Trip Report: LBNL/UC Berkeley ARUBA Project
Bangladesh 3/23/2007-4/7/2007

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April 12, 2007

Introduction

From March 23 to April 7, 2007, the authors (graduate students at UC Berkeley in physics and mechanical engineering, respectively) traveled to Bangladesh to field test the effectiveness of ARUBA (Arsenic Removal Using Bottom Ash) in removing arsenic from groundwater. We arrived in Dhaka, Bangladesh on March 25 and traveled to the city of Jessore on March 27. On March 28 and 29, we visited contaminated tubewells in five villages in Jhikargachha Upazila[1] and Abhaynagar Upazila (both of Jessore district in Khulna division) where we treated water samples from eight different tubewells. We returned to Dhaka on March 30. On April 5, we traveled to one village in Sonargaon Upazila, just outside of Dhaka, and treated water samples from one more tubewell.

Trip Objective

The objective of the trip was to demonstrate the ability of ARUBA to reduce the concentration of arsenic in Bangladeshi contaminated groundwater (with initial levels of 200-600ppb arsenic) to below the Bangladeshi standard of 50ppb.

Secondary objectives included conducting speciation tests (to determine As(III) vs. As(V) content), socio-economic observations, assessment of the accuracy of in-country arsenic testing facilities, resource identification, and collecting water samples for further lab work in Berkeley. However, this document only details the technical results relating to ARUBA.

Methods

Villages containing tubewells with high levels of arsenic were identified by BRAC, a Bangladeshi NGO, using the final report of their 1999-2000 arsenic study ("Combating a Deadly Menace; Early Experiences with a Community-Based Arsenic Mitigation Project in Bangladesh" - August 2000). During all of our field visits we were accompanied by at least one BRAC employee. In each village, BRAC employees, community leaders, and local villagers helped us identify households with contaminated tubewells.

At each tubewell visited we conducted an initial test of the tubewell's arsenic concentration (using the "QuickTest" for arsenic, manufactured and marketed by Industrial Test Systems, USA). Note that QuickTest provides arsenic concentration estimates that are generally within (20% +/- 2 ppb) of the high-quality ICP-MS (Inductively Coupled Plasma Mass Spectrometry) results

If arsenic levels were sufficiently high (in most cases, greater than 200ppb), we collected a water sample after pumping the tubewell for five minutes in order to ensure that the sample would be free from biological contamination and oxygenated water from the tubewell column. Samples

[1] Bangladeshi sub-district.

were treated with ARUBA after the day's field tasks were complete, or early the following morning. In one case, we treated water with ARUBA 30 minutes after collection in order to ensure that the lag time between collection and treatment did not affect the results.

As there was a delay of several hours between collection and treatment of the water, we always retested the sample for arsenic immediately before ARUBA treatment. At this time, we also prepared a sample for ICP-MS analysis in the US. Treatment of the water sample was undertaken by adding a single does of ARUBA media (1g) to 250ml of water and shaking for 30 minutes. After filtration (using Whatman #1 filter paper), we measured the post-treatment arsenic concentration using the QuickTest and prepared another sample for ICP-MS. If the arsenic level did not go below 50ppb after the first treatment, we repeated the treatment using a fresh water sample and twice as much ARUBA (2g per 250mL). In two cases, we treated with a quadruple dose of ARUBA (4g per 250mL). Note that quadruple doses were always given as two consecutive double doses- meaning that after initial treatment with a double dose, we added another double dose to the filtrate, as opposed to adding all 4g at once.

Preliminary Results

We collected a total of nine water samples from arsenic contaminated tubewells in six different villages. In all cases, we were able to reduce the amount of arsenic in the water to below the Bangladeshi standard of 50ppb (see Figure 1 and Table 1). In three cases, we were able to do this with a single dose of ARUBA, four cases required the use of a double dose, and two wells with very high arsenic levels (about 350ppb) required use of a quadruple doses. We did not attempt to reduce arsenic concentrations in each well to below the WHO standard of 10ppb, but based on the extremely low arsenic values obtained after double and quadruple doses, we strongly believe that this is possible with the addition of more ARUBA.

Table 1: Chart of Preliminary Results (based on arsenic QuickTest)

Tubewell	Upazila	Union	Village	Initial Concentration (ppb)	Final Concentration (ppb)	Dose of ARUBA
1	Jhikargachha	Godkhali	Kamalpoura	300	15	2g
2	Jhikargachha	Godkhali	Jafornagar	135	28	2g
3	Jhikargachha	Godkhali	Yousufpur	100	13	1g
4	Jhikargachha	Godkhali	Patuapara	30	3	1g
5	Abhaynagar	Prembug	Prembug	200	3	2g
6	Abhaynagar	Prembug	Prembug	350	0	4g
7	Abhaynagar	Prembug	Prembug	250	25	2g
8	Abhaynagar	Prembug	Prembug	200	36	1g
9	Sonargaon	Aminpur	Bugmusha	400	3	4g

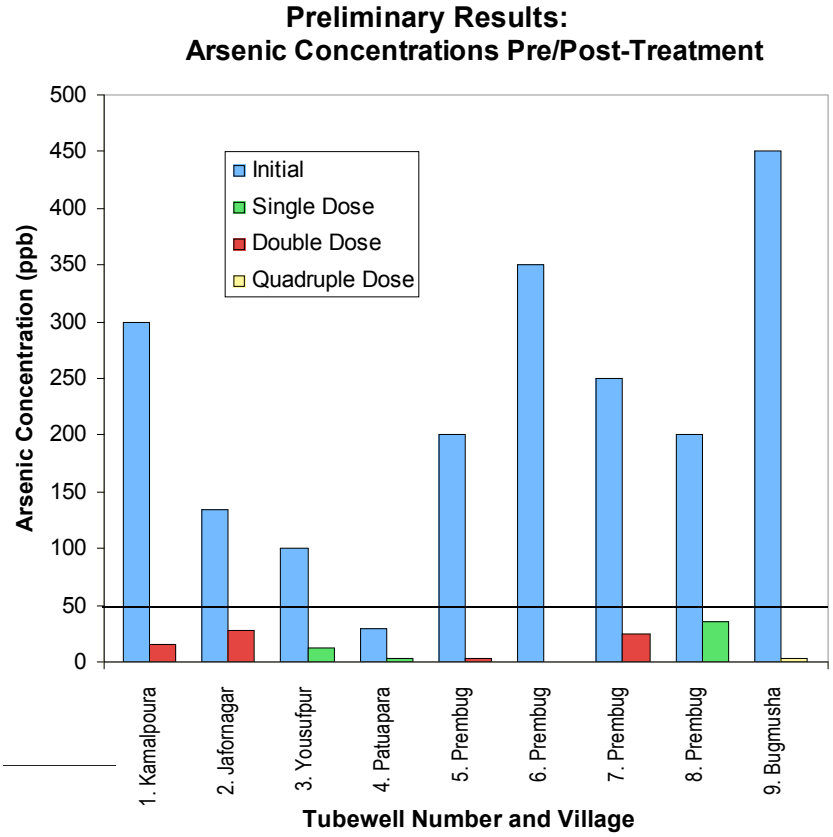


Figure 1. *Arsenic concentrations of tubewell water before and after treatment with ARUBA, and as measured with Quick Test. In each case only the initial and final (lowest) concentrations are plotted. Note that the concentration of arsenic in tubewell 6 dropped to 0 ppb with a quadruple dose. Also note that some precipitation of arsenic occurred in the sample bottles between collection and testing, resulting in some samples with initial arsenic levels below 200 ppb despite the fact that we intended to only collect samples above 200 ppb. Colors of bars for post-treatment concentrations of arsenic for tubewells 4, 5, 6 and 9 may be hard to discern. Post-treatment bar for well 4 is green (single dose), 5 red (double dose), and 6 and 9 yellow (quadruple dose).*

Conclusions

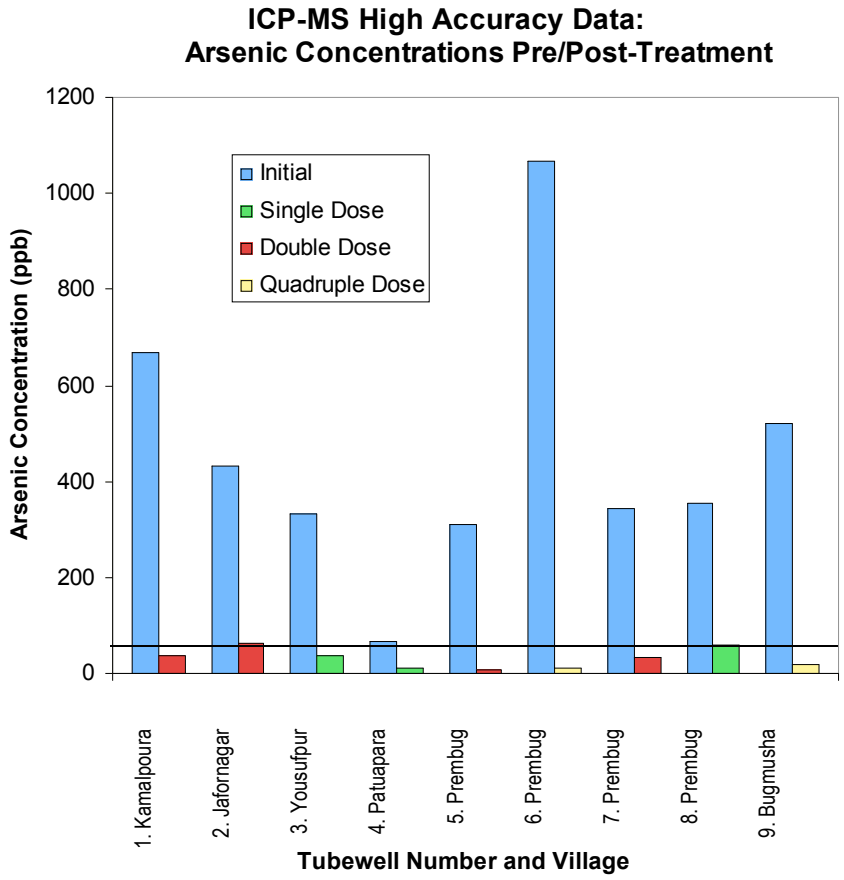
We have successfully demonstrated the ability of ARUBA to reduce arsenic concentrations in all collected samples of Bangladeshi groundwater from two geographically distinct areas of Bangladesh and across six different villages, to below the Bangladeshi standard of 50ppb. We also demonstrated the feasibility of reducing arsenic concentrations in the water to below the WHO standard of 10ppb by adding more ARUBA. As shown on the plot above, the amount of ARUBA needed to treat arsenic-contaminated water is roughly proportional to the amount of arsenic in the water. Therefore, with higher doses we believe ARUBA should be able to remove arsenic to below the WHO standard in all cases.

The data presented in this report is based on arsenic QuickTests completed in the field. Please see Appendix 1 for our final data which is based on ICP-MS arsenic testing performed in a laboratory in Berkeley, CA.

Appendix 1: Table and Figure of Final Results (based on arsenic ICP-MS measurements)
May 8, 2007

After completing the trip report, we received accurate results of arsenic concentrations in our samples, measured with ICP-MS, a much more accurate method of measuring arsenic concentrations in water (+/- 10%). The following is a summary of our ICP-MS results.

We found that our field estimates of the arsenic concentration (measured in the field using the QuickTest) were actually much lower than the actual concentration measured using ICP-MS. This means ARUBA is more efficient than we had previously predicted based on our preliminary results. In fact, ARUBA removes approximately 0.08 mg As / g ARUBA. Due to the fact that our field estimates of arsenic levels were low, in some cases (tubewells 2 and 8) we did not actually lower concentrations to below the Bangladeshi standard (50ppb). This is because we stopped ARUBA treatment once the measured concentration was well below 50 ppb, unaware that the actual concentration would be much higher. (This error in estimation occurred because, during lab comparisons, ICP-MS arsenic measurements are only about 10 ppb higher than QuickTest arsenic measurements. In the field, the error was in the same direction, but unexpectedly larger). However, we believe we could easily lower arsenic level concentrations in all of the wells to below 10ppb (the WHO standard) simply by adding more ARUBA, as demonstrated by tubewells 6 and 9.



ICP-MS Measurements

Tubewell	Upazila	Union	Village	Initial Concentration (ppb)	Final Concentration (ppb)	Dose of ARUBA
1	Jhikargachha	Godkhali	Kamalpoura	667	38	2g
2	Jhikargachha	Godkhali	Jafornagar	433	62	2g
3	Jhikargachha	Godkhali	Yousufpur	333	37	1g
4	Jhikargachha	Godkhali	Patuapara	67	12	1g
5	Abhaynagar	Prembug	Prembug	311	7	2g
6	Abhaynagar	Prembug	Prembug	1067	3	4g
7	Abhaynagar	Prembug	Prembug	344	32	2g
8	Abhaynagar	Prembug	Prembug	356	58	1g
9	Sonargaon	Aminpur	Bugmusha	522	17	4g