001$) than in rice from contaminated areas. Daily dietary intake of As from rice was 56.4 μg for adults (males and females) while the total daily intake of As from rice and from drinking water was 888.4 and 706.4 μg for adult males and adult females, respectively. From our study, it appears that the villagers are consuming a significant amount of As from rice and drinking water. The results suggest that the communities in the villages studied are potentially at risk of suffering from arsenic-related diseases.

Keywords: Chronic exposure to arsenic, groundwater irrigation, arsenic-related diseases, rice.

2.132. Dietary Intake of Methionine, Cysteine, and Protein and Urinary Arsenic Excretion in Bangladesh (2009)

[1,2] Julia E. Heck, [1]Jeri W. Nieves, [3]Yu Chen et.al

[1]Department of Epidemiology, Mailman School of Public Health and

[2]Institute for Social and Economic Research and Policy, Columbia University, New York, New York, USA.

[3]Department of Environmental Medicine, New York University School of Medicine, New York, New York, USA.

Abstract

Background: In Bangladesh, millions of people are exposed to arsenic in drinking water; arsenic is associated with increased risk of cancer. Once ingested, arsenic is metabolized via methylation and excreted in urine. Knowledge about nutritional factors affecting individual variation in methylation is limited.

Objectives: The purpose of this study was to examine associations between intakes of protein, methionine, and cysteine total urinary arsenic in a large population-based sample.

Methods: The study subjects were 10,402 disease-free residents of Araihazar, Bangladesh, who participated in the Health Effects of Arsenic Longitudinal Study (HEALS). Food intakes were assessed using a validated food frequency questionnaire developed for the study population. Nutrient composition was determined by using the U.S. Department of Agriculture National Nutrient Database for Standard Reference. Generalized estimating equations were used to examine association between total urinary arsenic across quintiles of nutrient intakes while controlling for arsenic exposure from drinking water and other predictors of urinary arsenic.

Results: Greater intakes of protein, methionine, and cysteine were associated with 10–15% greater total urinary arsenic excretion, after controlling for total energy intake, body weight, sex, age, tobacco use, and intake of some other nutrients.

Conclusions: Given previously reported risks between lower rates of arsenic excretion and increased rates of cancer, these findings support the role of nutrition in preventing arsenic-related disease.

Keywords: Health Effects of Arsenic Longitudinal Study, Nutrient composition, arsenic excretion.

2.133. Chronic respiratory symptoms in children following in utero and early life exposure to arsenic in drinking water in Bangladesh (2009)

Smith AH[1], Yunus M, Khan AF, Ercumen A et.al

[1]Arsenic Health Effects Research Program, School of Public Health, University of California, Berkeley, CA, USA, International Centre for Diarrhoeal Disease Research, Dhaka, Bangladesh, Department of Medicine, University of California, San Francisco, CA, USA, Department of Community Health Sciences, Fielding School of Public Health, University of California, Los Angeles, CA, USA.

Abstract

BACKGROUND: Arsenic exposure via drinking water increases the risk of chronic respiratory disease in adults. However, information on pulmonary health effects in children after early life exposure is limited.

METHODS: This population-based cohort study set in rural Matlab, Bangladesh, assessed lung function and respiratory symptoms of 650 children aged 7-17 years. Children with in utero and early life arsenic exposure were compared with children exposed to less than 10 µg/l in utero and throughout childhood. Because most children drank the same water as their mother had drunk during pregnancy, we could not assess only in utero or only childhood exposure.

RESULTS: Children exposed in utero to more than 500 µg/l of arsenic were more than eight times more likely to report wheezing when not having a cold [odds ratio (OR) = 8.41, 95% confidence interval (CI): 1.66-42.6, P < 0.01] and more than three times more likely to report shortness of breath when walking on level ground (OR = 3.86, 95% CI: 1.09-13.7, P = 0.02) and when walking fast or climbing (OR = 3.19, 95% CI: 1.22-8.32, P < 0.01]. However, there was little evidence of reduced lung function in either exposure category.

CONCLUSIONS: Children with high in utero and early life arsenic exposure had marked increases in several chronic respiratory symptoms, which could be due to in utero exposure or to early life exposure, or to both. Our findings suggest that arsenic in water has early pulmonary effects and that respiratory symptoms are a better marker of early life arsenic toxicity than changes in lung function measured by spirometry.

Keywords: Arsenic; children; in utero; lung function; pulmonary; respiratory

2.134. Effect of rice-cooking water to the daily arsenic intake in Bangladesh: results of field surveys and rice-cooking experiments (2009)

K. Ohno, Y. Matsuo, T. Kimura et.al

Department of Socio-Environmental Engineering, Hokkaido University, N13W8, Sapporo, 060-8628, Japan.

Department of Geology and Mining, University of Rajshahi, Rajshahi, 6205, Bangladesh.

Creative Research Initiative "Sousei", Hokkaido University, N21W10, Sapporo, 001-0021, Japan.

Abstract

The effect of rice-cooking water to the daily arsenic intake of Bangladeshi people was investigated. At the first field survey, uncooked rice and cooked rice of 29 families were collected. Their arsenic concentrations were 0.22±0.11 and 0.26±0.15 mg/kg dry wt, respectively. In 15 families, arsenic concentration in rice increased after cooking. Good correlation (R2=0.89) was observed between arsenic in rice-cooking water and the difference of arsenic concentration in rice by cooking. In the second survey, we collected one-day duplicated food of 18 families. As a result, we estimated that six of 18 families likely used the arsenic contaminated water for cooking rice even they drank less arsenic-contaminated water for drinking purpose. We also conducted rice-cooking experiments in the laboratory, changing arsenic concentration in rice-cooking water. Clear linear relationships were obtained between the arsenic in rice-cooking water and the difference of arsenic concentration in rice by cooking. Factors that affect arsenic concentration in cooked rice are suggested as follows: (1) arsenic concentration in uncooked rice, (2) that in rice-cooking water, (3) difference in water content of rice before and after cooking, and (4) types of rice, especially, the difference between parboiled and non-parboiled rice.

Keywords: Arsenic; Bangladesh; cooking water; daily intake; duplicate portion sampling; rice.

2.135. Leaching of Arsenic from Wastes of Arsenic Removal Systems (2009)

A. B. M. Badruzzaman

Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh

Abstract

Arsenic in groundwater was first detected in Bangladesh at Chapai Nawabgonj district in 1993. Since then arsenic contamination problem has been reported from almost every parts of the country. It is estimated that approximately 27% of the wells are contaminated with levels above 50ppb, the current drinking water standard for arsenic in Bangladesh (Kinninburg, D. G., et al., 2001). It is also estimated that about 77 million people are at risk of arsenic poisoning. A number of technologies are now available for end-of –the -pipe treatment arsenic present in groundwater. These are primarily based on coagulation and filtration. Some of the technologies use alum or ferric chloride as coagulants followed by filtration through a sand column. Other technologies are based on sedimentation and/or filtration through activated/doubly activated column/g ranular ferric hydroxide column. Aggressive leaching adopted in the Toxicity Characteristic Leaching Procedure (TCLP) at pH≤5 when applied to the wastes collected from different arsenic removal units has not produced lechate concentrations significant enough to term the wastes toxic as per the USEPA regulatory levels. However, TCLP may not be suitable for assessment of long -term leaching of arsenic from arsenic-rich waste, because such leaching may be

kinetically restricted. Thus, modification of TCLP to represent the natural leaching environment comparable to real disposal conditions is necessary. Tests under modified TCLP may provide different results. The users are currently practicing a number of arsenic-sludge disposal options. The sub-aqueous disposal 162 Fate of Arsenic in the Environment and buried in mud or mixed with organic matters has been considered for studying the anaerobic leaching of arsenic from solids and multiphasic sludge. This option addresses the situation where the users dispose the sludge/waste into a nearby pond where it is mixed with mud and a small amount of domestic sewage. For both the solid wastes and the multiphasic sludge, the leaching of arsenic into the overlying aqueous phase showed similar trend where the arsenic concentration peaked within the first week and then tapered off and disappeared after twelve weeks. Absences of residual arsenic in the solids following anaerobic leaching indicate that a significant amount of arsenic is lost through bio-methylation induced by the presence of organic matters used in the leaching experiment.

Keywords: Arsenic Removal Systems, Leaching of Arsenic, arsenic poisoning.

2.136. Groundwater chemistry and arsenic mobilization in the Holocene flood plains in south-central Bangladesh (2009)

[1]Prosun Bhattacharya, [2]M. Aziz Hasan, [3]Ondra Sracek et.al

[1]KTH-International Groundwater Arsenic Research Group, Department of Land and Water Resources Engineering, Royal Institute of Technology (KTH), 100 44, Stockholm, Sweden.

[2]Department of Geology, University of Dhaka, Dhaka, 1000, Bangladesh.

[3]Institute of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 2, 611 37, Brno, Czech Republic.

Abstract

A comparative study of arsenic enrichment in the Bengal Delta (BD) was carried out in three alluvial aquifers in south-central Bangladesh. Investigated sites included Sonargaon in Narayanganj, Chandina in Comilla and Sirajdikhan in Munshiganj districts. At all sites samples from different depths were collected, and water chemistry and redox status vs. depth trends were determined. The concentrations of DOC and HCO3 − were highest at Sirajdikhan site, while at the Sonargaon and Chandina sites the concentrations were lower. On the contrary, the NH4 + concentration was high at the Chandina site as compared to the other sites. There was a good match between dissolved As and Fe at the Sirajdikhan and Sonargaon sites, but not at the Chandina site. The dissolved aqueous concentration of Mn was low at the Chandina site, which suggested that the Mn(IV) redox buffering step was missing. Speciation modeling indicated a possibility of siderite precipitation at all sites, but precipitation of rhodochrosite only at the Sonargaon and Sirajdikhan sites. At the Sirajdikhan site, the log PCO2 values were very high (−1.37), which revealed the production of CO2 in redox processes. Principal component analysis (PCA) indicated an impact of sea water and redox status of different samples. These results suggest that the dissolved As is de-coupled from dissolved Mn because when released, As is re-adsorbed onto the Fe(III) minerals in solid phase, as well as from dissolved Fe when precipitation of Fe(II) minerals controls the aqueous concentrations of Fe. In addition, several other concurrent redox processes may exert kinetic constraints depending on refractory characteristics of Fe(III) minerals.

Keywords: Arsenic enrichment, concentration of DOC.

2.137. Effects of in utero arsenic exposure on child immunity and morbidity in rural Bangladesh (2009)

Rubhana Raqib, Sultan Ahmed, Rokeya Sultana et.al

Abstract

Chronic exposure to arsenic, a potent carcinogen and toxicant, via drinking water is a worldwide public health problem. Because little is known about early-life effects of arsenic on immunity, we evaluated the impact of in utero exposure on infant immune parameters and morbidity in a pilot study. Pregnant women were enrolled at 6-10 weeks of gestation in Matlab, a rural area of Bangladesh, extensively affected by arsenic contamination of tubewell water. Women (n = 140) delivering at local clinics were included in the study. Anthropometry and morbidity data of the pregnant women and their children, as well as infant thymic size by sonography were collected. Maternal urine and breast milk were collected for immune marker and arsenic assessment. Maternal urinary arsenic during pregnancy showed significant negative correlation with interleukin-7 (IL-7) and lactoferrin (Ltf) in breast milk and child thymic index (TI). Urinary arsenic was also positively associated with fever and diarrhea during pregnancy and acute respiratory infections (ARI) in the infants. The effect of arsenic exposure on ARI was only evident in male children. The findings suggest that in utero arsenic exposure impaired child thymic development and enhanced morbidity, probably via immunosuppression. The effect seemed to be partially gender dependent. Arsenic exposure also affected breast milk content of trophic factors and maternal morbidity. © 2009 Elsevier Ireland Ltd. All rights reserved.

Keywords: Arsenic IL-7 In utero, Lactoferrin, Morbidity, Thymus.

2.138. Arsenic in water and sediments of major rivers in Bangladesh (2009)

M.A.I. Chowdhury[a], M. Feroze Ahmed[b] and M. Ashraf Ali[b]

[a]Shah Jalal University of Science and Technology, Sylhet, Bangladesh
[b]Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

Abstract

Arsenic (As) concentrations in river water, suspended sediments and riverbed sediments of three major rivers in Bangladesh – Jamuna, Padma and Meghna - have been assessed. The As concentrations in the river water samples have been found to be very low, mostly below the detection limit of 1□g L-1. Suspended solids collected from the rivers during post-flood period (September-October) were found to contain significant amount of As, varying from 4.07 to 5.47mg kg-1 and the As concentrations in suspended sediments did not differ significantly among the rivers. Arsenic concentrations of river bed sediments were lower than those of the suspended sediments. Clay fraction of the sediments contained the highest concentration of As, followed by silt and sand fractions. The As load carried annually with suspended sediments of the Jamuna, Padma and Meghna rivers have been estimated to be 3054, 4121 and 4584 tons, respectively. Arsenic concentrations in suspended and riverbed sediments have been found to be comparable to those reported for aquifer sediments in Bangladesh. This study suggests that the recent riverbed and floodplain sediments could be an important source of As, from which As could be mobilized into the groundwater.

Keywords: Arsenic, river water, suspended solids, river bed sediment, clay, sand, silt.

2.139. Implementation of food frequency questionnaire for the assessment of total dietary arsenic intake in Bangladesh: Part B, preliminary findings (2009)

Nasreen Islam Khan[1,2], David Bruce[3], Ravi Naidu[1], Gary Owens[1]

[1]Centre for Environmental Risk Assessment and Remediation (CERAR), Mawson Lakes Campus, University of South Australia, South Australia, 5095, Australia
[2]Department of Geography and Environment, Dhaka University, Dhaka, 1000, Bangladesh
[3]School of Natural and Built Environments, City East Campus, University of South Australia, South Australia, 5095, Australia

Abstract

Dietary intake of water and food has been identified as one of the major pathways for arsenic (As) exposure in the rural population of Bangladesh. Therefore, realistic assessment and measurement of dietary intake patterns are important for the development of an accurate estimate of As exposure and human health risk assessment. One important consideration is to identify an appropriate tool for measuring dietary intake. In this study an interviewer-administered Food Frequency Questionnaire (FFQ) was implemented to determine age and gender specific dietary intake. The developed FFQ was unique because it developed a synergy between field dietary assessment and As concentration measurements in various environmental media. The resulting integrated database provided an accurate framework for the process of As exposure and human health risk assessment. The preliminary results reported here from the FFQ demonstrated that this technique could be used in rural areas as a tool to assess As exposure and the associated human health risk.

Keywords: Dietary intake, health risk.

2.140. Integrated Community based Arsenic Mitigation Project (2009 to 2012)

Contact Person
Name: ANM FajlulHadiSabbir
Designation: Executive Director
Telephone: 0631.61816
Mobile:01711.961317
Email: sabbirbff@gmail.com

Objective of the Project/Research
-Awareness Raising;
-Arsenicosis Patient Treatment;
-Alternative Water Option Management;
-Provide Training and Referral.

2.141. Promotion of Water Supply, Sanitation and Hygiene in Hard-to-Reach Areas in Rural Bangladesh (PWaSH in HtR) (2009)

Prepared by

Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

- Community needs identified for promoting climate-resilient WatSan technologies.
- 411 VDCs comprising of 33% female and 36.9% hardcore poor created demand among the communities for safe WatSan services.

The Project tabbing the LGI leadership has contributed in increasing safe water supply coverage by 12.6% (18,900 HHs, 88,200 people; m-45,203, f-42,998) from its base status of 28% (196,000 people; m-100,450, f 95,550) for water.

Key Findings

- Community needs identified for promoting climate-resilient WatSan technologies.
- 411 VDCs comprising of 33% female and 36.9% hardcore poor created demand among the communities for safe WatSan services.

The Project tabbing the LGI leadership has contributed in increasing safe water supply coverage by 12.6% (18,900 HHs, 88,200 people; m-45,203, f-42,998) from its base status of 28% (196,000 people; m-100,450, f 95,550) for water.

2.142. Integrated Community Based Arsenic Mitigation Project, Bangladesh (ICBAMP) (2009)

Prepared by

Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To improve the overall quality of life of arsenic groundwater affected communities.

Key Findings

- Integrated activities improved the health status of the arsenic affected patients.
- Improved standard of living for Arsenicosis affected patients and families through income generation services.

Ward Arsenic Mitigation Committees were found very sensitive and effective for raising voices about the problem and remedial measures as well as guiding the communities towards the mitigation.

2.143. Decentralization and Local Public Goods: How does allocation of Decision making authority affected provision? – A research project in Bangladesh (2009)

Prepared by

Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

- To develop the effective decision making system in allocation of decision making authority.

To conduct action research on ground water quality, management and allocation from the public and private.

Key Findings

The study found that the Regulated Community Approach significantly improves access to safe drinking water relative to the other two approaches namely Top down approach and Community participatory approach.

2.144. Sustainable Arsenic Mitigation (SAsMit) (2009)

Prepared by

Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

- Develop a sustainable option for safe drinking water for rural and disadvantaged community through targeting safe aquifers for installation of community hand tubewells.
- Replication trials in Bangladesh and elsewhere.
- Increase global awareness of the problems associated with high As groundwater of geogenic origin.

Key Findings

Identify the sediment color for local drillers to install well in arsenic safe aquifer.

2.145. Enhancing Governance and Capacity of Service Providers and Civil Society in Water Supply and Sanitation Sector (EGCSC in WSS) (2009)

Prepared by

Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To ensure good governance in promotion of pro-poor safe and sustainable water supply and sanitation services.

Key Findings

- A total of 162 confirm arsenicosis patients have been identified among them 75 are female and 87 are male, all confirmed patients have been provided with medicine support.
- IGA support was provided among the 15 vulnerable patients.
- Technology specific different health concerned parameters including arsenic, FC of installed water points of around 200 nos were tested.

Within the project location around 13,000 water options were randomly selected to test arsenic using HACH kit and around 17,000 water options were selected to examine FC using Microkit. According to available data water options were found arsenic free and 79% water options found FC free.

2.146. Study on Alternative Arsenic Free Water Option (Project: ICBAMP) (2009)

Prepared by

Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To improve the quality of life in the arsenic affected communities in different parts of the arsenic contaminated areas by improving access to the arsenic free drinking water source.

Key Findings

- A comparative finding revealed that highest no. of people have the knowledge on arsenic and safe water option in flooding area followed by in coastal area and drought area.
- People of different areas have expressed different reasons for preferring specific types of option, but mostly expressed their preference on deep tubewell and second preference water option is RWHS followed by AIRP and PSF.
- Site selection of water options installed by the government in different areas was not reflected the community demand.

A comparative finding showed that a major number of arsenic safe alternative water options were installed in no arsenic contaminated area by Department of Public Health Engineering whereas under ICBAMP, Bangladesh a large number of water options were installed in highly arsenic contaminated areas and not a single water option was installed arsenic free areas.

2.147. Cancer Mortality and Morbidity among Arsenicosis Patients in Rural Bangladesh. (Project: ICBAMP) (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

The major objectives of the research were as follows:

- To determine overall morbidity risk for any cancer among chronically arsenic exposed population.
- To determine the risk of developing cancer among arsenic exposed individuals.
- To assess overall mortality risk for any cancer in Bangladesh.
- To determine overall mortality risk for any cancer among chronically arsenic exposed population.

To assess current water use pattern of the study participants.

Key Findings

- The study finds the overall estimated mortality risk for any cancer is 106 (95% CI: 85 – 148), and the overall estimated mortality risk for any cancer among chronically arsenic exposed population is 165 (95% CI: 80 – 290). Estimated lifetime excess risk of mortality from any cancer attributable to chronic arsenic exposure is 59 per 100,000 population. The overall estimated morbidity risk for any cancer among chronically arsenic exposed population is 130 (95% CI: 60 – 250). The risk of developing cancer is 3.2 (95% CI: 1.6 – 6.2) times higher among chronically arsenic exposed population compared to unexposed population.
- The current study explored that still the arsenicosis patients are facing social problems such as Jobless, Reduce income, Problem in marriage, discrimination and divorce.

Due to lack of medical doctors and health workers who are capable to diagnose, identify and treat arsenicosis patients properly, there are areas where arsenicosis patients are hardly detected or receive appropriate treatment.

2.148. To improve the overall quality of life of arsenic groundwater affected communities (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To improve the overall quality of life of arsenic groundwater affected communities.

Chapter 3

Compendium on Sanitation

3.1. Water Sanitation and Hygiene (WaSH) Promotion in Selected Areas of Southern Bangladesh (July, 2014 to June, 2016)

Contact Person
Name: Md. Asaduzzaman
Designation: Programme Manager
Telephone: 041.2833839
Mobile: 01712.181110
Email:asadkaligonj@yahoo.com; ashcvp@cssbd.org; wash@cssbd.org

Project Director/Chief Researcher
Name: Ms. Tania Rahman
Designation: Director Health (Acting)
Telephone: 041.720776
Mobile: 01714.162315
Email: tania@cssbd.org

Objective of the Project
- Provision of Effective Village Development Committees (VDCs);
- Social Marketing in Sanitation;
- Community Participation in WaSH Activities;
- Rain Water Harvesting.

Major Findings
- Shortage of Tube-well, Rainwater harvester, Sanitary Latrine; Lack of Awareness on Diarrhoea, Dysentary and Typhoid.

3.2. Improvement of Living Environment through EcoSan-toilet Expansion in Rural Areas of Bangladesh (April, 2013 to March, 2016)

Contact Person
Name: Mosleh Uddin Parvez
Designation: Manager, Program
Telephone: 02.9899574
Mobile: 01714.389363
Email: mmuparvez@yahoo.com

Project Director/Chief Researcher
Name: Dr. Kunio Takahashi
Designation: Country Representative
Telephone: 02.9899574
Mobile: 01727.431341
Email: nqg48559@nifty.com

Project Title/Research Title
Objective of the Project
To spread EcoSan-toilet nationwide in rural areas of Bangladesh
Project Duration: April, 2013 to March, 2016

Major Findings
- 295 units of EcoSan-toilet have been constructed;
- Marketing of human excreta as fertilizer is underway;
- Community Based Organization (CBO) has been functioning for overall management on the way forward.

3.3. Activity to Improve the Living Environment of Urban Slum Aiming at Resource Recycling in Khulna City of Bangladesh (April, 2012 to March, 2015)

Contact Person
Name: Qazi Azad-uz-zaman
Designation: Manager, RME
Telephone: 02.9899574
Mobile: 01556.358547
Email: aazad013@yahoo.com

Project Director/Chief Researcher
Name: Mr. Akira Sakai
Designation: Chairperson, JADE
Telephone: 02.9899574
Mobile: N/A
Email: sakai_a@khaki.plala.or.jp

Objective of the Project
- Installation of Sanitary Facility Aiming at Appropriate Human Excreta Management along with Resource Utilization of Human Excreta: to Provide Energy and Organic Fertilizer;
- To Provide Incentive to the Slum Community to Improve their Living Environment;
- Resource Utilization has Possibility to Reduce Financial Burden (Fuel Cost Reduction, Medical Expenditure Reduction) on Family Finance of the Dwellers and Generate Income;
- Improvement of Slum Living Environment Leads to Healthy and Hygienic Environment, Reduction of Disease Occurrence and Medical Expenditure;
- To Reduce Environmental Impact.

Major Findings
- Slum People have got Healthy, Hygienic, Private and Secured Community Toilet Facilities;
- Bio-gas based Toilet Facilities Provide them Gas for Cooking;
- Gas Selling Money Utilize for Facilities Management;
- Slum People have got Community Space for Recreation;
- Kitchen Garbage Collected and Made Compost.

3.4. Factors influencing knowledge and practice of hygiene in Water, Sanitation and Hygiene (WASH) programme areas of Bangladesh Rural Advancement Committee (2014)

Akter T[1], Ali AM[2]
[1]Bangladesh Rural Advancement Committee, Dhaka, Bangladesh.
[2]Innovations for Poverty Action, Dhaka, Bangladesh.

Abstract

INTRODUCTION: Improved hygiene is one of the most effective means of reducing disease occurrence. However, complete understandings of the factors that contribute to such improvement are not clear. This study explored factors that facilitate and/or impede hygiene behavior in water, sanitation and hygiene (WASH) intervention areas using qualitative research techniques.

METHODS: The Bangladesh Rural Advancement Committee (BRAC) has been providing WASH intervention to 150 rural upazilas (sub-districts) since 2006. For qualitative data collection, in-depth interviews were conducted with 144 purposively selected women from six upazilas across Bangladesh. A woman in the household was considered as a case and interviewed regarding various aspects of sanitation and hygiene, using a checklist. Some practices, such as cleanliness of latrines, and availability of soap, water, slippers in their designated place were physically verified.

RESULTS: The respondents' hygiene behavior was mainly facilitated by improved knowledge and awareness of health and environment-related issues. Latrine ownership increased through financial assistance, resulting in improved privacy, social prestige, and a heightened sense of responsibility towards maintaining a healthy life. However, lack of interest in attending cluster meetings, traditional knowledge, poverty, and lack of will were some of the factors impeding knowledge and hygiene practice. In addition, attitude played a definitive role, with some respondents not practicing hygiene in spite of having the financial ability to do so. They expected full financial support for creating sanitation and hygiene facilities in their household despite BRAC's policy of providing such support only to the 'ultra-poor'.

CONCLUSIONS**:** The identified impeding factors often act as barriers to transformation of hygiene-related knowledge into practice and practice into habit. More motivational cluster meetings with large-scale participation and periodic home visits by the programme organizers are imperative as they markedly improve hygiene behavior.

Keywords: Evidence-based Care; Postgraduate; Public Health; Researcher.

3.5. User perceptions of shared sanitation among rural households in Indonesia and Bangladesh (2014)

Nelson KB[1], Karver J[2], Kullman C[3], Graham JP[4].

[1]Department of Epidemiology and Biostatistics, Milken Institute School of Public Health, The George Washington University, Washington, D.C., United States of America.

[2]Washington, D.C., United States of America.

[3]World Bank Water and Sanitation Program, Washington, D.C., United States of America.

[4]Department of Environmental and Occupational Health and Department of Global Health, Milken Institute School of Public Health, The George Washington University, Washington, D.C., United States of America.

Abstract

BACKGROUND: The practice of sharing sanitation facilities does not meet the current World Health Organization/UNICEF definition for what is considered improved sanitation. Recommendations have been made to categorize shared sanitation as improved sanitation if security, user access, and other conditions can be assured, yet limited data exist on user preferences with respect to shared facilities.

OBJECTIVE: This study analyzed user perceptions of shared sanitation facilities in rural households in East Java, Indonesia, and Bangladesh.

METHODS: Cross-sectional studies of 2,087 households in East Java and 3,000 households in Bangladesh were conducted using questionnaires and observational methods. Relative risks were calculated to analyze associations between sanitation access and user perceptions of satisfaction, cleanliness, and safety.

RESULTS: In East Java, 82.4% of households with private improved sanitation facilities reported feeling satisfied with their place of defecation compared to 68.3% of households with shared improved facilities [RR 1.19, 95% CI 1.09, 1.31]. In Bangladesh, 87.7% of households with private improved facilities reported feeling satisfied compared to 74.5% of households with shared improved facilities [RR 1.15, 95% CI 1.10, 1.20]. In East Java, 79.5% of households who reported a clean latrine also reported feeling satisfied with their place of defecation; only 38.9% of households who reported a dirty latrine also reported feeling satisfied [RR 1.74, 95% CI 1.45, 2.08].

CONCLUSION: Simple distinctions between improved and unimproved sanitation facilities tend to misrepresent the variability observed among households sharing sanitation facilities. Our results suggest that private improved sanitation is consistently preferred over any other sanitation option. An increased number of users appeared to negatively affect toilet cleanliness, and lower levels of cleanliness were associated with lower levels of satisfaction. However, when sanitation facilities were clean and shared by a limited number of households, users of shared facilities often reported feeling both satisfied and safe.

Keywords: Households, satisfaction, latrine.

3.6. Transition overtime in household latrine use in rural Bangladesh: a longitudinal cohort study (2014)

Tahera Akter[1*], Abu RMM Ali[2] and Nepal C Dey[3]

* Corresponding author: Tahera Akter

[1] Senior Research Associate, Environment Research Unit, Research and Evaluation Division, BRAC Centre, 75, Mohakhali, Dhaka 1212, Bangladesh.

[2] Project Associate, Innovations for Poverty Action, Apt # 6B, House # 35, Road # 7, Block-G, Banani, Dhaka 1213, Bangladesh.

[3] Research Fellow & Coordinator, Environment Research Unit, Research and Evaluation Division, BRAC Centre, 75, Mohakhali, Dhaka 1212, Bangladesh.

Abstract

Background: In a low-income country like Bangladesh, where the poverty rate is higher in rural compared to urban areas, the consistent use of sanitary latrines over time is a challenge. To address this issue, the Water, Sanitation, and Hygiene (WASH) program of the Bangladesh Rural Advancement Committee (BRAC) was devised to improve health of the rural poor through enhanced sanitation services, such as by providing loans or education. Sanitary latrine use in households and changes over time were assessed in this study.

Methods: This was a longitudinal cohort study of the baseline, midline, and end line status of the WASH project. Households assessed in all three rounds of surveys (26,404 in each survey) were included in the

analysis. Thirty thousand households from 50 *upazila*s (sub-districts) were selected in two stages: i) thirty villages were selected from each of the 50 *upazila*s by cluster sampling, and ii) twenty households were chosen systematically from each selected village. A female member capable of providing household-level information was interviewed from each house using the pre-tested questionnaire. Spot observations of some components were made to assess the quality of sanitary latrine use. The adjusted log-binomial regression was performed and risk ratios with 95% confidence intervals were estimated for sanitary latrine use. Data were analyzed using Statistical Package for the Social Sciences (SPSS) and Stata software.

Results: The use of sanitary latrines by households increased significantly from the baseline (31.7%) to midline (41.5%) and end line (57.4%) assessment points. The proportion of physically verified clean latrines increased significantly from 33.4% at baseline to 50.8% at the midline and 53.3% at the end line. Analysis of changes in latrine-use showed that 73.3% of the baseline latrine-using households continued to do so at the end line, while the rest switched to unsanitary practices. Households with better socioeconomic status were more likely to use sanitary latrines.

Conclusion: There are improvements in ownership and use of sanitary latrines by households over the years in WASH intervention areas. However, switching of some households from sanitary to unsanitary latrines remains a matter of concern regarding sustainability.

Keywords: Transition; Sanitary latrine; Unsanitary latrine; Log-binomial regression; BRAC WASH.

3.7. Targeted interventions of ultra-poor women in rural Rangpur, Bangladesh: do they make a difference to appropriate cooking practices, food habits and sanitation? (2014)

Yeasmin L1, Akter S2, Shahidul Islam AM2 et.al

[1]Senior Research Associate, Environment Research Unit, Research and Evaluation Division, BRAC Centre, 75, Mohakhali, Dhaka 1212, Bangladesh.

Abstract

This study aimed to assess whether teaching good cooking practices, food habits and sanitation to ultra-poor rural women in four rural communities of Rangpur district, Bangladesh, with a high density of extremely poor households, would improve the overall health of the community. The sample size was 200 respondents combined from the target and control areas. In the target area, twelve in-depth interviews and four focus group discussions were undertaken for knowledge dissemination. Descriptive and mixed-model analyses were performed. The results show that washing hands with soap was 1.35 times more likely in the target than the control group ($p<0.01$). Further, after intervention, there was a significant improvement in hand-washing behaviour: before cutting vegetables, preparing food, feeding a child and eating, and after defecating and cleaning a baby ($p<0.05$). Also, the target group was more likely to moderately and briefly boil their vegetables and were 19% less likely to use maximum heat when cooking vegetables than the control group ($p<0.01$). Improved knowledge and skills training of ultra-poor women reduces the loss of nutrients during food preparation and increases their hygiene through hand-washing in every-day life.

Keywords: Dissemination, ultra-poor, nutrients.

3.8. Toys and toilets: cross-sectional study using children's toys to evaluate environmental faecal contamination in rural Bangladeshi households with different sanitation facilities and practices (2014)

Vujcic J[1], Ram PK, Hussain F et.al

[1]State University of New York at Buffalo, New York, NY, USA

Abstract

OBJECTIVE: To evaluate household faecal contamination using children's toys among 100 rural Bangladeshi households categorised as 'cleaner' (toilet that reliably separates faeces from the environment and no human faeces in/around living space) or 'less clean' (no toilet or toilet that does not reliably separate faeces from the environment and human faeces in/around living space).

METHODS: We distributed toy balls to each household and rinsed each study toy and a toy already owned by the household in 200 ml of Ringer's solution. We enumerated faecal coliforms and faecal streptococci from each rinse using membrane filtration methods.

RESULTS: Study toys from 39 cleaner households had lower mean faecal coliform contamination than toys from 61 less clean households (2.4 log10 colony-forming units (CFU)/200 ml vs. 3.2 log10 CFU/200 ml, P = 0.03). However, wealth measures explained a portion of this relationship. Repeat measures were moderately variable [coefficient of variation (CV) = 6.5 between two toys in the household at the same time, CV = 37.6 between toys in the household at two different times 3-4 days apart]. Too few households owned a non-porous toy to compare groups without risk of bias.

CONCLUSION: In rural Bangladesh, improved sanitation facilities and practices were associated with less environmental contamination. Whether this association is independent of household wealth and whether the difference in contamination improves child health merit further study. The variation found was typical for measures of environmental contamination, and requires large sample sizes to ascertain differences between groups with statistical significance.

Keywords: Bangladesh; coliforms; environmental faecal contamination; sanitation; toilets; toys.

3.9. Water and Sanitation in Developing Countries (2014)

Yoshiaki Tsuzuki y.tsuzuki@uq.edu.au (2)

2. Engineering, Architecture and Information Technology (EAIT), the University of Queensland, Brisbane, QLD, Australia

Abstract

There are many kinds of technological options in water supply, sanitation and wastewater treatment. The water MDGs may be achievable in 2015, however, the sanitation MDGs may be hard to be achieved. Therefore, low-cost sanitation is necessary especially in the critical regions. In this chapter, some alternatives for the conventional wastewater treatment and sanitation systems in the concept of low-cost sanitation are explained to consider the methods to develop appropriate municipal wastewater treatment systems. Some typical wastewater treatment planning schemes in Japan will also give some suggestions to developing countries especially with larger MDG sanitation indicator.

Keywords: Technological options, wastewater treatment, MDG, municipal wastewater treatment.

3.10. A qualitative comparative analysis of well-managed school sanitation in Bangladesh (2014)

Christie Chatterley, [1]Amy Javernick-Will,[1]Karl G Linden et.al

[1]Department of Civil, Environmental and Architectural Engineering, University of Colorado, Boulder, USA.

[2]School Health and Nutrition Department, Save the Children, Dhaka, Bangladesh.

[3]Department of Education and Child Development, Save the Children, Washington, USA.

Abstract

Background: Continued management of sanitation and hygiene services, post-intervention, is a global challenge, particularly in the school-setting. This situation threatens anticipated impacts of school sanitation and hygiene investments. To improve programming and policies, and increase the effectiveness of limited development resources, we seek to understand how and why some schools have well-managed sanitation post-intervention, while others do not.

Methods: Based on in-depth qualitative data from 16 case schools in Meherpur, Bangladesh, we employ fuzzy-set qualitative comparative analysis to identify the necessary and sufficient conditions, or combinations of conditions (referred to as *pathways*), that lead to either well-managed or poorly managed school sanitation. We include posited sustainability determinants from the literature and factors that emerged from the cases themselves in the analysis.

Results: We identified three distinct pathways sufficient to support well-managed services, providing multiple options for how well-managed school sanitation could be encouraged. Two of these are applicable to both government and non-government schools: (1) quality construction, financial community support and a champion; and (2) quality construction, financial government support, a maintenance plan and school management committee involvement. On-going financial support for operations and maintenance was identified as a necessary condition for continued service management, which was absent from many schools with poorly managed services. However, financial support was insufficient alone and other conditions are needed in conjunction, including quality construction and incentivizing conditions, such as school management committee involvement in sanitation specifically, a sanitation champion, and/or one teacher clearly responsible for toilet maintenance. Surprisingly, the number of students per toilet (ranging from 18–95 students) and toilet age (ranging from 8–32 months) had no significant effect on sanitation conditions.

Conclusions: Findings corroborate those from a similar study in Belize, and comparison suggests the need for financial community support and the possibly tenuous reliance on local champions in the absence of adequate government support for operations and maintenance. Sub-determinants to the necessary conditions are also discussed which have implications for school sanitation in Bangladesh and may have broader relevance for other low-income countries though further research is needed.

Keywords: School sanitation, Handwashing, Qualitative comparative analysis, Hygiene, Sustainability, Bangladesh, Asia.

3.11. Assessment of urine diverting dehydrating toilets as a flood-resilient and affordable sanitation technology in the context of Bangladesh (2014)

Saif Mohammad Uddin, Mariska Ronteltap and Jules B. van Lier

Sub-Divisional Engineer, Bangladesh Water Development Board, 72 Green Road, Dhaka, Bangladesh. UNESCO-IHE Institute for Water Education, Westvest 7, 2611 AX, Delft, The Netherlands. Sanitary Engineering Section, Water Management Department. Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN, Delft, The Netherlands.

Abstract

Bangladesh has made a significant contribution to supply improved sanitation facilities in rural areas in recent years. As it is the most known option, pit latrines were the most favourable technology. Yet, as Bangladesh is a country of flooding and high groundwater table, pit latrines not only flush out and cause pollution; they also become inaccessible during floods, and remain filled with silt after the floods. Every year floods destroy many sanitation facilities and force people to resort to open defecation, despite the capital-intensive investment. Urine Diversion Dehydration Toilets (UDDTs) were evaluated on their suitability in flood-prone areas and their affordability in the context of Bangladesh. A survey conducted in two flood-prone areas of Bangladesh showed that with an average height of 0.69 m the UDDTs are higher than the average highest flood level of 0.31 m. To decrease cost and construction complexity, a local design was developed based on the current pit latrine, at 50% of the costs of the current UDDTs. Although the resulting cost is still not within reach for most Bangladeshi, the affordability could be increased by taking into account avoided emptying costs as well as the added value of human excreta as a fertilizer.

Keywords: Affordability; flood resilient sanitation; low cost; raised latrine; UDDT.

3.12. Factors affecting slum sanitation projects in Dhaka City: learning from the dynamics of social-technological-governance systems (2014)

Md Mizanur Rahman, Peter J. Atkins and Colin McFarlane

Jahangirnagar University, Geography and Environment, Social Sciences Faculty, Savar, Dhaka 1342, Bangladesh

Department of Geography, Durham University, UK

Abstract

Historically, the Government of Bangladesh has faced serious challenges in urban sanitation while public policy continuously bypasses questions related to the overall condition of the urban slums and their complex and filthy neighbourhood environment. Considering the diverse local settings of the urban slums, this paper attempts to explore the varied dynamics of 'social-technological-governance' (STG) systems from different categories of government (GO) and non-governmental organisation-managed slums where sanitation projects have been implemented. The analysis of STG systems not only uncovers different factors that affect sanitation projects but also offers a guideline that could address the overwhelming slum sanitation agenda in the context of metropolitan cities. The paper adopts a qualitative stance to explore the STG system and compare dynamics across the study areas. As is widely understood, local contextual issues are important in implementing sanitation projects and first-hand qualitative information has therefore been gathered and analysed to make sense of on-the-ground realities.

Keywords: Governance; government–NGO; sanitation; slum; society; technology

3.13. A strengths, weaknesses, opportunities, and threats analysis on integrating safe water supply and sustainable sanitation systems (2014)

Sayed Mohammad Nazim Uddin, Zifu Li, Heinz-Peter Mang et.al

Action Contre La Faim (ACF), Mongolia, Diplomatic Compound 95-11, Chingeltei District, 4th Khoroo, Ulaanbaatar, Mongolia.

Center for Sustainable Environmental Sanitation, University of Science and Technology Beijing, 30 Xueyuan Road, Haidian, 100083, Beijing, China.

Technologies for Economic Development, Polo Ground 49/3, PO BOX 14621, Maseru 100, Lesotho.
Action Contre la Faim, 4, rue Niepce 75662 Paris, France.

Abstract

This paper applies a 'comprehensive' strengths, weaknesses, opportunities, and threats (SWOT) analysis to compare the 'before and after' scenarios of integrating a safe water supply (SWS) into a sustainable sanitation system (SSS) in the peri-urban Ger areas of Ulaanbaatar. Qualitative field investigations, including interviews and focus group discussions, are conducted with stakeholders and key informants to collect data on the scenarios before the SSS and to develop a conceptual framework after the SSS implementation. The before-implementation scenario has one strength, that is, the interest of communities and NGOs toward the SWS–SSS integration, which facilitates the acceptance and up-scaling of sustainable technologies. The after-implementation scenario shows additional strengths, such as community acceptance and satisfaction with SSS. The identified weaknesses are attributed to the lack of community-based organizations, community participation, and inter-sector coordination. The marketing of SSS, the involvement of banks and micro-credit systems, and the reuse of treated greywater have been identified as opportunities. The before-implementation scenario identifies the use of pit latrines and the lack of political will as the primary threats, whereas the after-implementation scenario identifies technology innovations for the extreme cold as a primary threat. The application of the SWS–SSS integration in other cases must be investigated further.

Keywords: integration; safe water supply; sustainable sanitation system; SWOT; urban development; WASH.

3.14. School-based mass distributions of mebendazole to control soil-transmitted helminthiasis in the Munshiganj and Lakshmipur districts of Bangladesh: An evaluation of the treatment monitoring process and knowledge, attitudes, and practices of the population (2013)

Hafiz I[1], Berhan M[2], Keller A[3] et.al.

[1]Ministry of Health and Family Welfare (MOH&FW), Bangladesh. Electronic [2]Children Without Worms, The Task Force for Global Health, Atlanta, GA, USA. [3]Center for Global Health, Centers for Disease Control and Prevention, Atlanta, GA, USA.

Abstract

Bangladesh's national deworming program targets school-age children (SAC) through bi-annual school-based distributions of mebendazole. Qualitative and quantitative methods were applied to identify challenges related to treatment monitoring within the Munshiganj and Lakshmipur Districts of Bangladesh. Key stakeholder interviews identified several obstacles for successful treatment monitoring

within these districts; ambiguity in defining the target population, variances in the methods used for compiling and reporting treatment data, and a general lack of financial and human resources. A treatment coverage cluster survey revealed that bi-annual primary school-based distributions proved to be an effective strategy in reaching school-attending SAC, with rates between 63.0% and 73.3%. However, the WHO target of regular treatment of at least 75% of SAC has yet to be reached. Particularly low coverage was seen amongst non-school attending children (11.4-14.3%), most likely due to the lack of national policy to effectively target this vulnerable group. Survey findings on water and sanitation coverage were impressive with the majority of households and schools having access to latrines (98.6-99.3%) and safe drinking water (98.2-100%). The challenge now for the Bangladeshi control program is to achieve the WHO target of regular treatment of at least 75% of SAC at risk, irrespective of school-enrollment status.

Keywords: Bangladesh; Mass drug administration; Mebendazole; Process evaluation; STH; Treatment coverage survey

3.15. Designing a handwashing station for infrastructure-restricted communities in Bangladesh using the integrated behavioural model for water, sanitation and hygiene interventions (IBM-WASH) (2013)

Kristyna RS Hulland, [1]Elli Leontsini, [1]Robert Dreibelbis et.al
[1]Social and Behavioral Interventions Program, Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

Abstract

Background: In Bangladesh diarrhoeal disease and respiratory infections contribute significantly to morbidity and mortality. Handwashing with soap reduces the risk of infection; however, handwashing rates in infrastructure-restricted settings remain low. Handwashing stations – a dedicated, convenient location where both soap and water are available for handwashing – are associated with improved handwashing practices. Our aim was to identify a locally feasible and acceptable handwashing station that enabled frequent handwashing for two subsequent randomized trials testing the health effects of this behaviour.

Methods: We conducted formative research in the form of household trials of improved practices in urban and rural Bangladesh. Seven candidate handwashing technologies were tested by nine to ten households each during two iterative phases. We conducted interviews with participants during an introductory visit and two to five follow up visits over two to six weeks, depending on the phase. We used the Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH) to guide selection of candidate handwashing stations and data analysis. Factors presented in the IBM-WASH informed thematic coding of interview transcripts and contextualized feasibility and acceptability of specific handwashing station designs.

Results: Factors that influenced *selection* of candidate designs were market availability of low cost, durable materials that were easy to replace or replenish in an infrastructure-restricted and shared environment. Water storage capacity, ease of use and maintenance, and quality of materials determined the acceptability and feasibility of specific handwashing station designs. After examining technology, psychosocial and contextual factors, we selected a handwashing system with two different water storage capacities, each with a tap, stand, basin, soapy water bottle and detergent powder for pilot testing in preparation for the subsequent randomized trials.

Conclusions: A number of contextual, psychosocial and technological factors influence use of handwashing stations at five aggregate levels, from habitual to societal. In interventions that require a handwashing station to facilitate frequent handwashing with soap, elements of the technology, such as capacity, durability and location(s) within the household are key to high feasibility and acceptability. More than one handwashing station per household may be required. IBM-WASH helped guide the research and research in-turn helped validate the framework.

Keywords: Formative research, Qualitative methods, Trials of improved practices, Handwashing, Hygiene behaviour, Behaviour change, Behavioural model, Handwashing technology, Enabling technology, Handwashing station, Soapy water, Feasibility, Acceptability

3.16. Cluster-randomised controlled trials of individual and combined water, sanitation, hygiene and nutritional interventions in rural Bangladesh and Kenya: the WASH Benefits study design and rationale (2013)

Benjamin F Arnold, [1]Clair Null, [2,3]Stephen P Luby[4,5] et.al

[1]School of Public Health, University of California, Berkeley, California, USA
[2]Rollins School of Public Health, Emory University, Atlanta, Georgia, USA
[3]Innovations for Poverty Action, New Haven, Connecticut, USA
[4]Centre for Communicable Diseases, International Centre for Diarrhoeal Disease Research, Dhaka, Bangladesh
[5]Stanford University, Stanford, California, USA

Abstract

Introduction: Enteric infections are common during the first years of life in low-income countries and contribute to growth faltering with long-term impairment of health and development. Water quality, sanitation, handwashing and nutritional interventions can independently reduce enteric infections and growth faltering. There is little evidence that directly compares the effects of these individual and combined interventions on diarrhoea and growth when delivered to infants and young children. The objective of the WASH Benefits study is to help fill this knowledge gap.

Methods and analysis: WASH Benefits includes two cluster-randomised trials to assess improvements in water quality, sanitation, handwashing and child nutrition—alone and in combination—to rural households with pregnant women in Kenya and Bangladesh. Geographically matched clusters (groups of household compounds in Bangladesh and villages in Kenya) will be randomised to one of six intervention arms or control. Intervention arms include water quality, sanitation, handwashing, nutrition, combined water+sanitation+handwashing (WSH) and WSH+nutrition. The studies will enrol newborn children (N=5760 in Bangladesh and N=8000 in Kenya) and measure outcomes at 12 and 24 months after intervention delivery. Primary outcomes include child length-for-age Z-scores and caregiver-reported diarrhoea. Secondary outcomes include stunting prevalence, markers of environmental enteropathy and child development scores (verbal, motor and personal/social). We will estimate unadjusted and adjusted intention-to-treat effects using semiparametric estimators and permutation tests.

Ethics and dissemination: Study protocols have been reviewed and approved by human subjects review boards at the University of California, Berkeley, Stanford University, the International Centre for Diarrheal Disease Research, Bangladesh, the Kenya Medical Research Institute, and Innovations for Poverty Action. Independent data safety monitoring boards in each country oversee the trials. This study is funded by a grant from the Bill & Melinda Gates Foundation to the University of California, Berkeley.

Keywords: Drinking Water, Sanitation, Handwashing.

3.17. Status of solid waste disposal and management practices in Bangladesh (2013)

Palash Chandra Roy and Shimul Roy
Department of Computer and Systems Sciences, Stockholm University, 164 40 Kista, Sweden.
Department of Water and Environmental Studies, Linkoping University,

Abstract

Dhaka, the capital of Bangladesh is one of the densely populated megacities over the Asian countries where solid waste generation is increasing at an unprecedented rate. This study was intended to explore the status of solid waste disposal and management Mohammadpur and Uttara where a survey design was used to collect the necessary information. The study showed the worsening situation in waste of dustbins, poor responsibility of city authority, improper waste collection & management systems, inadequate trained workers and identified the necessities to implement proper waste in order to reduce environmental pollution, sustainable urban development. Waste management system in Dhaka city there needs a conjunct government and private sectors whereas community based waste management practices could play a vital role.

Keywords: Dhaka city, management, solid waste, waste disposal.

3.18. Achievements of BRAC Water, Sanitation and Hygiene Programme Towards Millennium Development Goals and Beyond (2013)

Bangladesh Rural Advancement Committee (BRAC)

Abstract

It is evident that the risk of death can be lessened by ensuring access to safe water, sanitation and improved hygiene practices. With this propitious wisdom, BRAC WASH programme envisage improvement in health by ensuring access to safe water, sanitation and by providing hygiene education to all including men, women, adolescent girls and boys, and children. But it is given that poverty and physical facilities for life living and the environment act as impediments towards improving this situation. Thus, to overcome such constraint and to improve health status of the rural poor, BRAC WASH programme has been launced in 150 *upazilas* (sub-districts) in three phases effective middle of 2006. The BRAC Research and Evaluation Division conducted baseline, midline and end line surveys in 50 *upazilas* of the first phase.The study evaluated the impact of the programme on various issues related to water, sanitation and hygiene at household and educational institutions.

We followed a cross-sectional comparative design between baseline (2006), midline (2009) and end line (2011) statuses. Fifty upazila of the first phase of BRAC WASH I programme were selected for baseline, midline and end-line surveys. These *upazilas* were known as low performing areas in terms of water, sanitation and hygiene coverage compared to the national average. Thirty thousand households from 50 *upazilas* were selected in two steps: i) 30 villages were selected from each *upazila* by cluster sampling, and ii) 20 households were chosen systematically from each village. The end line survey covered 26,404 households.

The analysis of the study result reveals that over 97% of the households across the survey area used tubewell water for drinking, while it was least used for bathing in viii both rainy and dry seasons. The use of tubewell water for food preparation significantly increased over time, which is one of the prior concerns of World Health Organization for improvement of health. The proportion of arsenic-free own tubewell increased from baseline (57.8%) to midline (60%) and to end-line (64.6%) ($p<0.001$), but

decreased for shared tubewells across the surveys. Households using sanitary latrines increased significantly at midline (41.5%) and end line (57.4%) from baseline (31.7%) respectively.

Keywords: Bangladesh, Sanitation, Hygiene, Tubewell, Sanitary latrine.

3.19. Impact of micronutrient fortification of yoghurt on micronutrient status markers and growth – a randomized double blind controlled trial among school children in Bangladesh (2013)

Sunil Sazawal[1*], AKM Ahsan Habib[3], Usha Dhingra[1] et.al

* Corresponding author: Sunil Sazawal

[1] Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD USA

[2] Center for Micronutrient Research, Department of Biochemistry, Annamalai University, Tamil Nadu, India

[3] Department of Community Medicine, Shaheed Ziaur Rahman Medical College, Bogra, Bangladesh

Abstract

Background: Interventions providing foods fortified with multiple micronutrients can be a cost-effective and sustainable strategy to improve micronutrient status and physical growth of school children. We evaluated the effect of micronutrient-fortified yoghurt on the biochemical status of important micronutrients (iron, zinc, iodine, vitamin A) as well as growth indicators among school children in Bogra district of Bangladesh.

Methods: In a double-masked randomized controlled trial (RCT) conducted in 4 primary schools, 1010 children from classes 1–4 (age 6–9 years) were randomly allocated to receive either micronutrient fortified yoghurt (FY, n = 501) or non-fortified yoghurt (NFY, n = 509). For one year, children were fed with 60 g yoghurt everyday providing 30% RDA for iron, zinc, iodine and vitamin A. Anthropometric measurements and blood/urine samples were collected at base-, mid- and end-line. All children (FY, n = 278, NFY, n = 293) consenting for the end-line blood sample were included in the present analyses.

Results: Both groups were comparable at baseline for socio-economic status variables, micronutrient status markers and anthropometry measures. Compliance was similar in both the groups. At baseline 53.4% of the population was anemic; 2.1% was iron deficient (ferritin <15.0 μg/L and TfR > 8.3 mg/L). Children in the FY group showed improvement in Hb (mean difference: 1.5; 95% CI: 0.4-2.5; p = 0.006) as compared to NFY group. Retinol binding protein (mean diff: 0.05; 95% CI: 0.002-0.09; p = 0.04) and iodine levels (mean difference: 39.87; 95% CI: 20.39-59.35; p < 0.001) decreased between base and end-line but the decrease was significantly less in the FY group. Compared to NFY, the FY group had better height gain velocity (mean diff: 0.32; 95% CI: 0.05-0.60; p = 0.02) and height-for-age z-scores (mean diff: 0.18; 95% CI: 0.02-0.33; p = 0.03). There was no difference in weight gain velocity, weight-for-age z-scores or Body Mass Index z-scores.

Conclusion: In the absence of iron deficiency at baseline the impact on iron status would not be expected to be observed and hence cannot be evaluated. Improved Hb concentrations in the absence of a change in iron status suggest improved utilization of iron possibly due to vitamin A and zinc availability. Fortification improved height gain without affecting weight gain.

Keywords: Micronutrient fortification; Retinol binding protein; Iodine; Bangladesh; Zinc.

3.20. Environmental Sanitation at Rural Households in BRAC WASH-I Programme Areas (2013)

Nepal C Dey and Tahera Akter
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

A comprehensive intervention of safe water, sanitation and hygiene is required to ensure environmental sanitation, thus, to break the cycle of disease transmission. BRAC WASH-I programme has been working in 150 *upazilas* (sub-districts) since 2006 to improve health status of the rural poor. This study aimed to measure indicators of environmental sanitation by economic groups (e.g. ultra poor, poor and non-poor) from baseline to end line. Thirty thousand households from 50 *upazilas* were selected following a multi-stage sampling design. Data were collected from households through direct interview using pre-tested questionnaire. The matched households in both surveys were included in the analysis. Chi-square and T-tests compared the differences between indicator values. Results show that change in use of tubewell water from baseline to end line among the poor and non-poor increased by 14.7% and 9.6%, while the status remained nearly same among the ultra poor (by 0.6%). The change in building concrete platform was found highest among the ultra poor (by 124.9%) compared to the poor (by 53.6%), and non-poor (by 37.2%) respectively. Cleanliness of tubewell platform increased by 183.3% in the ultra poor which was better performing group than the poor, and non-poor. Sanitary latrine use increased in all the economic groups by 159.2% in the ultra-poor, 99.6% in the poor and 53.6% in the non-poor from baseline to end line respectively. The change in latrine cleanliness was found higher among the poor (by 66%) compared to the ultra poor (by 60.1%) and non-poor (by 54%). Disposal of children feces at fixed place was found nearly twice as high among the ultra-poor than that of other economic groups. Nevertheless, the practice of disposing waste water generated from tubewell to a fixed hole decreased by 2.4% and 9.1% among the ultra-poor and non-poor, while the situation remained almost same among the poor (by 0.2%) respectively. Reported sickness decreased from baseline to end line by 83.1%, 81.6% and 80.3% among the poor, non-poor and ultra-poor respectively. Disposal of wastes (solid or liquid) needs to be in such way which resists disease transmission.

Keywords: Sanitation, Rural households, Ultra poor.

3.21. Implications of Fecal Bacteria Input from Latrine-Polluted Ponds for Wells in Sandy Aquifers (2013)

Peter S. K. Knappett,[1,*] Larry D. McKay,[1] Alice Layton[2] et.al

[1]Department of Earth and Planetary Sciences, The University of Tennessee, Knoxville, TN 37996-1410
[2]Center for Environmental Biotechnology, The University of Tennessee, Knoxville, TN 37996-1605

Abstract

Ponds receiving latrine effluents may serve as sources of fecal contamination to shallow aquifers tapped by millions of tube-wells in Bangladesh. To test this hypothesis, transects of monitoring wells radiating away from four ponds were installed in a shallow sandy aquifer underlying a densely populated village and monitored for 14 months. Two of the ponds extended to medium sand. Another pond was sited within silty sand and the last in silt. The fecal indicator bacterium *E. coli* was rarely detected along the transects during the dry season and was only detected near the ponds extending to medium sand up to

7 m away during the monsoon. A log-linear decline in *E. coli* and Bacteroidales concentrations with distance along the transects in the early monsoon indicates that ponds excavated in medium sand were the likely source of contamination. Spatial removal rates ranged from 0.5-1.3 $\log_{10}$/m. After the ponds were artificially filled with groundwater to simulate the impact of a rain storm, *E. coli* levels increased near a pond recently excavated in medium sand, but no others. These observations show that adjacent sediment grain-size and how recently a pond was excavated influence how much fecal contamination ponds receiving latrine effluents contribute to neighboring groundwater.

Keywords: Bacteria, removal rates, setback distances, tube-wells, latrine effluent, Bangladesh.

3.22. Do Water and Sanitation Interventions Reduce Childhood Diarrhoea? New Evidence from Bangladesh (2013)

Sharifa Begum, Mansur Ahmed, Binayak Sen
Senior Research Fellow, Research Associate, and Research Director, respectively at Bangladesh Institute of Development Studies (BIDS), Dhaka, Bangladesh.

Abstract

The incidence of diarrhoea has declined over time in Bangladesh but still it persists as a major cause of infant mortality, morbidity and acute child malnutrition. Much of the public policy thinking in the past was guided by public investment in providing improved access to safe water. While this measure has paid off, the paper provides evidence that the relevance of water as a tool for fighting diarrhoea may have changed over time. Its changing role now needs to be seen in the broader context of combined access with other inputs such as improved sanitation. The paper uses the Bangladesh Demographic and Health Survey data and the propensity score matching technique to suggest that only combined access to improved water and sanitation can lead to reduced incidence of diarrhoea among children in contrast to their isolated use. Mere accesses to safe water, or for that matter, access to sanitation do not have any statistically significant impact on the incidence of childhood diarrhoea. The results suggest a strong case for rethinking public policy by way of joint investment in water and sanitation measures to reduce diarrhoea along with bringing about favourable change in health-seeking behaviour to support such combined access policy.

Keywords: Diarrhoea, safe water, improved sanitation.

3.23. Exploring the gap between hand washing knowledge and practices in Bangladesh: a cross-sectional comparative study (2013)

Sifat E Rabbi, Nepal C Dey
Volume - 13 ,Issue – 89, BMC public health
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

Background: Hand washing is considered as one of the most effective hygiene promotion activities for public health in developing countries. This study compared hand washing knowledge and practices in BRAC's water; sanitation and hygiene (WASH) programme areas over time.

Methods: This study is a cross-sectional comparative study between baseline (2006), midline (2009) and end-line (2011) surveys in 50 sub-districts from the first phase of the programme. Thirty thousand households from 50 sub-districts were selected in two steps: i) 30 villages were selected from each sub-

district by cluster sampling, and ii) 20 households were chosen systematically from each village. The matched households were considered (26,404 in each survey) for analysis. Data were collected from households through face-to-face interview using a pre-tested questionnaire. Respondents were the adult female members of the same households, who had knowledge of day-to-day household activities related to water, sanitation and hygiene.

Results: A gap between perception and practice of proper hand washing practices with soap was identified in the study areas. Hand washing practice with soap before eating was much lower than after defecation. In baseline data, 8% reported to wash their hands with soap which significantly increased to 22% in end line. Hand washing knowledge and practices before cooking food, before serving food and while handling babies is considerably limited than other critical times. A multivariate analysis shows that socio-economic factors including education of household head and respondent, water availability and access to media have strong positive association with hand washing with soap.

Conclusion: Gap between knowledge and practice still persists in hand washing practices. Long term and extensive initiatives can aware people about the effectiveness of hand washing.

Keywords: Hand washing; Soap; Knowledge; Practices

3.24. Sanitation coverage in Bangladesh since the millennium: consistency matters (2013)

Y. Zheng, S. A. I. Hakim, Q. Nahar, A. van Agthoven and S. V. Flanagan

Water and Environmental Sanitation Section, UNICEF Bangladesh, 1 Minto Road, Dhaka 1000, Bangladesh.

School of Earth and Environmental Sciences, Queens College, City University of New York, Flushing, NY 11367 and Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA

Abstract

Household surveys in Bangladesh between 1994 and 2009 assessed sanitation access using questions that differed significantly over time, resulting in apparently inconsistent findings. Applying the WHO and UNICEF Joint Monitoring Programme's 2008 definition for open defecation and improved sanitation facilities excluding shared facilities to the compiled data set, sensible sanitation coverage trends emerge. The percentage of households openly defecating declined at a rate of about 1.8% per year from 30% in 1994 to 6.8% in 2009, primarily due to changes in rural areas. Access to individual improved sanitation facilities nearly doubled from about 30% in 2006 to 57% in 2009, with both rural and urban areas showing impressive progress. Access to shared improved latrines also nearly doubled from about 13% in 2006 to 24% in 2009, with the urban slums recording the greatest gain from 17% in 2006 to 65% in 2009. Shared improved latrines are only slightly less clean than individual ones. Dependence on shared improved latrines increases with population density. In 2007, 20% of the poorest households still openly defecated, although more of them (38%) shared a latrine of any type. A poverty reduction program is recommended to address this equity issue, although applying consistent definitions is crucial to documenting progress.

Keywords: Bangladesh; demographic and health survey; multiple indicator cluster survey; population density; sanitation; wealth.

3.25. Sanitation in developing countries: a systematic review of user preferences and motivations (2013)

Zakiya Seymour and Joseph Hughes
School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA
College of Engineering, Drexel University, Philadelphia, PA 19104, USA

Abstract

Empirical research on sanitation in emerging regions has shown that user preferences and behaviors do influence usage of sanitation technologies. The purpose of this review is to examine the existing literature investigating user preferences and perceptions on sanitation, with particular focus on satisfaction and motivation for usage. The scope was limited to research that provided detailed statistical information about the sample population and sanitation technologies examined. Selected literature is summarized into four areas: descriptive studies about sanitation user satisfaction; comparative work analyzing preferences for sanitation technologies; perspectives on sanitation usage and ownership; and importance of factors driving household sanitation installation. Our results indicate that the implementation of improved sanitation is not indicative of overall higher user satisfaction levels. In addition, motivations for usage of sanitation systems vary by technology and geographical setting.

Keywords: Adoption; attitude; behavior; preferences; sanitation, Bangladesh.

3.26. Assessment of Practices of Sanitation and Hygiene Comparison of a Declared Sanitation Area to a Non Area of Sirajganj District, Bangladesh (2013)

Mashura Shammi* and Mahedi Morshed
Department of Environmental Sciences, Jahangirnagar University,

Abstract

Poor hygiene practices and inadequate sanitary conditions play major roles in the increased burden of communicable diseases availability of information and practices of hygiene among the rural people non-declared sanitized area in Sirajganj District, Bangladesh separately for two Upazilas of Sirajganj District, namely, Kamarkhanda upazila (study area A) declared as 100% sanitized area where DPHE/UNICEF implemented SHEWA area B), where no NGOs implemented their activities regarding health and sanitation. In line with the and multistage sampling approaches, household who is in charge of her household's day hygiene, head of educational institutes and key informants of the local NGO project implementing health and sanitation were identified for the survey. Hygienic practice is important when people get adequate hygienic education and information which was well reflected in study area A. Electronic media can play an important role in dissemination of hygienic education and information which we found in study area B where 90% respondent described the role of electronic media re However, 100% sanitation was not achieved even in a declared area because people do not practice or follow the rules of hygiene regularly.

Keywords: Practices of Sanitation and Hygiene, household survey, key informant, 100% sanitation.

3.27. Water quality of shallow tube wells as affected by sanitary latrines and ground water flow (2013)

Syed Hafizur Rahman*1, A.N.M. Fakhruddin1, Mohammed Jamaluddin1 et.al
Department of Environmental Sciences, Jahangirnagar University, Dhaka 1342, Bangladesh

Abstract

The present study investigated the probable influence of latrines and groundwater flow on the water quality of shallow tube wells in Shinduria village (23̊52' N and 90̊ 14' E) of Dhaka district, Bangladesh. A questionnaire survey was made to collect basic information on tube wells and latrines. Four boreholes were drilled to investigate lithostratigraphy. Twenty one water samples were collected and their physico-chemical parameters (Dissolved Oxygen, pH, phosphate, sulphate, nitrate, nitrite and iron) were analyzed using standard method. Total viable bacterial count (TVBC),total coliform count (TCC),total faecal coliform count (TFCC),total salmonella shigella(TSS) and total vibrio count (TVC) were also made using membrane filtration method. Average depth of the tube wells was 120 ft and most of them were less then ten years old. About 85% latrines were ring slab type and about 50% of these were built during the last five years. rom borehole data, a shallow aquifer was identified at a depth of hundred feet from where local people extract drinking water. Although most of the physico -chemical parameters of the tested samples were within the Department of Environment (DoE) . But almost all of the tested samples failed to ensure the quality of acceptable level for drinking water recommended by World Health Organization (WHO) due to the presence of higher load of TVBC (5.07×10^3 cfu/100ml), TCC (8.44×103cfu/100ml), TFCC(5.16×10^2 cfu/100ml) and TSS (1.10×103cfu/100ml). Local geological conditions and proximity between tube well and latrine promoted bacterial transport towards tube well while groundwater flow direction from the adjacent Bangshi River influenced the phenomenon.

Keywords: Lithostatigraphy, Aquifer, Microbial load, Bangladesh.

3.28. Awareness Raising and Capacity Building on Appropriate Management of EcoSan-toilet in Rural Areas in Bangladesh (April, 2010 to March, 2013)

Contact Person
Name: MoslehUddinParvez
Designation: Program Manager
Telephone: 02.9899574
Mobile: 01714.389363
Email: mmuparvez@yahoo.com

Chief Researcher/Project Director
Name: Dr. Kunio Takahashi
Designation: Country Representative
Telephone: 02.9899574
Mobile: 01727.431341
Email: nqg48559@nifty.com
Research Title/Project Title

Objective of the Project/Research

To Improve Capacity and Knowledge of Target Area People for Appropriate Use and Management of EcoSan-toilet and Other Types of Toilets.

Major Findings Appropriate Management of EcoSan-toilet and Recycle of Human Excreta Derived Resources has been Adopted Properly.

3.29. Hard-to-Reach Areas: Providing Water Supply and Sanitation Services to All (2012)

Rokeya Ahmed and Shareful Hassan
World Bank Specialist

Abstract

Water Sanitation coverage in Bangladesh has significantly improved in the last couple of years but research outputs or reports and experience of water and sanitation (WatSan) service providers suggest that there exist pockets of areas in Bangladesh where WatSan services are not adequate by any standard. Based on practical experience, many of those areas have been identified and termed Hard to reach Areas (HtRAs), which creates the notion that WatSan service providers fail to reach or find it difficult to provide services to these specific areas, however in Bangladesh, HtRAs can be conceptualized and understood from wider perspectives. For practical purposes, HtRAs are defined in Bangladesh in terms of both their remote geographical location as well as population residing out of the range of development activities. This leads to consideration of issues covered in a socioeconomic factorial analysis, that is, cultural diversity, religious norms, traditional practices, and social norms and values, which play a crucial role in water and sanitation coverage as well as behavioral change in Bangladesh. The community composition, ethnicity, geo-physical traits and environment are determinant factors in achieving success in water and sanitation coverage and behavioral change.

Keywords: Sanitation coverage, water and sanitation, hard to reach areas.

3.30. Promotion and Impact of a Water and Sanitation Program in Rural Bangladesh (2012)

Profulla C. Sarker[ab] & Pranab Kumar Panday[c]

[a]Department of Social Work and Social Administration
[b]Humanities and Social Science Division, Beijing Normal University-HongKong Baptist University, United International College (UIC) , China
[c]Department of Public Administration , University of Rajshahi , Bangladesh

Abstract

This paper is an attempt to discuss the promotion and impact of a program undertaken for the improvement of water and sanitation problems in rural Bangladesh. This program is carried out through the Village Development Committees (VDCs) in partnership with local and international non-government organizations. The main focus of this article is to examinee the extent to which VDCs are able to solve the WatSan problems to get rid of waterborne diseases and arsenicosis in rural Bangladesh.

Keywords: Sanitation, WatSan problems, Village Development Committees (VDC),Rural Bangladesh.

3.31. Solid waste recycling in Rajshahi city of Bangladesh (2012)

Q. Hamidul Bari, K. Mahbub Hassan, M. Ehsanul Haque
Department of Civil Engineering, Khulna University of Engineering and Technology, Khulna 9203, Bangladesh

Abstract

Efficient recycling of solid wastes is now a global concern for a sustainable and environmentally sound management. In this study, traditional recycling pattern of solid waste was investigated in Rajshahi municipality which is the fourth largest city of Bangladesh. A questionnaire survey had been carried out in various recycle shops during April 2010 to January 2011. There were 140 recycle shops and most of them were located in the vicinity of Stadium market in Rajshahi. About 1906 people were found to be involved in recycling activities of the city. The major fraction of recycled wastes were sent to capital city Dhaka for further manufacture of different new products. Only a small amount of wastes, specially plastics, were processed in local recycle factories to produce small washing pots and bottle caps. Everyday, an estimated 28.13 tons of recycled solid wastes were handled in Rajshahi city area. This recycled portion accounted for 8.25% of the daily total generated wastes (341 ton d−1), 54.6% of total recyclable wastes (51.49 ton d−1) and 68.29% of readily recyclable wastes (41.19 ton d−1). Major recycled materials were found to be iron, glass, plastic, and papers. Only five factories were involved in preliminary processing of recyclable wastes. Collecting and processing secondary materials, manufacturing recycled-content products, and then buying recycled products created a circle or loop that ensured the overall success of recycling and generated a host of financial, environmental, and social returns.

Keywords: Recyclable solid waste; Recycling; Waste collectors; Recycling dealers; Recycling factories; Private sector.

3.32. Knowledge and Practice of Hygiene in BRAC's WASH Programme Areas (2012)

Tahera Akter and ARM Mehrab Ali
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

Improved hygiene behaviour is one of the most effective means of reducing disease occurrence. However, question may arise, which factors did contribute to such improvement? Past studies seldom addressed these issues systematically nor explained the influencing factors that facilitate or impede hygiene knowledge and practice from the perspectives of successful and unsuccessful households. This study, combining qualitative and quantitative methods, measured the changes in knowledge and practice of hygiene and explored factors that facilitate and/or impede hygiene behaviours in water, sanitation and hygiene (WASH) intervention areas of BRAC. Indepth interviews were conducted with 144 purposively selected women. Some of their practices were physically verified to get the proof of their claims. Besides, 30,000 systematically chosen households studied in the baseline were revisited in the midline survey for collecting quantitative data. Results on common variables investigated through both quantitative and qualitative approaches were triangulated. Findings show that respondent's hygiene behaviours were mainly facilitated by improved knowledge and awareness about health and environment-related issues. BRAC's financial assistance had positive impact on latrine ownership resulting in increased privacy and dignity of the households. Latrine or tubewell ownership also increased their social prestige and sense of responsibility. In this regard, maintaining hygiene behaviours for healthy life was perceived as everybody's responsibility. On the other hand, lack of interest in attending cluster meeting, traditional knowledge, poverty, difficulties in carrying water, location of

latrine, lack of will to practice, and complex mind-set were the impeding factors to hygiene knowledge and practice. Mainly the psychosocial aspects made the difference between successful and unsuccessful households, as successful households followed hygiene behaviours irrespective of poverty and other barriers. To increase awareness to a further extent and to transform knowledge into practice and practice into habit, more cluster meetings ensuring participation of all including children and home visits by the programme organizers are imperative.

Keywords: Hygiene behavior, Latrine, WASH Programme, BRAC.

3.33. Economic Impacts of Inadequate Sanitation in Bangladesh (2012)

DeFrancis, Marc P.
World Bank

Abstract

This study estimates the nonmonetary, financial, and economic costs of poor sanitation in the areas of health, drinking water, and domestic water, as well as user preference and welfare. Financial costs refer to the direct financial expense paid in monetary terms by someone, such as changes in household and government spending and real income losses for households. Nonmonetary costs consist of both longer-term financial impacts (such as less educated children, fewer children, and loss of working people due to premature death or relevant morbidity), and nonfinancial implications, such as the value of loss of life, time-use of adults and children, and intangible impacts. Bangladesh has made inadequate progress toward the sanitation-related millennium development goal (MDG) target. The country's financial commitment and political priority for sanitation also has shown inadequate progress (Water-Aid, 2008). Therefore, to mitigate the adverse effects of poor sanitation and hygiene practices, intervention is necessary. The aim of this study is to provide concrete evidence of the impact poor sanitation has on the population and the environment and, consequently, on the economy. This study provides estimates of the current and long-term effects of poor sanitation, which cover not only the negative impacts of poor sanitation but also the potential gains that different sanitation interventions could achieve. Policy makers and water and sanitation advocacy organizations are the target audience of this study.

Keywords: poor sanitation, millennium development goal, hygiene practices.

3.34. Grassroots initiative to develop effective sanitation system in rural schools (2012)

Shamim Arfeen
Executive Director, An Organisation for Socio-Economic Development

Abstract

The Southwest coastal region of Bangladesh is a vulnerable region due to its geographic locationand low elevation. Dacope Upazila (sub-district) is under Khulna district of the region where the status ofhealth and hygiene is very poor and the awareness level at the dimming condition. The sanitation statusand behavioral practice is below the mark thereby resulting in suffering of the community due to waterborne diseases. The whole region has also been neglected and deprived of normal development fordecades, resulting in poverty much above the national average. The people mainly depend on naturalresources, but their access to natural resources is also very meager. The situation of safe water andsanitation facilities is risky as well.

In this regard, AOSED has taken a pilot initiative to implement the Sustainable School Sanitation Project with financial cooperation of Simavi School Sanitation Fund from December 2008 to November2009.

The main objective of the pilot project was to develop and establish effective school sanitationsystem in rural area. Through this initiative, a total of nine secondary schools were brought undersanitation coverage. This project promoted ideal hygiene and sanitation practice among the studentsand teachers. This project developed and improved sanitation infrastructure and facility in the schoolpremises; developed a special room for menstrual period of girls in one of the girl's school; developedeasy understating educational and awareness materials about proper sanitation, water management andhealth hygiene practices; developed School Sanitation Management Committee (SSMC) and separated own fund for maintenance of School sanitation. It also sensitized government offi cials at local level andlocal elected bodies about the role of WATSAN in preserving general health in the region.

This is the fi rst time that schools in Dacope are motivated by means of a short term project to takecare of the hygiene of the students, especially the adolescent girls. Schools are now providing extraeducation regarding menstruation problem to the girls and hygiene for all students. Nine schools nowhave a Sanitation Management Committee that is responsible to maintain school sanitation system byown fund as well as local resources mobilization; the students are gradually changing their behaviourabout sanitation and personal hygiene practices and they are sharing obtained knowledge with theirfamily as well as community.

Students are future citizens and if their behaviour is moulded in the right direction, it will last fora lifetime. Schools can be a central point to disseminate knowledge, information and idea to widercommunity and it was found very effective. The coordination among School management committee, guardians and local elected bodies can effectively bring about any necessary reform. The participationof women among the parents/guardians of the students in the sanitation campaign can also make suchprogram more effective. Through this program, the benefi ciaries have learnt about the importance ofhealth and hygiene especially in terms of sanitation. They have been organized and motivated forsanitary hygiene practice and its management. Teachers have learnt about what should be taught tothe students regarding sanitation and menstruation while parents of the students have become awareof the necessity of sanitation practice for maintaining good health. Further, the experience of AOSEDin Dacope taught that development of WATSAN facilities in the regions such as Dacope is one of thecritical factors that can change the lives and livelihoods of the people by providing them with a chancefor better health.

Keywords: Coastal region, rural, school, hygiene.

3.35. Interim evaluation of a large scale sanitation, hygiene and water improvement programme on childhood diarrhea and respiratory disease in rural Bangladesh (2011)

Tarique Md. Nurul Huda[a], Leanne Unicomb[a], Richard B. Johnston[b] et.al

[a]International Centre for Diarrheal Diseases Research, Bangladesh
[b]Swiss Federal Institute of Aquatic Science and Technology, Switzerland

Abstract

Started in 2007, the Sanitation Hygiene Education and Water Supply in Bangladesh (SHEWA-B) project aims to improve the hygiene, sanitation and water supply for 20 million people in Bangladesh, and thus reduce disease among this population. This paper assesses the effectiveness of SHEWA-B on changing behaviors and reducing diarrhea and respiratory illness among children < 5 years of age. We assessed behaviors at baseline in 2007 and after 6 months and 18 months by conducting structured observation

of handwashing behavior in 500 intervention and 500 control households. In addition we conducted spot checks of water and sanitation facilities in 850 intervention and 850 control households. We also collected monthly data on diarrhea and respiratory illness from 500 intervention and 500 control households from October 2007 to September 2009. Participants washed their hands with soap < 3% of the time around food related events in both intervention and control households at baseline and after 18 months. Washing both hands with soap or ash after cleaning a child's anus increased from 22% to 36%, and no access to a latrine decreased from 10% to 6.8% from baseline to 18 months. The prevalence of diarrhea and respiratory illness, among children <5 years of age were similar in intervention and control communities throughout the study. This large scale sanitation, hygiene and water improvement programme resulted in improvements in a few of its targeted behaviors, but these modest behavior changes have not yet resulted in a measurable reduction in childhood diarrhea and respiratory illness.

Keywords: Water; Sanitation; Hygiene; Large-scale; Bangladesh; Diarrhea; Respiratory illness; Children

3.36. Changes in the Use of Safe Water and Water Safety Measures in Water, Sanitation and Hygiene Intervention Areas of Bangladesh: A Midline Assessment (2011)

Nepal C Dey and ARM Mehrab Ali
BRAC

Abstract

The BRAC Water, Sanitation and Hygiene (WASH) programme reached 150 *upazila*s (sub-districts) in collaboration with the Government of Bangladesh since 2006. This study assessed the changes in the use of tubewell water and water safety measures in the households in the 11 *upazila*s of Bangladesh after BRAC WASH interventions. Data were collected from 6,600 households where 3,812 tubewells were traced in baseline (2006-7) and 3,591 tubewells in midline (2009). Most of the households (98-99%) used tubewell water for drinking, 70-73% for cooking, 62-66% for washing utensils, 70-73% for cleaning after defecation, and 24-36% for bathing in midline both in the dry and rainy seasons. The numbers were significantly larger in midline than in baseline ($p<0.01$) except for drinking in the rainy season. Overall arsenic-free tubewells increased from 58% in baseline to 60% in midline and most households (83%) drank arsenic-free tubewell water in midline. The study revealed that water safety measures including awareness of cleaning/purifying water and hygienic management of water increased significantly ($p<0.01$). The concrete-built platform increased from 63% in baseline to 69% in midline. Tubewell platforms were cleaned (32%) in baseline, which increased to 46% in midline. However, there still remained impediments to 100% safe water use by the households include arsenic contamination of tubewell water, financial inabilities of the ultra poor and poor households for installing tubewells for arsenic-free water, unmarked tubewell (whether contaminated by arsenic or not). The study concluded that WASH intervention has succeeded in increasing access to safe water use, hygienic management of water, and cleanliness of water collecting point in the study areas. It is encouraging to note that ultra poor households had interest to get new tubewells and preferred to pay the costs in monthly instalments, which indicates that these households were aware of the benefits of safe water. Thus, BRAC WASH programme needs to pay further attention to these impediments at the household level in order to further improve the current situation.

Key words: BRAC, MDG, Tubewell, Ultra poor, WASH.

3.37. Comparative Status of Safe Water Use and Hygiene Practices in Areas with and without NGO-led Water, Sanitation and Hygiene (WASH) Programme (2011)

Shyamal C. Ghosh, ARM Mehrab Ali and Tahmid Arif
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

Introduction: More than 90% people in Bangladesh have access to improved water supply system, but arsenic is posing a threat to this achievement. Additionally, hygiene is considered as one of the challenging areas to deal in the development sector. A number of organizations (both government and non-goverment) are working to improve the water supply, sanitation and hygiene practices through various water, sanitation and hygiene programmes.

Objective: The overall objective of this study is to reveal the role of non-government organizations (NGOs) in improving safe water use and hygiene practices by the rural people of Bangladesh.

Methods: Ten upazilas with both NGO-led sanitation programme intervention and without any such activity (Comparison group) were selected for the study. Among the study upazilas, four were comparison upazilas, three were with BRAC facilitated WASH programme intervention areas and the rest three were with other NGO-led intervention areas. A multistage 30-cluster sampling method was adopted and 420 households were selected randomly from every upazila for the survey. In selecting 30 villages from every upazila, interval-sampling method was used.

Key Findings

1. Tubewell water was used predominantly for drinking in the study areas. Significantly higher proportion of households in the BRAC WASH areas used tubewell water for drinking than the comparison and other NGO intervention areas ($p<0.001$).

2. The expenditure for tubewell drilling was mostly covered by self-arrangement (95.1%) in the study areas. However, in BRAC WASH intervention areas 1.2% and in other NGO-covered areas 1.1% tubewells were financed by NGOs. Households not having their own tubewell mentioned financial problem (90.8%) as the major reason for not being able to install tubewell.

3. Overall knowledge about the demerits of using arsenic-contaminated water in the comparison areas was found less than the NGO-led WASH intervention areas. Regardless of the NGO-facilitated WASH programme prevalence, social institutions (54%), NGOs (23.5%) and mass media (26.6%) were the most common sources of information for knowing the demerits of using arsenic contaminated water.

4. Significantly higher proportion of people in NGO intervention areas (either BRAC or other NGOs) mentioned to wash hands during critical times than the comparison areas. The overall hygiene practice among the households in the other NGO intervention areas with regard to all relevant issues was found higher than the BRAC WASH and comparison areas, since less proportion of respondents mentioned not to know about the hygiene issues ($p<0.001$).

5. Respondents from all intervention areas strongly opined for the necessity of NGO-led WASH programme for the improvement of safe water use (95.1%) and hygiene (95.8%) practices.

6. While asked about the source of information regarding safe water use and hygiene practices social institution and mass media were found predominant among all intervention areas. However, in areas

with WASH programme intervention the respondents also mentioned NGO as a major information source.

Conclusions: The overall status of use of tubewell water and hygiene practices was found better in the NGO-led WASH intervention areas than the comparison areas. People mentioned about the effects of NGO interventions on the improvement of use of safe water and hygiene practices through the support for tubewell installation, arsenic testing, motivation and raising awareness through the village level committees organized by the NGOs. Majority of the respondents mentioned about the necessity of NGO intervention for ensuring 100% safe water use and hygiene practices. However, it needs more support (both tubewell supply and awareness activities) from the NGO targeting the illiterate, poor and ultra poor households.

Keywords: Safe Water Use, Hygiene Practices, NGO, WASH, Tubewell.

3.38. Knowledge, Attitudes and Practice about Sanitation and Hygiene: A Midline Evaluation in WASH areas of BRAC (2011)

Sifat-E-Rabbi and ARM Mehrab Ali
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

This study aimed to evaluate the impact of BRAC WASH (Water, Sanitation and Hygiene) programme on hygiene knowledge and practice of the people in intervention areas compared to baseline status. A population-based cross-sectional study with a pre-test and post-test design was conducted in 50 sub-districts of rural Bangladesh where BRAC WASH programme exists. A two-stage systematic sampling design was followed in drawing the sample. Data collection took place during November 2006–June 2007 at baseline and April-June 2009 at midline using a pre-tested structured questionnaire and physical verification. Findings reveal that knowledge and practice of hand washing at critical times (such as after contact with feaces and waste, before eating, cooking and serving food) significantly increased at midline compared to baseline. Knowledge about water contamination and water-borne diseases, water purification procedure, sanitation hygiene, rules of maintaining good health, and waste disposal at fixed place increased at midline. Availability of slippers, soap and water nearby latrine increased in intervention areas. However, there still exists room for improvement because practice of hygiene behavior was not universal although they had knowledge of its importance. To achieve the targets of Millennium Development Goal, the WASH programme needs to pay more attention in providing knowledge related to personal hygiene.

Keywords: BRAC WASH programme, Evaluation, Baseline status.

3.39. Different treatment strategies for highly polluted landfill leachate in developing countries (2011)

Kashif Mahmud[a], Md. Delwar Hossain[b], Shahriar Shamsa,

[a]Department of Civil and Environmental Engineering, Islamic University of Technology (IUT), Gazipur 1704, Bangladesh

[b]Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka 1000, Bangladesh

Abstract

The aim of this research was to determine appropriate treatment technique for effective treatment of heavily polluted landfill leachate. We accomplished several treatment experiments: (i) aerobic biological treatment, (ii) chemical coagulation, (iii) advanced oxidation process (AOP) and (iv) several combined treatment strategies. Efficiency of these treatment procedures were monitored by analysing COD and colour removal. Leachate used for this study was taken from Matuail landfill site at Dhaka city. With extended aeration process which is currently used in Matuail landfill site for leachate treatment, maximum COD and colour removal of 36% and 20%, respectively could be achieved with optimum retention period of 7 days. With optimum aluminium sulphate dose of 15,000 mg/L and pH value of 7.0, maximum COD and colour removals of 34% and 66%, respectively were observed by using chemical coagulation. With optimum pH of 5.0 and optimum dosages of reagents having H2O2/Fe2+ molar ratio of 1.3 the highest removal of COD and colour were found 68% and 87%, respectively with sludge production of 55%. Fenton treatment which is an advanced oxidation process was the most successful between these three separate treatment procedures. Among the combined treatment options performed, extended aeration followed by Fenton method was the most suitable one.

Keywords: Biological treatment; Chemical coagulation; Extended aeration; Fenton process; Leachate; Organic matter.

3.40. Eco-san Toilet for Sustainable Sanitation Practice in Bangladesh (2011)

Pramanik Biplob, Ram Chandra Sarker, Dipok Chandra Sarker
Department of Civil Engineering, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh

Abstract

Bangladesh has always to face pressing sanitation problems due to its vulnerable geographical location and lack of appropriate and a daptive technological options. EcoSan toilets are found as one of the most appropriate and proven technological options, as these are cost effective, established and environmentally as well as socially sounds and reliable option can effectively contribute in solving the existing and emerging sanitation problems of Bangladesh. Eco-San toilet is a urine diversion toilet and based on the idea that urine, faeces and water are resources in an ecological loop. It has two defecation holes at the top of each vault that receive faeces. Sufficient ashes are used to cover new faeces for protecting odor, flies, insects and pollutions. Moreover, it does not need to use water for cleaning and flashing. However, Eco-san can effectively contribute in safely transforming human urines and faces into high-potent organic fertilizers for eco-friendly agriculture and producing qualitative nutrient food-crops. Human urines are contained with high level of Nitrogen (75%- 87%), Phosphorus (45%-50%) and Potash (50%-54%). On the other hands, human faces contain 10% Nitrogen, 40% Phosphorus and 12% Potash. The general perceptions of people on ECOSAN were found encouraging. Almost 80% of the users apply these resources in their field. Similarly, due to lack of agricultural land, 12% of them shared with the neighbors once the urine collection tanks are full while the remaining 8% used to throw it down the drain. On the other hand, 72% of the Eco-san users had experience of increment in production, 19% noted little difference, and 9% found no change in production at all. Therefore, Eco-san toilet protect public health, prevent pollution and at the same time return valuable nutrients. This recycling of nutrients helps to ensure food security. The basic objective of this paper is to share the status of Eco-san toilet towards demonstrating sustainable sanitation for environment, health and development in Bangladesh.

Keywords: Vulnerable, Ecological Sanitation, Food security, Groundwater Contamination, Sustainable.

3.41. Child Care Hygiene Practices of Women Migrating From Rural to Urban Areas of Bangladesh (2011)

Housne Ara Begum, PhD[1], Shanta Shyamolee Moneesha, MPS[2], Amir Mohammad Sayem, MPS[3]

[1]Associate Professor, Institute of Health Economics, University of Dhaka, Dhaka, Bangladesh
[2]Department of Population Sciences, University of Dhaka, Bangladesh
[3]Research Associate, Bangladesh Institute of Social Research (BISR), Dhaka, Bangladesh

Abstract

Children's hygiene is very important for better health but there is a paucity of studies in this area. This questionnaire study examined the child care hygiene practices of mothers of young children. A total of 354 women from slum areas of Dhaka city, Bangladesh, who migrated from rural to urban areas were selected for this study. The mean score on hygiene practice was 6.21 of 10 items (SD = 2.113). Low (score = 3) and high hygiene practice (score = 7-10) were practiced by 12.4% and 45.8% of participants, respectively. Multivariate regression analysis indicated that independent variables explained 39.9% of variance in hygiene practices. Eight variables have significant effect: participant's education (0.108; P < .05), time spent since marriage to first birth (0.030; P < .05), number of children (−0.105; P < .05), number of antenatal visits (0.319; P < .001), microcredit status (0.214; P < .001), breastfeeding (0.224; P < .001), husband's monthly income (0.146; P < .001), and household economic status (−0.0114; P < .05). The overall hygiene practice indicates the necessity of awareness building initiatives.

Keywords: Hygiene Practices, migration, slum areas.

3.42. South Asian People's Perspective on Sanitation - Synthesis Review (2011)

Water Aid

Abstract

South Asia is a region of great contrast. On one hand there are promising GDP growth rates, but these are countered by poor human development, poverty and disease, with hundreds of millions of men, women and children with no access to sanitation. There is political commitment to change, with new policies and investment for public services, but there are also significant barriers to enabling people to live safe and dignified daily lives. The biggest, and often overlooked, problems are exclusion and inequality. Millions of poor and marginalised people continue to be denied their basic rights, and as development initiatives concentrate on numbers, the excluded are marginalised still further.

It is now time to move from talk to action; to ensure that economic growth translates into human development and wellbeing for the people of South Asia.

This review is the result of a series of open-ended interviews and focus group discussions with a cross section of poor and marginalised social groups across Bangladesh, India, Nepal, Pakistan and Sri Lanka. We asked people about their sanitation and hygiene practices, the status of sanitation infrastructure and facilities in their communities, and their reflections on why interventions and projects in their settlements had succeeded or failed.

The resounding response from the people we are trying to reach is that they want a 'clean' and 'healthy' environment for themselves and their families, dignity, privacy and freedom from the shame and embarrassment of having to defecate in the open. All countries in South Asia are signatories to the right

to water and sanitation; however, almost half the region's population is without improved sanitation and more than seven hundred million people defecate in the open every day. This review, and the collaborative energy and determination with which it is infused, signal the commitment of our three organisations – Freshwater Action Network, WaterAid and the Water Supply and Sanitation Collaborative Council – in making this right a reality.

About the publisher

The Water Supply and Sanitation Collaborative Council (WSSCC) is an international organization that works to improve access to sustainable sanitation, hygiene and water for all people. It does so by enhancing collaboration among sector agencies and professionals who are working to provide sanitation to the 2.6 billion people without a clean, safe toilet, and the 884 million people without affordable, clean drinking water close at hand. WSSCC is part of the UN system and contributes to development through knowledge management, advocacy, communications, and the implementation of a sanitation financing facility. WSSCC supports coalitions in more than 30 countries, and has a broad membership base and a small Secretariat in Geneva, Switzerland. www.wsscc.org

WaterAid is an international charity working in 26 countries in Africa, Asia and the Pacific region. WaterAid's mission is to overcome poverty by enabling the world's poorest people to gain access to safe water, sanitation and hygiene education. www.wateraid.org

Freshwater Action Network (FAN) is a major network of civil society organizations (CSOs) implementing and influencing water and sanitation policy. The regional coalition in South Asia (FANSA) aims to strengthen the engagement of civil socitety in policy-making and development initiatives to achieve the international targets on water and sanitation, improve regional co-operation between civil society organizations of differing perspectives, priorities and skills and increase the number of NGOs to advocate and communicate for the issues. http://www.freshwateraction.net/content/south-asia

3.43. A Critical Review of Technologies for Pit Latrine Emptying in Developing Countries (2011)

Yoke Pean Thye[a], Michael R. Templetona & Mansoor Ali[b]
[a]Department of Civil and Environmental Engineering , Imperial College London, London ,United Kingdom
[b]Practical Action , Schumacher Centre for Technology & Development, Bourton-on-Dunsmore , Rugby, United Kingdom

Abstract

Pit latrines are the most common forms of sanitation in urban slums and unplanned settlements in developing countries. Often, little consideration is given to how to deal with the pits once they fill up. The authors summarize pit emptying technologies that have been designed to date to overcome the problem of fecal sludge management in such settings and presents a framework to assist decision makers in identifying potential pit emptying methods based on local technical conditions.

Keywords: Sanitation, onsite sanitation, pit latrin sludge management.

3.44. Long-term Sustainability of Rural Sanitation in Bangladesh (2011)

Speaker: Craig Kullmann, Water & Sanitation Specialist, TWIWP
Chair: Ming Zhang, Sector Manager, SASDU, Washington, D.C.

Abstract

In 2010, the Water and Sanitation Program conducted a study to investigate the sustainability of sanitation behaviors, facilities and programs in rural Bangladesh - specifically related to the management human excreta. The rational for this study was to get insights into whether sanitation (i.e. latrine use) outcomes from community led total sanitation approaches are sustainable over the long-term. The study analyzed 53 local governments that were declared 100 percent sanitized/Open Defecation Free almost five years ago, and used a mixed method study design of quantitative and qualitative instruments including a 3,000 household survey sample. The study shows that 90 percent of households in these local governments have sustained use of a latrine that adequately confines feces, but that hygienic maintenance is relatively poor.

The factors that the study found to be associated with sustained use of latrines include: a shift in social norms away from open defecation to using a latrine on-going sanitation programming that reinforces latrine use; and easy access to private sector sanitation providers. In addition, a comparative analysis of four programmatic approaches used to reach 100 percent sanitation coverage and cessation of open defecation revealed little variation in sustained outcomes in these local governments. This finding suggests that the political will at all tiers of government in Bangladesh, during the 2003-2006 total sanitation campaign to stop open defecation and promote collective outcomes, may be more important than programmatic nuances.

Keywords: Rural Bangladesh, Sanitation, Open defecation, Sustainability.

3.45. Impact of population and latrines on fecal contamination of ponds in rural Bangladesh (2011)

Peter S.K. Knappett[a], Veronica Escamilla[b, c], Michael Emchb, [c] et.al

[a]Department of Earth and Planetary Sciences, The University of Tennessee, Knoxville, TN 37996-1410, United States

[b]Department of Geography, University of North Carolina-Chapel Hill, NC 27599-3220, United States

[c]Carolina Population Center, University of North Carolina-Chapel Hill, NC 27516-2524, United States

Abstract

A majority of households in Bangladesh rely on pond water for hygiene. Exposure to pond water fecal contamination could therefore still contribute to diarrheal disease despite the installation of numerous tubewells for drinking. The objectives of this study are to determine the predominant sources (human or livestock) of fecal pollution in ponds and examine the association between local population, latrine density, latrine quality and concentrations of fecal bacteria and pathogens in pond water. Forty-three ponds were analyzed for E. coli using culture-based methods and E. coli, Bacteroidales and adenovirus using quantitative PCR. Population and sanitation spatial data were collected and measured against pond fecal contamination. Humans were the dominant source of fecal contamination in 79% of the ponds according to Bacteroidales measurements. Ponds directly receiving latrine effluent had the highest concentrations of fecal indicator bacteria (up to 106 Most Probable Number (MPN) of culturable E. coli per 100 mL). Concentrations of fecal indicator bacteria correlated with population surveyed within a distance of 30–70 m ($p < 0.05$) and total latrines surveyed within 50–70 m ($p < 0.05$). Unsanitary latrines (visible effluent or open pits) within the pond drainage basin were also significantly correlated to fecal indicator concentrations ($p < 0.05$). Water in the vast majority of the surveyed ponds contained unsafe levels of fecal contamination attributable primarily to unsanitary latrines, and to lesser extent, to

sanitary latrines and cattle. Since the majority of fecal pollution is derived from human waste, continued use of pond water could help explain the persistence of diarrheal disease in rural South Asia.

Keywords: Diarrheal disease; Fecal source tracking; Bacteroidales; Adenovirus; Latrine effluent; Asia.

3.46. Health, hygiene and appropriate sanitation: experiences and perceptions of the urban poor (2011)

Deepa Joshi[1], Ben Fawcett[2], Fouzia Mannan[3]

[1]Irrigation and Water Engineering Group, Centre for Water and Climate, Building 100, Droevendaalsesteeg 3a, 6708 PB, Wageningen, The Netherlands.
[2]Advanced Water Management Centre, University of Queensland, Brisbane, Queensland 4072, Australia.
[3]4th Floor, Arts Building, Dhaka University, Dhaka 1000, Bangladesh.

Abstract

"Don't teach us what is sanitation and hygiene." This quote from Maqbul, a middle-aged male resident in Modher Bosti, a slum in Dhaka city, summed up the frustration of many people living in urban poverty to ongoing sanitation and hygiene programmes. In the light of their experiences, such programmes provide "inappropriate sanitation", or demand personal investments in situations of highly insecure tenure, and/or teach "hygiene practices" that relate neither to local beliefs nor to the ground realities of a complex urban poverty. A three-year ethnographic study in Chittagong, Dhaka, Nairobi and Hyderabad illustrated that excreta disposal systems, packaged and delivered as low-cost "safe sanitation", do not match the sanitation needs of a very diverse group of urban men, women and children. It is of little surprise that the delivered systems are neither appropriate nor used, and are not sustained beyond the life of the projects. This mismatch, far more than an assumed lack of user demand for sanitation, contributes to the elusiveness of the goal of sanitation and health for all. The analysis indicates that unless and until the technical, financial and ethical discrepancies relating to sanitation for the urban poor are resolved, there is little reason to celebrate the recent global declaration on the human right to water and sanitation and health for all.

Keywords: Sanitation, hygiene, safe sanitation.

3.47. Knowledge, attitudes, practices and implications of safe water management and good hygiene in rural Bangladesh: assessing the impact and scope of the BRAC WASH programme (2011)

Stephanie Fisher[1], Babar Kabir[2], Edward Lahiff and Malcolm MacLachlan[3]

[1]Corresponding author
[2]Babar Kabir
BRAC Centre (8th floor), 75 Mahakhali, Dhaka 1212, Bangladesh
[3]Edward Lahiff & Malcolm MacLachlan
Centre for Global Health, 3–4 Foster Place, Trinity College, Dublin 2, Ireland

Abstract

A substantial component of BRAC's WASH programme involves educating rural Bangladeshis about safe water management, good hygiene and the causes of diarrhoea. By conducting questionnaires and focus group discussions in two BRAC WASH villages and one control village, this investigation sought to assess

the impact of BRAC's programme on knowledge, practices and diarrhoeal burden, to explore the extent to which knowledge determines practices, and to evaluate which factors were most predictive of diarrhoeal incidence. It was found that the programme had a beneficial effect on the subjects' knowledge and practices, and on the diarrhoeal incidence among their children. Furthermore, except for where personal financial expenditure was required, practices tended to follow on from knowledge. However, BRAC's intervention affected neither the frequency of soap use in handwashing by the mother, nor the child's consumption of unclean water outside of the home. These factors, along with the child's consumption of unclean water inside the home, were shown to be those most predictive of diarrhoeal incidence among the under-fives. It is recommended that BRAC continues to emphasize the importance of these points, while also potentially promoting the use of less costly alternatives to soap and cheaper point-of-use treatment materials, to induce positive behaviour change.

Key words: Attitudes, diarrhoea, hygiene, knowledge, practice.

3.48. Enhancing Environmental Health by Community Organizations (EEHCO) in Khulna City (April, 2009 to December, 2011)

Contact Person
Name: Kazi Wahiduzzaman
Designation: Chief Executive
Telephone: 041.720155, 041.810855
Mobile: 01711.422678
Email: nabolok@khulna.bangla.net
nabolok@nabolokbd.org

Objective of the Project
Ensure the Access and Rights to Water and Sanitation through the Empowerment of the Urban Slum Dwellers by Creating a Sustainable Process to Overcome Water and Sanitation Poverty Mainstreaming Policy of Urban Governance.
Project Area: 8, 11, 13, 15, 21, 22, 31 No Ward under Khulna City Corporation (KCC)

Major Findings
- There was no Joint Plan in the Every Slum Resulting a Gap among Stakeholders and was Possibility to Overlap the Activities;
- The Tenure of the Project is Limited than Expected Brings Incompletion some Rights based Activities;
- The Resources and Staffs were Limited as per Need Resulting Hamper in Implementing the Activities in Full Swing;
- Not Effective Coverage in Public Place and Institutions.

3.49. Effects of BRAC Water, Sanitation and Hygiene (WASH) Programme in improved Sanitation: Changes from Baseline to Midline Survey (2010)

Shyamal C Ghosh; AKM Masud Rana; ARM Mehrab Ali; Tahmid Arif

BRAC Centre, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

To facilitate achieving national target of 100 percent sanitation in Bangladesh by the year 2013, BRAC Water, Sanitation and Hygiene (WASH) programme has been working in 150 upazilas for improving water supply, sanitation and hygiene practices. This study investigated the effect of BRAC WASH

programme on sanitation in the intervention areas after two years of implementation, by comparing the data of baseline and midline surveys. Data of 30,000 households from 50 upazilas were used to measure the improvement in sanitation at household level. The sanitation situation in the same upazilas at institutional level was studied by surveying educational institutions (2,395 during baseline and 1,487 during midline), which were financed by the BRAC WASH programme for arranging improved sanitation facilities. Use of sanitary latrines increased significantly ($p<0.001$) both at household (7.1%) and institutional level (2.4%). Additionally, the quality of sanitary latrines improved significantly ($p<0.001$). During midline survey higher percentage of latrines were found clean (17.2% at the households, 23.7% at the educational institutes) and with available water nearby the latrines (5.5% at the households, 11.4% at the institutes). There were also reduced percentage of latrines with stink (14.8% at the households, 22.4% at the institutes) and residual fecal left (12.8% at the households, 21.6% at the institutes). The improvements of sanitation status could be attributed to the BRAC WASH activities implemented in the study areas for 2 years. However, there were some impediments revealed from the study, i.e., shifting of households using sanitary latrines to unsanitary practices, poverty, illiteracy etc., which were slowing down the sanitation improvements. Thus, the BRAC WASH programme needs strengthening of ongoing activities addressing the key impediments at household level together with extended support for educational institutions to achieve the set goals.

Keywords: Sanitation, Household, Sanitation improvements.

3.50. Women's Role in Managing Household Water in Rural Bangladesh (2010)

Nepal C Dey and ARM Mehrab Ali
BRAC

Abstract

The BRAC WASH (Water, Sanitation and Hygiene) programme was initiated in 150 upazilas in three phases (50 in each phase) aiming to improve water, sanitation and hygiene conditions in rural Bangladesh. The study explores women's role in managing household water i.e. collecting and storing water and maintaining cleanliness of the tubewells. Participants were selected through a two-stage sampling procedure. Respondents were the women of the households who had knowledge of the household day-to-day activities related to water, sanitation and hygiene. Most of the women (97%) were responsible for collecting water from both single-used and shared tubewells in baseline, which decreased significantly to 95% in midline. Putting cover (lid) on the opening of water vessels during fetching and storing drinking water increased significantly from 18% and 31% in baseline to 51% and 39% in midline, respectively. Besides, putting cover on the opening of water vessels for storing water for cooking increased significantly from 14% in baseline to 20% in midline. Multivariate analyses show that due to WASH interventions, the proportion of tubewells increased in the female-headed households compared to the male-headed ones in midline. Significant improvement in cleanliness of tubewell platforms was observed in midline where higher proportion of cleaned tubewell platforms was observed among non-poor households compared to poor and ultra poor households. The study reveals that WASH intervention has succeed in increasing women's role in household water management and cleanliness of tubewell platforms, which may reduce the prevalence of waterborne diseases. Other household members except women should come forward to collect water or maintain tubewells, which may allow increasing participation of women in other productive work after taking break from tedious work. The ongoing WASH interventions should be strengthened and more emphasis should be given on the routine monitoring at household level to establish proper hygienic management of water by the women and other family members.

Keywords: BRAC, Tubewell, Upazila, WASH.

3.51. Exploring Reasons of Variation in Target Achievement in Sanitary Latrine Construction Under School Sanitation Programme of BRAC WASH (2010)

Tahmid Arif; Shamim Ahmed
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

Since 2007 BRAC's Water, Sanitation and Hygiene (WASH) programme has been promoting construction of sanitary latrines with water source and waste management provision at the girls' secondary educational institutes in 150 subdistricts across Bangladesh. In all cases BRAC offered partial financial support for constructing sanitary latrines and rest of the cost was managed by the school authority. Three educational institutes from each union in a sub-district were considered for this intervention. Each educational institute received Tk. 35,000 from BRAC for procuring construction materials. However, it was observed that target achievement in constructing sanitary latrine was not equal in all the regions. For instance, in the south target achievement was lower compared to the north. Although, it was assumed that in the south achievement would be higher compared to the north as socioeconomic status of the south is better compared to the north. This study explored the reasons of different levels of target achievement in constructing sanitary latrine for girls' in those two regions. A qualitative study was done in Bogra, Thakurgaon, Khulna and Jessore districts. The first two districts were selected from the north and the rest two from the south. Each subdistrict represented one district. From each sub-district five unions were selected for this study. Data were collected through focus group discussions, in-depth interviews and observations from WASH staff, school teachers, school management committee (SMC) members and guardians. Findings show that financial support of BRAC played a vital role in attracting majority of the institutions to construct the sanitary latrine. However, for some of the institutions particularly for those in the south, the amount of money allocated by BRAC was not attractive.

It also shows that unanticipated price hike of construction materials, natural disasters such as cyclone and flood, political affiliation, unwillingness of some of the SMC members and school authorities, negotiation-related issues, school selection criteria and misconception about BRAC were some other major constraints against achieving the target in the south. Whereas in the north, necessity and design of the latrine, donation from the community people, self-interest of teachers; SMC members and guardians, role of village WASH committee, role of female teachers, reputation of BRAC and support from the union parishad chairmen helped in achieving the target.

Keywords: Sanitation and Hygiene (WASH) programme, Sanitary latrine, School Sanitation Programme.

3.52. Assessment of Water Use and Sanitation Behavior in a Rural Area of Bangladesh (2010)

Attia Zeinalabdeen Taha[a], Zohair Ahmed Sebai[b], Muhammad Shahidullah[c] et.al

[a] Department of Family and Community Medicine , College of Medicine and Medical Sciences King, Faisal University , Dammam, Saudi Arabia
[b] Health Development International , Al Khobar, Saudi Arabia
[c] National Institute of Preventive and Social Medicine , Dhaka, Bangladesh

Abstract

A health development project was established in a rural area of Bangladesh that entailed training village health promoters to provide health education and to motivate families to install tubewells and sanitary

latrines. Following a 2-y period of project implementation, the authors sought to assess knowledge and practice of mothers and family members about use of safe water and household tubewells. A household survey in the project area was compared with a similar one in a nearby control area. Three-hundred households in each area were selected, and mothers were interviewed with a standard questionnaire. Significantly more mothers in the health development project area (45.7%) used tubewell water for domestic purposes than in the control area (32.8%). However, hygienic practices of mothers were inadequate. Sanitary latrines were present in less than 20% of households in both areas. Approximately 97% of mothers and 78% of adult family members always used household latrines. However, the use of household latrines by children was low (26.7%). There was no statistically significant difference in the use of household latrines between the project and control areas. The results showed an improvement in use of household tubewells in the project area; however, there was no improvement in sanitation practices of families in the project area. Health education alone, without improvement of socioeconomic status, is not effective in changing behavior.

Keywords: Health education, Health development project, Rural Bangladesh, Household latrine.

3.53. Measuring Changes in Self-reported Hand-washing Practices with Soap among Women: A Community-based Empirical Study in Rural Bangladesh (2010)

AKM Masud Rana, Milan Kanti Barua and Babar Kabir

Abstract

Objective: To examine the changes in hand-washing practices with soap among women as a result of water, sanitation and hygiene (WASH) intervention of BRAC.

Methods: A community-based study was conducted in 50 rural sub-districts of Bangladesh where BRAC (a non-governmental organization) has been offering WASH intervention since middle of 2006. Through a multi-stage thirty-cluster random sampling 27,662 adult women were selected for this study. The intervention includes promotional activities to install tubewells, sanitary latrines and improve hygienic practices including demonstration of hand-washing with soap. In villages with ≥80% sanitation coverage, the ultra poor received grant for sanitary latrine. The intervention is provided through cluster meetings, mosque sermons during Friday prayer, preventive home visits, and popular theater. To facilitate intervention, village WASH committees were formed across the villages. Data were collected before the inception and following two-year of intervention from the same households. Primary outcomes include changes in self-reported hand-washing practices with soap after contact with faces and waste; and before eating, cooking and serving food.

Results: At follow-up, a significant improvement was pronounced for hand-washing with soap irrespective of socioeconomic status in various indicators such as after contact with faeces, and waste; and before eating, cooking and serving food (ranges: 3%-15%). Multivariate analyses show that probability of washing hands with soap was higher among the non-poor and literate and less likely who reported to use unsanitary latrine. Participants who attended village WASH committee meetings were more likely to use soap for hand-washing.

Conclusion to make universal use of soap for hand-washing persistent intervention is due to prevent its related diseases and to enhance some of the targets of Millennium Development Goals.

Keywords: Hand-washing, Soap, Rural, Women, Community-based, Bangladesh.

3.54. Social-epidemiological study for evaluation of water supply and sanitation systems of low-income urban community in Dhaka, Bangladesh (2010)

Kabirul A. Mollah and Toshiya Aramaki
Natural, Biotic and Social Environmental Engineering,
Interdisciplinary Graduate School of Medicine and Engineering,
University of Yamanashi, 4-3-11 Takeda, Kofu Yamanashi, 400-8511, Japan
Department of Regional Development Studies, Toyo University, 1-1-1 Izumino, Itakura, Oura Gunma, 374-0193, Japan

Abstract

This study aims at quantification of health losses, considering social and environmental factors. Morbidity and mortality cases of diarrhoea for children under five years old were used to estimate the disability adjusted life years (DALYs) lost for the target households in low-income communities in Dhaka, Bangladesh. Water supply facilities and sanitation systems, along with hygiene practices and their health outcomes, were studied at community level. Demographic, socio-economic and socio-cultural aspects were also studied to support the research findings and give a better understanding of the local conditions. The four selected communities, Ward 60 (W60), Ward 61 (W61), Ward 62 (W62) and Ward 65 (W65), all had different existing urban services such as water supply, sanitation, garbage management and drainage facilities. All of these services existed in W62, but W60 did not have any of the services; W61 had sanitation and drainage coverage, whereas W65 had only a water supply facility. The results conclusively showed that, compared with the null (absence of services) scenario (W60), the other three scenarios (W61, W62 and W65) showed a substantial decrease of diarrhoea (1.219, 1.284 and 2.052 DALYs/household/year, respectively) reported for children under five years old. Besides urban services, other socio-economic characteristics might also influence the prevalence of diseases.

Keywords: Diarrhoea; disability adjusted life years; health implications; low-income urban community; sanitation; water supply.

3.55. Composting barrel for sustainable organic waste management in Bangladesh (2010)

Md Azizul Moqsud[1], Quazi Sifat Bushra[1], MH Rahman[2]

[1]Institute of Lowland Technology, Saga University, Saga, Japan
[2]BUET, Dhaka, Bangladesh
Md.Azizul Moqsud, Institute of Lowland Technology, Saga University, Saga, 840-8502, Japan

Abstract

To ensure quick and uniform aerobic stabilization of biowaste through domestic composting and to prevent malodorous emissions, two modifications were made to a conventional steel barrel composter by: (1) providing 0.0125 m diameter openings throughout the sides and (2) placing a 0.0254 m diameter perforated polyvinyl chloride (PVC) pipe in the middle portion of the barrel. The volume of composting waste before modification of the composting barrel was 40% of the original volume and it was 70%, 4 weeks following the modifications. In addition, the nutrients in the compost were found to be in a more suitable range after modification of the composting barrel. The carbon–nitrogen ratio (C/N) of the compost was in the ideal range of 11–15 in the modified composting reactor but it was quite high (24–25) in the conventional barrel. This modified barrel composting plant proved to be an efficient, eco-friendly, cost-effective solution for the management of organic solid waste materials in developing and technologically less sophisticated countries such as Bangladesh.

Keywords: Biowaste, composter, carbon–nitrogen ratio.

3.56. Long-Term Sustainability of Improved Sanitation in Rural Bangladesh (2010)

Dr. Suzanne Hanchett, Dr. Laurie Krieger, Mohidul Hoque Kahn et.al
World Bank Bangladesh

Abstract

Sanitation needs are significant in Bangladesh, which is the most densely populated country in the world and one of the poorest. Adding to the challenge, about one-third of Bangladesh experiences annual floods and other parts of the country suffer seasonal water shortages. All of these factors have implications for the ability of rural Bangladeshis to construct and maintain latrines. Improving sanitation is a high priority national policy goal in Bangladesh. The goal of this study is to provide the Government of Bangladesh (GoB) and it's in country partners with evidence on what makes sanitation behaviors, facilities, related benefits, and programs sustainable in the Bangladesh context. The study focused on five specific objectives: determine the current status of latrine facilities built pre-and post-(Open Defecation-Free) ODF declaration and sanitation practices; understand the perceived benefits to households and communities from community-wide ODF approaches since declaring ODF status; understand whether programmatic inputs from local and national governments and civil society sanitation programs had been sustained to support communities in maintaining their ODF status and helping the poor obtain access to latrines; understand how the growth or attrition of sanitation products and services has affected the sustainability of sanitation behaviors and facilities and ODF status; and most importantly, understand why households and communities had or had not sustained improved sanitation behaviors since ODF declaration.

Keywords: Sanitation needs, latrines, latrine facilities, Open Defecation-Free.

3.57. Sanitation Market Development: A Head Start for Healthier Living (2010)

Rokeya Ahmed, Christopher Juan Costain, Jaehyang So

Abstract

Given a choice, poor people in Bangladesh will like to be treated the same as any other consumers who go to the market, assess all the options, and then make their purchases either with a lump-sum payment or through an installment plan. Even with an interest component, installment buying gives them greater economic liberty. The Water and Sanitation Program (WSP) not only facilitates this economic liberty, but, more importantly, it also promotes sanitation reform through affordable means of waste management that include hand washing, waste management, and sustainable latrine options. To promote the sustainability of the sanitation program, with the aim of scaling up, WSP designed and implemented a small project Scaling Up and Sustainability of Total Sanitation in Bangladesh (SSTSB) from April 2008 to March 2009. As a result, rural consumers in the five piloted villages of Jamalpur district (Mohanpur, Ghoradhap, Chandpur, Chontia, and Kalibari) now can choose from among 20 latrines that cost from Tk 400 to Tk 20,000 ($5.50 to $290), hand-washing devices (from $.60 to $7), and solid- and liquid-waste-management technology (from $5 to $10). This smart lesson describes how this progress came about.

Keywords: Sanitation market, consumers, Water and Sanitation Program (WSP), Sustainability of Total Sanitation in Bangladesh.

3.58. Housing and Sanitation Pattern of Garo Community in Mymensingh, Bangladesh (2010)

Md Riad Hasan
Environmental Science, Khulna University, Bangladesh

Abstract

The present work aimed at to study the housing and sanitation conditions of Garo community at Dhobaura upazila in Mymensingh district. Housing parameters such as floor materials, wall materials, roof materials, animal shelter, ventilation system, lighting system, cleanliness and sanitation parameters such as source of drinking water, household water use, latrine and household waste disposal system were taken as dependent variables towards characterizing the housing and sanitation status. Otherwise, five indexing parameters such as the age, education, family size, farm size and family income of household heads of the family were taken as independent variables towards characterizing the housing and sanitation status. Data were collected from some randomly selected 160 household heads during November, 2007 to April, 2008 through structured questionnaire. The qualitative and quantitative evaluation information was characterized in suitable scales. The correlation analysis was used to describe the effect of selected individual characteristics of household head with housing and sanitation status. An inverse relationship was found in the age of household heads and sanitation system. Education had a great effect on housing and sanitation status. Farm size and family income of household heads were positively correlated with housing and sanitation. In general, the living standard of the people of the study area seemed to be quite satisfactory.

Keywords: Sanitation Pattern, Garo community, waste disposal system.

3.59. NGO and Civil Society Networking Project for Total Sanitation (2010)

Contact Person
Name: Sajal Kumar Saha
Designation: Program Coordinator
Telephone: N/A
Mobile: 01711.481896
Email: vord.org@gmail.com

Project Director/Chief Researcher
Name: DipakRanjanChowdhury
Designation: Executive Director (Former)
Telephone: N/A
Mobile: 01715.120113
Email: biplobchow@gmail.com

Objective of the Project
- To Mobilize Civil Community for Playing Effective Role in Cover Total Sanitation;
- To Strengthen UP Capacity on Sanitation Issue;
- To Develop Link with Potentials Stakeholders within GO, NGO & Private Sectors.

Project Duration: 2007 to 2010

Major Findings
- Community have Less Awareness on Total sanitation;
- UP have no Enough Capacity to Manage Fund;
- Awareness does't means Positive Change of Behavior.

Remarks
Generate Action to Strengthen UP's Capacity on how to Implements Fund/Project.

3.60. An Initiative to Establish a Model Village through Eco-friendly Technologies Emphasizing on EcoSan-toilet (2010)

Contact Person
Name: Tofayel Ahmed
Designation: Deputy Country Representative
Telephone: 02.9899574
Mobile: 01715.499376
Email: tofaeljade@dhaka.net

Objective of the Project
- To Intensify Knowledge, Attitude and Practice (KAP) of the Community People on Safe Drinking Water and Improved Sanitation;
- To Increased Number of EcoSan-toilet for Achieving the Purpose of Better Living Environment;
- To Adopt on Recycling of Human Excreta Derived Resource for Agricultural Production;
- To Enhance Capacity of the Community People for Sustainable Management of Provided Options;
- To Disseminate Information Regarding Benefits of EcoSan-toilet.

Project Duration: March, 2010 to November, 2010

Major Findings
- Increased number of EcoSan-toilet drastically changed village living environment by confining fecal substances;
- Villagers adopted to use fecal sludge as fertilizer in dried state.

3.61. Effect of Water, Sanitation and Hygiene Intervention in Reducing Self-reported Waterborne Diseases in Rural Bangladesh (2009)

AKM Masud Rana
Research and Evaluation Division, BRAC Centre, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

Background: Waterborne medical conditions represent substantial global burden of diseases. Under-five children are more likely to get these conditions compared to adults. This study examines effect of water, sanitation and hygiene (WASH) intervention of BRAC on waterborne diseases.

Methods: An experimental study was done in 50 sub-districts in rural areas of Bangladesh where WASH programme is in place since middle of 2006. A total of 29,885 households were selected randomly for this study through multi-stage 30 clusters sampling design. The intervention included promotional activities to install tubewells, sanitary latrines and health education for improving hygienic behaviour. Ultra poor received grant for sanitary latrine in the villages where sanitation coverage reached ≥80%. To

facilitate intervention, village WASH committees were formed. The intervention was provided through cluster meeting, preventive home visits, popular theater and celebrating sanitation month. Diarrhoea, dysentery, jaundice, worm infections and typhoid fever were considered as marker of self-reported waterborne diseases.

Results: Findings reveal that overall prevalence of waterborne diseases reduced from 10% at baseline to 7% at follow-up ($p<0.001$). Among under-five children it reduced from 22% to 13% ($p<0.001$). Although, prevalence was higher among women than men at baseline ($p<0.001$) no significant difference was noted between them during follow-up. Prevalence was found to be significantly higher among illiterate and who reported to use unsanitary latrine. Logistic regression analyses show that among the under-five children probability of reporting waterborne diseases was significantly higher at both periods. Non-poor and participants from the central, north and the south-east regions were less likely to report waterborne diseases.

Conclusions: This study underlines that to reduce waterborne disease water, sanitation and hygiene intervention plays important role. Attenuation of waterborne diseases might impact on child mortality and economic status of the households where out-of-pocket medical expenditure is pervasive.

Key words: Waterborne diseases, children, rural, water, sanitation, hygiene.

3.62. An Assessment of the Impacts of Floods on Sanitation in Rural Bangladesh (2009)

Shamim Ahmed
Research and Evaluation Division, BRAC, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

Bangladesh faces multiple challenges in the sanitation, hygiene and water sector. According to the MDG data for Bangladesh, latrine coverage stood at 33% by 2003. But, sanitation coverage is increasing, moving from 33% in 2003 to 39% in 2004 to about 48% in 2005. But in attaining this goal a major constrain is the recurring annual floods of Bangladesh. This study aimed to review the damage to sanitation facilities during floods. It also explored the possibilities of overcoming the negative impacts of floods on sanitation. The study was conducted among 880 households from selected eight flood affected areas of BRAC WASH programme. Two unions having high sanitation coverage from each of these districts were selected. One village from each of these unions was selected that was affected by flood and had at least fifty five households. Households with latrines having at least 3 rings and 1 slab were selected for the study. Findings of the study results suggest that almost 73% latrines were damaged during the flood. Out of those damaged latrines 62% became unusable within the first week of the flood. On average, 26% flood affected people defecated at other's house during flood whereas almost 55% defecated from floating places like boats, rafts, hanging latrines etc. Around 19% people defecated in the bush or field during flood. Ninety nine percent of the respondents thought that the reason behind this damage was flood. Though almost all the respondents mentioned flood to be the reason behind damaged latrines, we identified some other factors which might have significant role in the damage of the latrines during floods. There are several contributory factors in this category. Latrines were more likely to be damaged during flood if they were installed by non experts (95% CI 0.15-0.29: OR 1.58: $p<0.001$), had exposed rings (95 % CI 1.12-1.99; OR 1.50; $p<0.005$), installed below homestead level (95 % CI 4.05-7.67; OR 5.58; $p<0.001$) and were flooded under water (95 % CI 9.78 – 21.27; OR

14.42; p <0.001). Damage to the latrines could be prevented or reduced if they were installed by experts at a level at least higher than homestead. The rings should be installed under ground level properly and should not be exposed. It should also be ensured that the seals are not broken by water while submerged. Moreover, measures should be taken to increase the awareness about market price of different sanitary materials.

Keywords: Flood, Sanitation, Market Price, Bangladesh, Latrine.

3.63. Integrated approaches to promoting sanitation: A case study of Faridpur, Bangladesh (2009)

M. Ali , L. Stevens
Access to Services Programme, Practical Action, Bourton on Dunsmore, Rugby, Warwickshire CV23 9QZ, United Kingdom

Abstract

This paper summarises the experience of Practical Action in promoting water, sanitation, waste and hygiene-related infrastructure and services in the town of Faridpur, Bangladesh. In addition to the improvement in health and local environment, the project attempted to increase income and employment through the provision and operation of services. Practical Action and its partners have organized community groups and developed participatory slum improvement plans. This then leads to the prioritisation of immediate needs and agreeing roles and responsibilities in the delivery. To address other needs identified in the plans, slum dwellers were encouraged to develop partnerships with the municipality and other service providers. The involvement of people and their empowerment has lead to better use and maintenance of water and sanitation-related infrastructure and services. Community members, once organized have also negotiated better deals with the municipality. However, income and employment from the services, appears to be a more complicated issue in practice as compared to what was planned in the project. This is because of social structures in the slum areas and community expectations. Overall, the Faridpur model appears as a potential model to improve access to services in urban slums of Asia to achieve health, environment and well-being outcomes.

Keywords: Urban; Slum improvement; Participatory planning; Income from sanitation services and Bangladesh.

3.64. A crisis in governance: Urban solid waste management in Bangladesh (2009)

Shahjahan H. Bhuiyan
Department of Public Administration, Kazakhstan Institute of Management, Economics, and Strategic Research (KIMEP), 4 Abai Avenue, Almaty 050010, Kazakhstan

Abstract

This paper analyzes and reviews the role of governance in solid waste management as administered by the city governments in Bangladesh. An attempt has been made to examine how and to what extent operational problems impede delivery of conservancy services to urban dwellers. The study is primarily based on empirical data gathered in the years 2000, 2003 and 2009. The data document the lack of good governance which has a negative effect on the performance of a conservancy department. As a result, the department delivers inadequate and unsatisfactory services, thus rendering city governments vulnerable to citizens' complaints. A direct consequence of the poor performance of the conservancy department is the growth of community-based initiatives, private and non-government organizations,

which are increasingly playing an important role in delivering conservancy services. In the light of its findings, the paper argues that city government, instead of showing indifference to private and community initiatives that have succeeded in reaching the service users, should share the service delivery responsibility with them. The results suggest that a well-built public–private partnership can ensure effective solid waste management and thus good urban governance in Bangladesh. The key lessons learned are: a number of challenges that stem from the lack of good governance thwarted an effective solid waste management; formation of public–private partnership was possible in a politically divided society; and, partnership emerged as an instrument for better service delivery.

Keywords: Governance; Solid waste management; Public–private partnership; Bangladesh

3.65. Status of water use sanitation and hygienic condition of urban slums: A study on Rupsha Ferighat slum, Khulna (2009)

M.D. Sohel Rana
Town Planner, Meherpur Municipality, Meherpur 7100, Bangladesh

Abstract

The number of slums has significantly increased in Bangladesh over the last three decades along with the expansion of cities and towns. Rapid urbanization, caused largely by heavy influx of migrants from rural areas, has exerted severe pressure on urban housing and public services in the metropolitan city of Khulna with which the expansion of infrastructure and basic urban services could not cope. This situation coupled with the destitute economic condition of poor migrants has given rise to the formation of a large number of slums where service inadequacies have been compounded and multiplied on a massive scale, resulting in hazardous environmental condition. Against this background the study was performed. Data has been collected from field survey, some secondary sources and focused group discussion. Some experts and several officials were also interviewed whose agencies are likely to responsible for the extension of the services to the slum in the event of upgrading work being taken up. The study reveals that status and practice regarding water, sanitation and hygiene. This paper has also explored that assessment of water resource availability and quality at source point of consumption; problems faced in getting safe drinking water; and knowledge of the features of hygienic latrine; awareness about health. In addition to the above, the survey maintained a specific focus on adult man, women and young generation. The paper may attribute to further research on water supply and sanitation study it will guide those who will work to improve the present.

Keywords: Sanitation; Slum; Water resource.

3.66. Social constraints before sanitation improvement in tea gardens of Sylhet, Bangladesh (2009)

M. Ahmed[1], Anwara Begum[2], M. A. I. Chowdhury[1]
[1]Department of Civil and Environmental Engineering, Shah Jalal University of Science and Technology, Sylhet, 3114, Bangladesh
[2]Department of Public Administration, Shah Jalal University of Science and Technology, Sylhet, 3114, Bangladesh

Abstract

Sylhet, the northeastern divisional city of Bangladesh, is the major tea-producing region of the country where a large number of low-income workers completely depending on extremely labor-intensive economic activity for their bread and butter, live in and around the tea gardens. The living conditions of these communities are remarkably meager due to the lack of proper utility facilities, especially in water

supply and sanitation sectors. A study was conducted at Lakkatura and Ali Bahar Tea Estates to assess the deteriorated sanitation condition of the tea garden workers community and to determine the constraints before the improvement of the condition. It was found that the existing sanitary condition of both of the tea garden slums is very poor because of the same topographical condition and socioeconomic and cultural status of the dwellers. About 50% to 60% tea garden workers still are used to open defecation causing various excreta related diseases and not practiced with washing hand after defecation. Lack of knowledge and awareness about health and hygiene, unwillingness, poverty, superstitions, etc. are responsible for the deteriorated condition of the sanitation system. Based on the analysis, providing latrines free of costs, undertaking extensive motivational and awareness programs and publicity, regular consultation of tea garden workers with the health specialists, and vector control staff of concerned utilities as well as an integrated water supply, sanitation, and hygiene promotion programs should be considered as the priority in order to improve the deteriorated sanitary conditions in two tea gardens.

Keywords: sanitation, tea garden, sanitary condition.

3.67. Women's Participation in Water, Sanitation and Hygiene Programme of BRAC at Community Level (2009)

Rumana Ali
Research and Evaluation Division, BRAC Centre, 75 Mohakhali, Dhaka 1212, Bangladesh

Abstract

This study describes women's participation in the decision-making process during participatory rural appraisal (PRA), Village WASH Committee (VWC) and cluster meetings of the Water, Sanitation and Hygiene (WASH) programme of BRAC. This study aimed to determine the challenges, if any, faced by female members in participating in and influencing the decision-making process, and to determine BRAC's role in dealing with any problems faced by women. Seven villages were selected for this study from Balaganj, Srimongal, Gajipur and Feni districts. Data were collected through participant observation, focus group discussions and in-depth interviews of community people, VWC members, programme assistants, programme organizers and upazila managers. Findings reveal that almost in all cases attendance of female members in the meetings was equal or higher than men. Most of the females did not voluntarily express their opinions, especially the ultra poor and adolescent girls. As a result, they failed to influence in decision-making. Male members always spoke on many issues, about their problems though they did not have much influence on decisions, except in a few cases. Decisions were mostly made by BRAC representatives. However, male members were seen to express their voice voluntarily in most of the time in the meeting. Women's participation in these meetings can be ensured by sensitizing community people, VWC members and WASH field staff about the benefits of equal participation of both sexes in development activities. An enabling environment should be created where all members of the community, especially adolescent girls and hardcore poor, can express their opinions in meeting. Participation of adolescent girls can be increased by decreasing the number of target households for cluster meetings, as we found that attendance of adolescent girls was much lower. Presently in formation of cluster larger geographical coverage is considered to include 50 households often from the distant places of the village. In cluster with scattered households most parents do not allow their adolescent daughters to attend meetings. Finally, holding of meetings at convenient time for women may also ensure their higher participation.

Keywords: WASH, Female members, Village WASH Committee, Cluster meeting.

3.68. Improving Quality Sanitation in Bangladesh (Evaluation Report) (2009)

LGD, Ministry of Local Government, Rural Development and Cooperatives
Corp. Author: Water and Sanitation Program - South Asia
Pub. Name: LGD, Ministry of Local Government, Rural Development and Cooperatives and Water and Sanitation Program - South Asia

Abstract

The Horizontal Learning Program (HLP) aims to strengthen the capacity of union parishads in water supply and sanitation service delivery through a program of outcome-based peer learning. This report looks at the thematic workshop held in 2009.

Keyword: Horizontal Learning Program, HLP, Quality Sanitation, Improving sanitation, sanitation, water supply, peer learning, horizontal learning.

3.69. Quantitative assessment of medical waste generation in the capital city of Bangladesh (2009)

Patwary MA[1], O'Hare WT, Street G et.al
[1]School of Science and Technology, University of Teesside, Middlesbrough, TS1 3BA, UK.

Abstract

There is a concern that mismanagement of medical waste in developing countries may be a significant risk factor for disease transmission. Quantitative estimation of medical waste generation is needed to estimate the potential risk and as a basis for any waste management plan. Dhaka City, the capital of Bangladesh, is an example of a major city in a developing country where there has been no rigorous estimation of medical waste generation based upon a thorough scientific study. These estimates were obtained by stringent weighing of waste in a carefully chosen, representative, sample of HCEs, including non-residential diagnostic centres. This study used a statistically designed sampling of waste generation in a broad range of Health Care Establishments (HCEs) to indicate that the amount of waste produced in Dhaka can be estimated to be 37+/-5 ton per day. The proportion of this waste that would be classified as hazardous waste by World Health Organisation (WHO) guidelines was found to be approximately 21%. The amount of waste, and the proportion of hazardous waste, was found to vary significantly with the size and type of HCE.

Keywords: Medical waste, waste management plan, Health Care Establishments.

3.70. Strategies to Reduce Exclusion among Populations Living in Urban Slum Settlements in Bangladesh (2009)

Rashid, Sabina Faiz

Abstract

The health and rights of populations living in informal or slum settlements are key development issues of the twenty-first century. As of 2007, the majority of the world's population lives in urban areas. More than one billion of these people, or one in three city-dwellers, live in inadequate housing with no or a few basic resources. In Bangladesh, urban slum settlements tend to be located in low-lying, flood-prone, poorlydrained areas, having limited formal garbage disposal and minimal access to safe water and sanitation. These areas are severely crowded, with 4-5 people living in houses of just over 100 sq feet. These conditions of high density of population and poor sanitation exacerbate the spread of diseases. People living in these areas experience social, economic and political exclusion, which bars them from

society's basic resources. This paper overviews policies and actions that impact the level of exclusion of people living in urban slum settlements in Bangladesh, with a focus on improving the health and rights of the urban poor. Despite some strategies adopted to ensure better access to water and health, overall, the country does not have a comprehensive policy for urban slum residents, and the situation remains bleak.

Keywords: Informal settlements; Social exclusion; Slums; Slum settlements; Urban health; Bangladesh.

3.71. Appropriate technology – A comprehensive approach for water and sanitation in the developing world (2009)

Heather M. Murphy, Edward A. McBean, Khosrow Farahbakhsh
School of Engineering, University of Guelph, 50 Stone Road East, Guelph, ON. N1G 2W1, Canada

Abstract

Appropriate technologies (AT) are only a fraction of the solution in achieving sustainable and safe access to water and sanitation worldwide. The challenges of rapid population increases, urbanization, climate change, poverty, and widespread diseases will affect what are deemed "appropriate" solutions in addressing needs in the water and sanitation sector. Traditional engineering approaches need to be augmented with more flexible trial and error techniques, user participation, and multi-disciplinary collaborative learning in order to create innovative solutions and empower impoverished communities to achieve their own development goals.

There are countless historical definitions of AT, all of which are accompanied by individual criteria for a technology to be deemed appropriate. This paper presents a comprehensive definition for AT and demonstrates its application and relevance today with regard to the water and sanitation sector in a developing world context. Rather than prescribing strict criteria, considerations for AT will be outlined and examined through three case studies: the Lorena Cookstove-Guatemala, a Women's Outhouse in Nepal, and Innovation Rice Practices in Bangladesh.

Keywords: Appropriate Technology; Water supply; Sanitation; Developing countries; Technology transfer

3.72. NGO & Civil Society Networking Project (NCSNP) (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To improve quality of life of people by introducing sustained hygiene practice and improved safe water supply and sanitation facilities and services with increased access to those by the poor.

Key findings

- During the project period, 334 UPs, 1,396 FNGO staffs and 631 PSO representatives along with 8,594 caretakers capacitated through the Project's capacity-building activities.

- The UPs are developing action plans, preserving and updating WatSan information, conducting regular meetings, maintaining the functionality of WatSan committees, and other related activities in this connection. Besides, 91% of the LGIs are capable and exercising administrative authorities delegated to them; 92% of the UPs as well have become capable in leading the implementation of WatSan activities satisfactorily while another 8% UPs were found partly capable in this regard.
- Capacity of the PSOs, Community Based Organisations (CBOs) to facilitate access to and availability of low cost appropriate hygienic latrine and safe water option increased.
- Advocacy and networking with policy makers and civil society strengthened to facilitate promotion of enabling sectoral policies and relevant issues.

Knowledge, awareness, motivation and skills of Facilitating NGOs, Private Sector Operators (PSO), Local Government Institutions (LGI) and relevant stakeholders increased to lead Community Led Total Sanitation (CLTS), SHB and SWS at community level.

3.73. Community Mobilization and Development of Action Plan for Rural Non-Piped Water Supply Scheme and Community Awareness Building on Sanitation and Hygiene (BRWSSP) (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

- To mobilize and capacity building of the Local Government Institutions i.e. Union Parishads, Union Water and Sanitation (WATSAN) Committees, and affected communities to manage the arsenic and/or other water contamination e.g. salinity crisis.

- To promote sustainable sanitation services with special focus on people still defecating in the open as well as improvement of the quality of coverage for the existing population using unhygienic latrines.

Key Findings

It is too early to comment on major findings about the project.

3.74. Developing Southern Civil Society Advocacy in Water and Sanitation in Sub-Saharan Africa, South Asia and Central America (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To improve the accountability and responsiveness of the Governments and service providers in the water and sanitation sector of Bangladesh.

Key Findings

- The project has been able to mobilize & sensitize all the 67 UPs to open budget declaration.
- It is observed that through the facilitation support in conduction of open budget sessions it has been possible to increase participation of citizens in the budget process which ultimately contributed in ensuring the transparency of the UPs.

Local allies and civil society organization representatives have started raising their voice in different forums.

3.75. Community Managed Water Supply and Sanitation Programme for the Rural Poor of Chittagong Hill Tracts (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To contribute to the reduction of the water and excreta born disease in the target communities and thereby contributing to an improvement in the public health conditions of the rural poor in CHT.

Key Findings

- Project has contributed in reducing water and excreta born diseases within the intervention area.
- Access to hygienic latrine has increased (58.9%) as well as open defecation reduced (17%) among the intended beneficiaries.

Diarrheal incidences among the under five years aged children has been reduced (3.7%).

3.76. Enhancing Environmental Health by Community Organizations (EEHCO) Rural (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To strengthen and increase the capacity of community base organization (CBO) and civil society organization (CSO) WatSan network to undertake WatSan related initiatives for increasing the access and rights of marginalized and make the service delivery organizations more responsive in favour of poor and vulnerable.

Key Findings

- There is a significant change observed during this project period among the people of the working area on using hygienic latrine due to the facilitation of CBO.
- Through discussion in open budget sharing meeting the union Parishad (UP) realize that tax collected by UP from citizens would be the way of different development initiatives within the union.

3.77. Enhancing Environmental Health by Community Organizations (EEHCO) Urban (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

To strengthen and increase the capacity of community based organizations (CBO) and civil society so that they can facilitate to increase the access and rights on WatSan by undertaking WatSan related advocacy initiatives within the city and become able to make the service delivery organizations more responsive in favour of poor and vulnerable.

Key Findings

- A total of 148 CBOs has been organized and 1804 members were capacitated and aware regarding their role as well as the responsibilities of the service provider regarding Watsan services.

3.78. Integrated Water and Sanitation Programme for Disadvantaged Off-shore Island People in the Coastal Belt (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

Mortality and morbidity caused by water and excreta-borne diseases reduced significantly among the disadvantaged off-shore island people in the coastal belt.

Key Findings

- Contributed to promotion of water and sanitation facilities among the char dwellers.
- Increase the knowledge level of climate change vulnerability on water and sanitation, and transform knowledge into practice by the targeted community.

3.79. Water and Sanitation for the Urban Poor (2009)

Prepared by
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

- Demonstrate replicable and financially viable water and sanitation service models that reach low income urban consumers.
- Build institutional and service provider capacity, together with supportive policies, which will sustain the improvement process into the future.
- Use evidence from 1 and 2 to mobilize and/or better target finance (household, public, private, Govt.) to fund the service improvement process into the future.

Key Findings

- A total of 100,000 people have access to improve water supply and 150,000 have access to improve quality of services.
- During the reporting period a total of 9,938 community people have been sensitized regarding sanitation facilities under the WSUP Project.
- Around the 26,000 students of 77 schools are getting the improved water and sanitary service facilities in slum area of Dhaka city.

3.80. Climate Change Effects in Off-shore Island and its Implication on WatSan (2009)

Prepared by
Dr. Quazi Alamgir Kabir, Telephone: 8154273

Contact Person
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 58154273-4, 8128258-9
Email: ngof@bangla.net

Objectives

The specific objective of the study were as follows:

- To investigate the effects of climate change and disaster in the study area.
- To assess the water, sanitation and health & situation in the study area.
- To share the burdens of climate change impacts upon health and WatSan.
- To understand the pressure upon the biodiversity and state of natural balance in the study area.
- To examine adverse impacts of climate change due to its geographical location.

To guide the policy makers to formulate geography based programmes in the Coastal belt areas.

Key Findings

- Bangladesh is likely to be one of the most vulnerable countries in the world in the event of climate change and it is found in some magnitude and with uncertainty. It is now clear that such changes are realized by root level people though they are not compatible with scientific findings of national climate change impact.
- People at root level, who are at the coastal zones, are the real sufferers undoing any harm to the environment related to climate change issues.
- Study found that any adaptive measure in these coastal areas for that potentially affected people should be focused according to their perspective to ensure successful implementation and long term operation.
- Development agencies, volunteering organizations and civil societies can play major role in influencing governments, people, private sectors, business, industrials and other stakeholders to make decision and changing behavior and practices to save the coastal belt and redress the grievances of people living there.

3.81. WatSan Contribution in Poverty Reduction (2009)

Prepared by
Name: Mahabub-Ur-Rahman Uzzal
Designation: Chief, Research
Telephone: 58154273
Email:ngof@bangla.net

Contact Person
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net
Date of Publishing: 2009

Objective

- To understand process (improved income, assets for the poor).

To understand behavior change functioning and more inclusive basic services)

Key Findings

- Access to safe and improved sanitation facilities have some contribution to improve the poverty situation of Bangladesh. It cannot be said that it has high significant role. Study findings revealed that socio-economic condition, natural calamity, education, infrastructure of the rural Bangladesh, personal hygiene knowledge and practices, behavior and beliefs are in-built with the whole thing.
- To meet the MDG target in association with an improved WatSan situation in Bangladesh, there is a need to reduce water and excreta borne diseases and the initiatives currently taken by GO and NGOs should have to be more integrated and focus oriented.

Study findings show that suffering to the personal life especially on women, causes child mortality and death occurrence. Finally it could be said that a healthy body and mind could bring success in every aspect not only in the case of reducing poverty but also ensuring a sound health.

3.82. Utilization of ADP Allocation Money towards Achieving Sustainable Sanitation Coverage in Bangladesh (2009)

Prepared by
Name: Mahabub-Ur-Rahman Uzzal
Designation: Chief, Research
Telephone:+88 02 58154273
Email: ngof@bangla.net

Contact Person
Name: S. M. A. Rashid
Designation: Executive Director
Telephone: 880-2-58154273-4, 8128258-9
Email: ngof@bangla.net

Objective

- Access the status knowledge and practice that exists among different stakeholders to utilize the ADP allocation money for sanitation.

Assess the selection criteria and constrains to indentify as well as to provide support for the hardcore poor.

Key Findings

- Affordable services should be promoted to ensure the 100% sanitation coverage within the shortest timeframe.
- As a minimum basic sanitation services and potable water within 200 m of a dwelling should be provided in the short-term, and upgraded when feasible.

Good hygiene practices, i.e. hand washing, safe water storage, and food hygiene and good waste management should be promoted through implementation of appropriate awareness campaigns.

Chapter 4

Recommendations And Way Forward

4.1. Arsenic

The debate within the scientific community about what really triggered release of arsenic in the shallow aquifers is still far from over. It is necessary that this issue is resolved on a priority basis. It appears that during the last few years' efforts directed towards arsenic mitigation and patient care has been diluted significantly. It is also likely that arsenic issue is in hibernation mode. But renewed efforts and increased research is needed to address this issue on a long term basis. Based on the review of research and development between 2009 and 2014, the following specific recommendations are made to strengthen capability of the sector to effective deal with the arsenic issue.

1.1 A monitoring program on arsenic contamination has been in place from the early 90s. But recently, it appears to have lost the priority it had earlier. It is, therefore recommended that the monitoring program be further strengthened to which should include the trend in arsenic contamination, both spatial and temporal.

1.2 At the height of the arsenic mitigation efforts a large number equipments and processes were developed for removing arsenic from ground water. This also included installation of pond sand filters. But presently these appear to have been side lined. It is, therefore, essential to revisit the equipments / gadgets / systems installed for arsenic removal and determine which system are working and why and which system are not working and the reasons for them. Based on status recommendations shall have to be formulated to find ways for improving their performance which should include operation, management and institutional issues for long term sustainability.

1.3 As of now arsenic has been detected mostly in the primary aquifers. Monitoring shall have to be started to determine the status of arsenic contamination of the secondary aquifers. Because big cities like Dhaka and coastal cities like Chittagong and Khulna abstracts water from secondary aquifers as these two aquifers are hydraulically connected. Also in much arsenic affected areas small diameter (5 cm) tube wells have been installed in deep aquifers for supplying drinking water.

1.4 Research should also be conducted to determine the impact of arsenic contamination for different periods of intermittent consumption of contaminated water. For example, what will be the long term impact of consumption of contaminated water for 6 months in a year and non contaminated water for the rest 6 months. Other combinations may also be evaluated. If study results show that arsenic contamination can prevented it will help eliminate installation of more expensive deep wells.

1.5 Monitoring should also be strengthened to identify trend in Arsenicosis and patient management. More specifically what were the impact of arsenic mitigation program implemented by the government and what needs to be done to further improve the situation?

1.6. Surface water use campaign seems to have lost momentum. Reasons need to be found out and the campaign needs to be strengthened. Because the filters used for removing arsenic from ground water have proven to be short term solutions (WHO, 2008).

1.7 Inadequate safe management and disposal of arsenic removed from the contaminated water still pauses a great threat to public health by going back to the shallow aquifers or entering the food chain. Research needs to be strengthened to find better and safe ways of disposal of arsenic residues. Potential for reuse of arsenic, especially in small rural industries need to be explored.

1.8 Research is needed to evaluate long term impact of arsenic-nutrition-interface on patient management is essential to determine the combined affect as short term research results indicated that

people who drink arsenic contaminated water and also have a poor nutrition status may be more seriously affected than well nourished persons drinking the same water.

1.9 The health impact of arsenic contamination in the presence of other pollutants including iron, has not yet been fully studied. It is quite important to determine whether presence of other pollutants worsen the 'arsenicosis' conditions or not. It should be recognized that presence of iron is in ground water. Similar studies may also be conducted for other commonly occurring elements.

1.10 Bangladesh has set a standard of 50 ppb of arsenic in drinking water. This was probably based as earlier guidelines established by WHO in 1993. With the realization that significant impact may also exist at lower concentration in the 10-50 ppb range, the National Policy for Arsenic mitigation, 2004. Based on presently available scientific information available on health impacts of arsenic contaminated water a value of 10 ppb is advisable (WHO, 1999).

1.11 Research on Social Impacts: The arsenic contamination has raised a number of unanticipated social problems which are not fully recognized. Studies confirmed that such social issues are mostly faced by the poorest people in the society (WHO, 2000) particularly the under nourished. These are also some social stigma associated with affected by arsenicosis, with the disease wrongly attributed to sins committed. Social research and campaigns are needed to overcome this situation.

1.12 Updating National Arsenic Mitigation Policy: The National Policy for Arsenic Mitigations was developed more than 10 years back in 2004. Since then a robust and rigorous campaign has been launched for mitigation. In the process a large number of research/studies were contacted and a significant number of projects were implemented. Based on the available information the policy needs to be revised and updated on a priority basis.

1.13 Research on optimal conjunctive use of surface, ground and rain water needs to be expanded and strengthened to reduce dependence on ground water. At the same time efforts to augment surface water supply should be reinforced through improved management of trans-boundary Rivers. Research on the feasibility of induced ground water recharge may be initiated during the monsoon in areas with visible signs of ground water mining.

1.14 Research should be strengthened to develop low cost arsenic removal equipment which can be fabricated by the rural smithy shops.

1.15 Monitoring program for identifying arsenicosis patients should be expanded and strengthened. At the same time research programs should be updated for improved treatment and patient management.

4.2 Sanitation

It has already been mentioned earlier that sanitation coverage in the country is significantly lower than water supply coverage. Also technologically, significant improvement is also needed to upscale sanitation. It is, therefore, necessary to conduct extensive research in the sanitation if the desired goal of 100% coverage has to be attained in the near future. A list of recommendations is given below to attain the above mentioned objectives:

2.1 The management of fecal sludge is almost non-existent in both the urban and rural areas which has paused significant threat not only to the environment but also to sources of drinking water supply. A well thought out research program has to be developed and implemented to address the issue which will include collection, transportation, treatment and safe disposal of fecal sludge.

2.2 To upscale sanitation research to develop inexpensive and more efficient equipment needs to be done. The equipments should be simple enough which can be manufactured by the small businesses in the rural areas with modest capital investment. Operation and maintenance of the equipments should also be very user friendly. At the same time research on social mobilization for up scaling sanitation should be strengthened.

2.3 Up scaling of sanitation will also require research in gender sensitiveness of the equipments both in terms of installation, siting, use and operation and management.

2.4 Hard to reach areas have very special needs and focused research will be needed to identify and address those special needs.

2.5 Special attention should be given for hazard proofing of the sanitation system. This will include research on equipment development, their siting, portability, ability to withstand, hazard shocks etc. The common hazards to be considered are flood, cyclone, river erosions etc.

2.6 In the coastal areas special attention shall have to given for developing saline resistant equipment. As the increase in salinity is both spatial and temporal, the demand for such equipment is expected to increase rapidly and the sector shall have to be ready with the required technology and management packages. Special needs for fecal management shall have to addressed by determining the impact of salinity on the fecal sludge.

2.7 Research on sanitation market is essential to determine as to how micro-finance can be used effectively to increase financing for sanitation equipment and services both for manufacturers and customers.

2.8 Study on the risk factor associated with the construction of sanitation infrastructure and water supply infrastructure both in urban and rural areas needs to be assessed. In Dhaka city it has become very critical as most of the raw water sources have been contaminated by domestic and industrial/commercial effluent.

2.9 It is recommended that all poverty alleviation projects should have a built-in research program to evaluate linkage of poverty with sanitation as well as its impact on quality of life.

2.10 Study on climate change impacts (through modeling and other tools) shall have to be conducted to predict impacts on sanitary system and equipment design, construction and operation and maintenance (For example: studies conducted indicated rise of sea level by about 80 cm by the end of 21st century). Climate change may also increase frequency, intensity duration etc. of flood and cyclonic events. All these shall have to be considered in developing a long term research program.

2.11 Pit/ septic tank emptying are considered to be a work of the 'untouchables'. It is also associated with risk of methane poisoning. Necessary research is needed to develop technology for socially acceptable, economically affordable, eco-friendly and aesthetic cleaning of pits and septic tanks.

2.12 For built up cities and towns research for development of small sewerage treatment systems will be essential. Adaptive research can also be done with such systems developed elsewhere in the region. In the Philippines the community type sewerage treatment plants where sewerage is both piped-in or hauled-in is a good candidate for adaptive research.

2.13 Innovative research will be needed for converting sewerage waste into organic fertilizer either independently or in combination with other organic waste. Recently Bill Gates foundation has funded a

research project where sewerage waste has been incinerated successfully and converted into fertilizer by solar energy. This technology can be pilot tested in Bangladesh for its adoption.

1.14 Behavioral change research will have to be strengthened and conducted periodically to monitor and update factors that favorably impacts changes. This can be stratified considering age groups, education level, economic status, rural and urban etc. Based on research results the change agents/factors can be updated/ strengthened accordingly. Special emphasis should be given to identify ways to engage women and students in program.

2.15 Focused and dedicated research shall have to be conducted in the urban slums and rural 'Hat'/ 'Bazars' for collection, transportation, treatment and disposal sewerage effluent and sludge.

4.3 General Recommendations

4.3.1 Availability of funds for research is totally inadequate. A dedicated fund, therefore may be created in the PSU to implement identified research programs in arsenic and sanitation.

4.3.2 ITN or any other suitable organization may be designated as the center of excellence to conduct and/or co-ordinate research in the sanitation sector.