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Provision of well-water treatment units to 600 households in Bangladesh: A longitudinal analysis of urinary arsenic indicates fading utility

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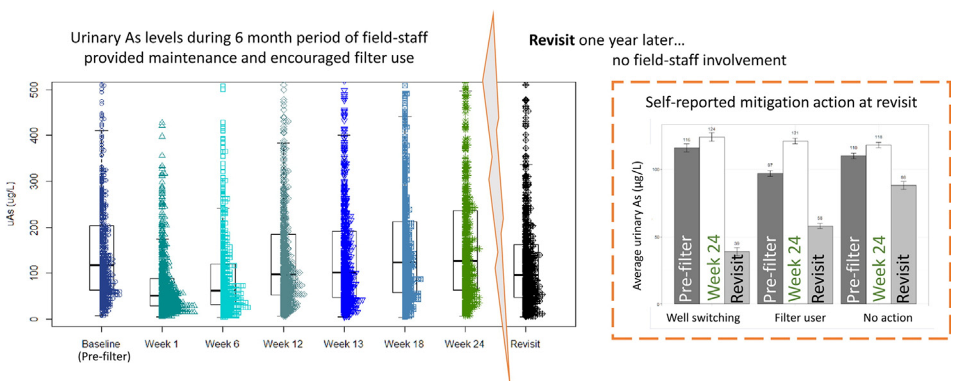
HIGHLIGHTS

- Sustainably reducing water As exposure is a major environmental health challenge.
- There is limited field evidence on prolonged efficacy of As removal water filters.
- We evaluated the effectiveness of household-level As removal filters in Bangladesh.
- Filters temporarily reduced urinary As, but only for a few weeks.
- Filters should not be considered as a long-term mitigation option.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Millions of villagers in Bangladesh remain exposed to high levels of arsenic (As) from drinking untreated well-water even though the scale of the problem was recognized 15 years ago. Water treatment at the household-level has been promoted as a viable complement but few longitudinal studies of their efficacy using an objective measure of exposure have been conducted. Participants (N = 622) of a nutrition trial in Araihazar, Bangladesh were each provided with READ-F filters at the beginning of the study and encouraged to use them over the 6 month duration of the intervention. Well-water As, treated water As, and urinary As were monitored periodically during the trial and measured again one year after the trial ended.

Results: The READ-F filters were initially well received and median urinary As levels for participants declined from 117 μg/L to 51 μg/L within a single week. However, median urinary As levels gradually rose back to 126 μg/L by the end of the trial. Fifty filters were replaced over the course of the trial because of insufficient As removal or reduced flow. With these exceptions, most of the treated water met the WHO guideline for As in drinking water of 10 μg/L. One year after the nutritional trial ended, 95% of participants had abandoned their filter citing inconvenience as the primary reason. At that time, median urinary As levels for 10 participants who had switched to a nearby low-As well had declined to 63 μg/L.

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Conclusions: Participants were probably no longer using the READ-F filter long before the 6 month nutritional intervention ended despite claiming that they were using them. Household-level treatment is likely to continue to play a minor role in the effort to reduce As exposure in Bangladesh. Understanding the limitations of such expensive interventions is important for future policy regarding As mitigation.

1. Introduction

Identifying sustainable ways of reducing exposure to arsenic (As) naturally contained in groundwater is a major public health challenge given the wide range of diseases it can cause (Straif et al., 2009; Carlin et al., 2015). Bangladesh is particularly affected, with the most recent national survey conducted in 2013 showing about 20 million villagers still routinely drink and cook with water containing >50 μg/L As, the national standard, and 40 million people consume water that does not meet the WHO guideline of 10 μg/L (BBS/UNICEF, 2015). Well testing and, as a result, households switching to a nearby private low-As well or a deep low-As community well have by far had the largest impact on exposure reduction to date in Bangladesh (Ahmed et al., 2006; Chen et al., 2007; van Geen et al., 2007; Johnston et al., 2014). But with probably less than half of the originally exposed population of Bangladesh currently served by these relatively simple forms of mitigation, there is still considerable interest in the many different ways As can be removed from drinking water (Singh et al., 2015).

In 2009, the Bangladesh Council of Scientific and Industrial Research provisionally approved six arsenic-mitigation technologies for public use (Johnston et al., 2010). Testing was conducted in a laboratory setting using artificial groundwater to verify the claims set by each company against various hydrogeological conditions found in Bangladesh (Johnston et al., 2010; Ahmed and Ahmed, 2014). A considerable number of more realistic field studies have been conducted in Bangladesh to demonstrate that these, or similar systems, remove As from actual groundwater for at least some time (Cheng et al., 2004a, b; Hussam and Munir, 2007; Jones-Hughes et al., 2013; Neumann et al., 2013). To our knowledge, however, only one such study paired the deployment of an As-removal system with the systematic monitoring of a biomarker to evaluate its effectiveness directly, instead of relying on the As content of the water and claims by the household that the system was systematically used (Milton et al., 2007). Although several lab-approved arsenic removal water filters exist, there is a paucity of research on their prolonged use in the field.

Faced with the challenge of reducing As exposure in a micronutrient supplementation trial intended to lower blood As concentrations (Peters et al., 2015), several hundred households in Araihazar, Bangladesh, were provided with one of the approved As-removal systems and encouraged to use them for 6 months. This intervention provided a unique opportunity to monitor the effectiveness of such a system because both untreated and treated water As, as well as urinary As, were monitored over the duration of the intervention and, for a subset of participants, measured again 12 months later.

2. Methods

2.1. The Folate and Creatine Trial (FACT)

The setting for the deployment of household filters was provided by FACT, a double-blind, placebo-controlled, randomized trial conducted in Araihazar, Bangladesh. Details on the study have been described elsewhere (Peters et al., 2015). Briefly, FACT examined how folate and creatine supplementation influence blood As levels over six-months. Between December 2009 and May 2011, the study recruited 622 otherwise healthy adults. For inclusion criteria, The FACT study recruited members of the Health Effects of Arsenic Longitudinal Study (HEALS) cohort (Ahsan et al., 2006) who had been consuming water As (wAs) > 50 μg/L, exceeding the Bangladeshi standard for As, for at least one year before the study began. The study excluded pregnant women, individuals taking nutritional supplements, individuals with protein in their urine, and individuals with known renal disease, diabetes, or gastrointestinal or other health problems. Ethical approval was obtained from the Institutional Review Board of Columbia Presbyterian Medical Center and the Bangladesh Medical Research Council. Informed consent was obtained from all participants.

All FACT participants (both those who received nutritional supplementation and those in the control group) received a free READ-F (Brota International, Inc.) point-of-use arsenic-removal unit when the trial began (Fig. 1). The filter was selected over two other household-level filters based on our analysis of treated water from systems deployed by UNICEF in Shahrasti upazila in 2007. The READ-F units are also portable and easy to use. Field staff showed participants how the filter worked, by simply pouring untreated well water in the top of the filter tank and collecting treated water from the tap (Fig. 1a), and instructed participants to use filter-treated water for all cooking and drinking throughout the duration of the six-month trial.

Field staff worked in pairs, one interviewer and one physician, to recruit and follow study participants through face-to-face home visits at week 0 (baseline), 1, 6, 12, 13, 18, and 24. Urine samples were collected at each of these visits. Field staff verified the filter was adequately lowering As throughout the six-month intervention by testing filter-treated wAs levels using the Hach EZ kit at each home visit. If measurement indicated filter failure (wAs > 10), or if participants cited filter failure, filters were repaired or replaced by the field staff. After the six-month nutritional intervention ended, participants were allowed to keep the filter, however, maintenance was no longer provided by field staff.

Beginning in December 2012, during routine HEALS cohort follow-up home visits, field staff returned to FACT participants and collected new water and urine samples. During this interval, the filters were no longer monitored and participants were not reminded to use the filter. Using a structured questionnaire, field staff asked participants about their experience with the filter and other mitigation options.

2.2. Arsenic levels in well-water (untreated)

Each tubewell used by a member of the HEALS cohort since 2000 is marked with a small numbered ID tag and a placard indicating its status with respect to As. The placard is often removed or lost over time but the small ID tag typically remains. The corresponding wAs level for each tubewell ID is tracked through a database. Fig. 1b shows the spatial distribution of all tubewells and their corresponding As levels tested and tracked through the database. At enrollment, participants' wAs level was identified through their reported tubewell ID and was used to enroll participants on the basis of their As content. For any participants indicating that they used an untested tubewell, the new well was tested in the field using the Hach EZ kit (Hach Company, Loveland, CO). The inclusion criterion was met if the test result indicated a water As concentration > 50 μg/L. The Bangladesh Arsenic Mitigation and Water Supply Project has used the Hach EZ kit to test millions of wells. Prior studies evaluating the accuracy of this kit found it to be fairly accurate, correctly identifying the status of tested wells 88% of the time, provided the reaction time is increased from 20 to 40 min (van Geen et al., 2015).

All well-water samples at the time of recruitment were collected and sent to Lamont-Doherty Earth Observatory (LDEO) of Columbia