Bright Lines, Risk Beliefs, and Risk Avoidance: Evidence from a Randomized Intervention in Bangladesh

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Abstract

We randomized 43 villages in Bangladesh to receive information on well-water arsenic that emphasized water safety relative to the national standard (bright-line message) or provided additional information on how risks from exposure increase with arsenic levels (gradient message). The gradient message led to 50% more switching of water sources when the arsenic level was moderately unsafe, but 40% less switching at high arsenic levels. The differences in behavior are at least partially explained by differences in risk perception that developed after the information campaign.

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1 Introduction

The use of health labeling and information disclosure policies is on the rise across many health policy domains. The explicit goal of these policies is to promote healthy behavior by increasing awareness and understanding of health risks associated with several forms of behavior. Examples of health labeling programs in the United States include the Nutritional Labeling and Education Act (NLEA) of 1990 which required uniform labeling of packaged foods, recent New York State law that requires fast food restaurants to post calorie counts on menu boards, campaigns that warn against excess fish consumption due to mercury, and campaigns promoting mitigation of lead and radon hazards in homes, among many others. Information-based policies have also been adopted in developing countries for the promotion of a wide array of health-related behaviors, ranging from HIV testing and prevention to the use of insecticide-treated bed nets or of cleaner sources of drinking water.

Despite the proliferation of such information-based public health policies, there is little agreement in the literature on how to present information in ways that best motivate health-improving behaviors. An issue that arises in many of these examples is how best to convey complex or multi-dimensional risks in ways that individuals can readily understand and use in decision-making. Policies have run the gamut from providing extensive and unprocessed information (e.g., nutritional labeling) to reducing the risk information to simple "bright-lines" decision guidance (e.g., fish consumption advisories). But little is known about the relationship between risk presentation and behavioral responses that would allow policy makers to better craft and target health messages. In addition, many studies have found that information programs are often ineffective at promoting health-protecting behavior among the most at-risk individuals.

This paper contributes to this literature by studying the impact of information format on behavior in the context of a program promoting mitigation against health risks from arsenic in drinking water in Bangladesh. The natural occurrence of arsenic (As) in groundwater is an important public health concern in several countries worldwide, including in China, India and the United States. Nowhere, however, is the problem more serious than in Bangladesh, where in 1999 an estimated 35 million people (about 30% of the population) were habitually drinking shallow tubewell water that exceeded the Bangladesh standard for arsenic in drinking water (50 micrograms per liter or parts per billion (ppb)), while 57 million (45%) drank water with concentrations above the World Health Organization (WHO) recommended limit of 10 ppb. Long-term exposure to arsenic in drinking water has been linked to several health risks, including skin lesions, several form of cancers and cardio-vascular diseases, with a latency period of 5 to 15 years for early health effects and 20 years or more for cancers (see Chen et al. 2007 and references therein). In Araihazar, Bangladesh, Argos et al. (2010) estimate that drinking groundwater with > 150 ppb arsenic almost doubles all-cause mortality compared to drinking water with up to 10 ppb. Despite the magnitude of the problem, the spatial heterogeneity in arsenic contamination in several areas is so marked that users of unsafe wells live no more than 1-200 meters from safe (or at least safer) wells (van Geen et al. 2003). In communities where tubewells' arsenic contamination is known, well-sharing among households is then often a viable short-term mitigation strategy (van Geen et al. 2002). By 2005, about 5 million tube wells had been tested free of cost as part of the widespread Bangladesh Arsenic Mitigation Water Supply Program (BAMSWP, see Ahmed et al. 2006). Information was provided in a bright-line format, by painting the spout of the tested tubewells red or green depending on whether the arsenic concentration was above or below the national standard of 50 ppb. This information disclosure program has been a relatively inexpensive and effective mitigation strategy. In Araihazar district, in locations proximate to our study areas, earlier studies have documented high rates of switching off unsafe wells following the provision of information (Schoenfeld 2005, Madajewicz et al. 2007, Opar et al. 2007, Chen et al. 2007, Ahmed et al. 2006). Chen et al. (2007) found significant reductions in urinary arsenic (a good indicator of exposure) among individuals who switched to safer sources in these areas.

Despite high levels of switching, there remain significant environmental health concerns. First, it is widely acknowledged that no known level of arsenic exposure is completely safe and that health benefits can result from any decrease in arsenic exposure. It is then cause of concern that the Bangladeshi standard is five times as large as the threshold adopted by the WHO and governmental organizations such as the United States Environmental Protection Agency (EPA). Second, decreased arsenic exposure from 400 ppb to 200 ppb yields significantly greater reduction in risk than reducing exposure from 60 ppb to 30 ppb (NRC 1999, NRC 2001). However, the bright-lines risk presentation by BAMWSP encourages the second switch but not the first. A related concern is that a household whose well tests positive for arsenic at 49 ppb has no incentive to move to a nearby well that has 1 ppb arsenic, despite the potentially significant health benefits associated with that switch.

This paper provides evidence on the effects of risk presentation on health behaviors using data from a cluster randomized controlled trial in risk presentation regarding arsenic in drinking water in Araihazar district. The intervention was designed to test whether highlighting the existence of a gradient in arsenic risk—exposure risk increases with the level of arsenic and lower arsenic exposure is always better—led to better choices relative to "bright lines" information provision that focuses on whether the arsenic level is above or below the country standard of 50 parts per billion (ppb).

We find that households that received the gradient message were 50% more likely to switch (35 vs. 23%) than bright-lines households when arsenic was in the moderately unsafe range (50-100 ppb) but 40% *less* likely to do so (28 vs. 47%) relative to bright-lines households for higher levels of arsenic which characterize most of the unsafe wells in the study area. The difference of the two differences is significant at the 5 percent level. There is no evidence that, conditional on switching, households receiving the gradient message chose safer sources. We use purposely collected information on risk perceptions to help explain these partly unexpected findings. Gradient households in the moderately unsafe range were more likely to perceive the tested water as unsafe, compared to households with similar arsenic levels who received the bright lines message. Among users of very unsafe wells (As> 100 ppb) this pattern was reversed (but not statistically significant). While some of this difference in risk perceptions could be ex-post rationalization, we offer evidence that this does not explain all of the discrepancy. In the context of our intervention, providing richer risk information yielded mixed results leading to better health choices among users of moderately unsafe wells and reducing mitigating behavior among well users with very high levels of arsenic.

This paper should be a useful contribution to the literature that studies how the format of health risk information affects individual behavior. The centrality of the format both in explaining risk and in influencing health-related behaviors has been long recognized in medicine and psychology (Edwards et al. 2000). Our result that richer information did not lead to better choices is consistent with studies on the impact of risk communication in genetic counseling, where some have suggested that knowledge about genetically-related risk factors may lead to fatalism and then discourage preventative behavior for some individuals (Marteau and Lerman 2001).

Our work is also related to a large literature that evaluates the use of simple thresholds in evaluating risk. For instance, since the 1970s, prenatal diagnostic guidelines in the United States and elsewhere have suggested that amniocentesis or other forms of invasive testing should be recommended only to women aged 35 years or older or, based on more recent advances, to women whose risk of fetus chromosomal abnormality are as high as that of an average woman in that age group (NIH 1979, Haddow et al. 1994).[1] However, this approach has been criticized because it

[1]The threshold was an estimate of the mother's age at which the risk of giving birth to a child with Down's syndrome was equal to probability of a procedure-induced miscarriage.

ignores differences in couples' preferences, so that testing should instead be offered to all women irrespective of age (Pauker and Pauker 1994, Harris et al. 2004). Smith et al. (1995) conducted a randomized experiment on household response to information on radon risk in homes. They found that the combination of qualitative information and bright-lines message was associated with higher levels of radon mitigation activity relative to quantitative risk information which provided richer, but also more complex, decision guidance.

More broadly this paper contributes to the literature on the health effects of health labeling and information programs, including nutritional labeling (Kim et al. 2000, Mathios 2000, Balasubramanian and Cole 2002, Neuhouser et al. 1999, Variyam and Cawley 2006, Harnack and French 2008, Downs et al. 2009, Wisdom et al. 2010) and food consumption advisories (Shimshack et al. 2007). These studies have found that nutritional information programs can improve health outcomes, but generally only for demographic groups that are at lower risk for diet-related chronic illness, including those with more education and higher incomes. One might expect that information programs are less likely to motivate changes among populations for whom the information is more difficult to understand (proxied by education) or who have constraints that limit their ability to make different choices (proxied by income). If lower education and income are also correlated with higher risk, then higher risk individuals may respond less to risk information campaigns. Our study also finds that high risk households are less responsive to information campaigns, although in our context higher exposure to As is not correlated with lower education or with higher opportunity costs of switching (measured as the distance to the nearest safe well). So the usual rationales for the lack of impact of information programs on higher risk individuals do not hold here. We explore other explanations that focus on perceptions of risk.

In addition to complementing the literature in health labeling in industrialized countries, this paper contributes to a growing literature on the potential role of information as a policy tool to improve health in developing countries. In a series of randomized controlled trials (RCTs) in Kenya, Tanzania and Trinidad, Coates et al. (2000) show that voluntary counseling and testing reduced self-reported at-risk sexual behavior significantly more than the provision of health information alone. Using experimental data from Delhi, India, Jalan and Somanathan (2008) find that households informed of the unsafe levels of fecal bacteria in their drinking water show an increased demand for clean water relative to a control group. Thornton (2008) uses data from an RCT in rural Malawi, and finds that awareness about HIV-positive status increased threefold the likelihood of purchasing condoms among sexually active individuals, although the number of condoms purchases remained very small. In a study carried out in western Kenya, Goldstein et al. (2008) estimate that learning one's HIV status has a marked impact on women's health-seeking behavior and investment decisions. In an RCT in Kenya, Dupas (2010) finds that girls exposed to information on the age profile of male HIV prevalence led to sizeable changes in self-reported sexual behavior and to a 28% decrease in pregnancies, while no such impact was associated to standard abstinence-only HIV education curriculum. Jensen (2010) uses data from the Dominican Republic to show that information about previously underestimated returns to education reduced drop-out rates among better-off students.

The paper proceeds as follows: Section 2 provides additional background on the arsenic problem in Bangladesh. Section 3 describes the randomized intervention and the data. Method and results can be found in Section 4 and we offer interpretations of our findings in Section 5. The final section concludes.

2 Background: Arsenic in Bangladesh

During the 1970s, the Bangladesh government together with UNICEF, began encouraging Bangladeshis to switch from surface water sources of drinking water to shallow tube wells. The main purpose was to reduce exposure to bacterial contamination of surface water, which was associated with high rates of infant and child mortality (World Bank 2000). Unfortunately, it later became known that groundwater in much of Bangladesh contains very high levels of naturally occurring arsenic. The switch to tube wells has exposed millions of Bangladeshis to highly toxic levels of arsenic and has been dubbed 'the largest case of mass poisoning in history' (Smith et al. 2000).

International aid agencies and the national government are actively seeking methods to reduce exposure to arsenic in drinking water. "While solutions such as deeper (and safer) community wells are already widely implemented throughout the country, piped-water supply systems and arsenic removal filters have not yet been shown to be practical on a sufficient scale (Ahmed et al. 2006, Howard et al. 2006). In the short-term, however, the largest reductions in exposure are attributable to switching between existing wells (van Geen et al. 2002). The reason that well-switching is a promising short-term policy is that arsenic has a fairly unusual feature among natural groundwater contaminants in that its concentration can vary substantially over a small spatial area (van Geen et al. 2003). A well with very elevated levels of arsenic may not be very far from a well that has low levels of arsenic.[2]

[2] Deep wells tend to be more uniformly low in arsenic. However, the depth at which a well is likely to be safe

In 1998, the World Bank and the government of Bangladesh began a widespread program of testing and labeling tube wells called the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP). The tube wells were tested on site by field workers supervised by the Bangladesh Rural Advancement Committee (BRAC) using accurate arsenic field test kits and were offered free of charge. Wells with arsenic levels in excess of the Bangladesh health standard for arsenic of 50 ppb were labeled "unsafe" and painted red, while those with arsenic levels below 50 ppb were labeled "safe" and painted green. By 2005, about 5 million tube wells had been tested under the program. Overall, it was estimated that about one-third of the wells were contaminated, therefore about 35 million people were thought to be consuming groundwater containing arsenic at concentrations greater than Bangladesh standard of 50 ppb and about 57 million people to be consuming groundwater containing arsenic at concentrations greater than World Health Organization standard of 10 ppb (BGS/DPHE 2001). At the same time as wells were being tested, BAMWSP also began a television campaign that explained the health effects of drinking arsenic-contaminated water and advocated switching to "safe" green wells for drinking water.

Previous research in Bangladesh suggests that providing households with bright-lines (safe/unsafe) information on arsenic status of tube wells encourages widespread switching from unsafe to safe wells. In Araihazar district, Bangladesh (in locations proximate to our study areas), Madajewicz et al. (2007) found that, after controlling for confounding factors, households informed of the unsafe concentration of arsenic in their well water were 37 percent more likely to switch to a different source of drinking water within one year than others whose water tested safe. Using data from a subsequent survey in the same areas, Opar et al. (2007) documented a 50 percent increase in the likelihood of switching water sources associated with the delivery of information about unsafe arsenic levels. Such large effects of information on behavior and health may have been facilitated by the fact that the area has been the subject of an intense interdisciplinary study led by the Columbia University Superfund Basic Research Program since 2000.[3] However, in neighboring areas not covered by the Superfund study, Schoenfeld (2005) documented a still remarkable 26 percent increase in the likelihood of switching to a different water source following the delivery of test results for unsafe wells. Soumya et al. (2010) find that previously documented switching behavior in Araihazar is persistent over time, with almost no households moving back to unsafe wells.

varies from 30 meters to 120 meters in Araihazar (van Geen et al. 2003, Gelman et al. 2004).

[3]See, for instance, van Geen et al. 2002, van Geen et al. 2003, van Geen et al. 2003, Parvez et al. 2006 and Chen et al. 2007. The research program studies the health effects, geochemistry, and remediation of Arsenic and Manganese, primarily in groundwater. For more information see `http://superfund.ciesin.columbia.edu/niehsWeb/index.jsp`.

Despite the huge magnitude of the BAMWSP testing campaign, which officially ended in 2006, millions of wells remain untested (WASH Research Team 2008). In fact, new wells are being privately installed every year, while close to no testing has been carried out outside of the BAMSWP project.[4] Although it is known that arsenic concentration typically drops sharply beyond a certain depth, the "safe" well depth varies geographically and while substantial scientific progress has been made in modeling safe well depths (Gelman et al. 2004), these depths are usually unknown to the people digging new wells. In view of the possibility of future new testing campaigns, evidence suggesting which communication modes are more effective at inducing mitigating behavior can then be invaluable.

3 Description of Data and Randomized Intervention

The study took place in a 100-km^2 area of Araihazar Upazila located approximately 30 km from the capital city of Dhaka. This region has experienced several rounds of arsenic testing. First, in 2003, BAMWSP conducted arsenic tests as described in Section 2 and painted wells red or green based on arsenic content. Further, the Columbia University Superfund Basic Research Program has had an active interdisciplinary research program in this area since 2000. Schoenfeld (2005) studied 75 villages in Araihazar that had not been part of the intensive public health study initiated by Columbia University in order to test whether switching rates differed substantially in villages without a prolonged presence by the Columbia University Superfund team. While collecting the data on switching behavior analyzed in Schoenfeld (2005), field workers drew water samples from any new or previously untested well identified in the study villages. This led to water samples from 533 wells in 48 villages. Two villages were later excluded from the study because they were used to pre-test the survey instrument and train enumerators, while another was not visited because it only included a single tested well. Finally, two villages were visited at baseline but not at follow-up, because each village had a single well tested in 2005 and that well was no longer in use in 2008. Hence, overall the study uses data from a total of 43 villages.

[4] The shallow tube wells that supply the vast majority of drinking water to rural households in Bangladesh can be sunk in one day at relatively low cost. A typical 50-feet (15m) deep well cost (in PPP) approximately 50 dollars (van Geen et al. 2003). Using the 2005 ICP World Bank PPP exchange rates, this corresponds to about 1,000 Taka (World Bank 2008. See in particular page 23 in `http://siteresources.worldbank.org/ICPINT/Resources/icp-final-tables.pdf`). For perspective, in our sample we estimate that the median total expenditure per month per household at baseline was 5000 takas, that is, \$220 in PPP terms.

In 2008, we conducted a randomized intervention on risk communication as part of the effort to disseminate the results for the set of 533 wells discussed above. Our intervention focused on communicating information on the health risks from arsenic in drinking water to users of these wells. We randomly assigned villages to receive one of two different messages regarding arsenic in their drinking water. We chose to randomize at the village level in order to minimize information spillovers among households in the same village that received different messages. Villages were stratified by union and randomly assigned to treatment or control within strata, by using a pseudo-random number generator.[5]

Unlike BAMSWP, which adopted the red-green painting to communicate safety levels, our team tagged the wells with a tin plate designed within the Columbia University project. Figure 1 provides a picture of a test result plate which shows that its most visible component is a pictorial information on whether the well is suitable for drinking. The plate shows a hand holding a drinking cup that is covered by a large cross when the arsenic level is above 50 ppb (as in the case of the well depicted in the figure). The plate also indicates the year when the water sample was collected and the specific arsenic concentration detected in the water tested from that well.

The metal plate also indicates the well ID, which was used to match the test results to the tube-wells, together with geographical coordinates and records of the tube-well owners' names. The unique identification number and the geographical coordinates were used to verify whether the tube-well that was sampled was the same tube-well for which results were being distributed. This step was crucial because tube-well owners sometimes use pipes and hand-pumps from their old wells to dig a new well without removing the identification plates. Relying only on the identification numbers to identify the wells might have been misleading, because the arsenic results are relevant only for the well at the location from where the water was sampled and the results were only delivered in case of concordance.

The intervention varied how the results were orally communicated to households. Households in the "control" villages received a bright-lines message similar to that used by the Government of Bangladesh, as well as by the Columbia University team. The English translation of the message read as follows:

> The national safety standard in Bangladesh is 50 ppb (again, that is micrograms per

[5]Unions are geographic administrative units in Bangladesh. Villages are the smallest units, followed by *mouzas* that contain 2-3 villages on average and unions which contain a collection of *mouzas*. Then aggregation proceeds into *upazila* (or *thana*), districts and divisions.

> liter). That means the federal government says drinking water with more than 50 ppb arsenic is not safe. When possible you should seek to fetch drinking water from a well that is labeled safe.

Households in the "treatment" villages received a message that also provided the government standard but emphasized that if the household has a choice between two or more wells they should choose water from the well with the lowest level of arsenic, even in situations where all wells have the same binary safety status. Specifically, the message read the follows:

> The national safety standard in Bangladesh is 50 ppb (again, that is micrograms per liter). That means the federal government says drinking water with more than 50 ppb arsenic is not safe. However, we want to emphasize that whatever the level of arsenic in your drinking water now, if you have a choice of water from several wells it is better to drink water from the well with the lowest level of arsenic. For example, if you have a choice between a well with 200 ppb arsenic and a well with 100 ppb arsenic, drinking water from the well with 100 ppb arsenic is better for you. If you have a choice between a well with 40 ppb arsenic and a well with 10 ppb arsenic, drinking water from the well with 10 ppb arsenic is better for you. When possible you should seek to fetch drinking water from the well with the lowest arsenic level.

We refer to this alternative treatment as the gradient message. We have 23 bright-lines villages and 20 gradient villages with 266 bright-lines households and 267 gradient households, respectively.

3.1 Description of the Data

The data used in this paper were collected in two separate household surveys carried out in 2008. The baseline survey was completed between February and April 2008, hereafter we refer to this survey as the Wave I survey. While administering the Wave I survey, we also delivered the results of arsenic tests. As explained above, wells were identified based on information on the owner's name as well as on global positioning system (GPS) data. Interviews were then completed with the household who owned the well and also with another household who used the same well, if present. The respondent from the owner household was asked to name any other households who used the same tube well. Names were recorded in the order mentioned by the respondent and the enumerator approached the households in the order listed and interviewed the first available "user" household. In all cases, the interview was attempted with a female adult respondent and whenever possible with the wife of the household head.

In November 2008, we completed a second survey to assess household responses to the information on arsenic that was presented in the spring. We refer to this second survey as the Wave II survey. We attempted to conduct the Wave II survey with the same respondent who had completed the survey in Wave I. Data used in this study were restricted to include only respondents using a well that had not been moved from the original tested location, who were using the tested well as a source of drinking water when we administered the Wave I survey, and who completed the Wave II survey. Of the initial sample of 533 tube-wells, 434 tube-wells were located in our 43 villages in their original location. We surveyed 668 households using those 434 wells in Wave I. Of the 668 households that received well test results, 596 were using the tested tube-wells as their primary drinking-water source at the time of our Wave I survey. The Wave II survey was completed for 533 households of those 596 households (that is, 89% of the sample). To summarize, our sample consists of a balanced panel of 533 households that completed the Wave I and Wave II surveys and who were using the tested well as the primary source of drinking water when we administered the Wave I survey in Spring 2008. Attrition was balanced across experimental arms (12% in bright-line vs. 9% in gradient communities) and in both groups it was about 2 percentage points higher among users of unsafe wells, although the difference is not statistically significant.

Table 1 reports selected summary statistics measured at baseline for the 533 households in our sample. Overall, households in the sample are relatively large (5.3 members on average), with low education and relatively low income and expenditure.[6] For perspective, the mean total monthly household expenditure corresponds to approximately 262 USD, using a purchasing power parity exchange rate of 22.64 Bangladesh Takas (BDTs) per USD. Only 33 percent of household heads are literate and 21 percent have achieved at least a secondary school diploma, although enrolment rates among 6 to 14-year old is relatively high, at 76 percent. Most households (80%) make regular use of a sanitary latrine and 11 percent live in a "pukka" (good quality) dwelling.

The mean level of arsenic is 116 ppb, more than twice the threshold used by the Government of Bangladesh to identify "unsafe wells". There is also considerable variation within the sample, as shown by the standard deviation equal to 149. While the high mean is partly driven by some wells with very high levels of arsenic, the median is very high as well (80 ppb) and 61 percent

[6] Income and expenditure data are measured using simple, one-shot questions, so these estimates are likely to be measured with considerable error.

of the tested wells had unsafe levels of arsenic. Consistent with the commonly found haphazard geographic distribution of arsenic (van Geen et al. 2003, Chen et al. 2007), we find remarkable heterogeneity in arsenic contamination even within villages. The heterogeneity is evident in Figure 2, which maps the study area and shows the location of safe and unsafe wells over the territory. Dots in green depict wells that have arsenic concentrations of less than 50 ppb. Dots in red depict wells that have arsenic concentrations greater than 50 ppb.

Despite high levels of arsenic, few households self-report symptoms of arsenic poisoning. In less than four percent of households (and for 1 percent of individuals) do we find anyone reporting any symptoms of arsenic poisoning. In almost all cases, such symptoms consist of skin lesions.[7]

We have GIS coordinates for all wells used in this study and all wells tested by BAMWSP in 2003. For all of these wells, field workers also recorded whether the arsenic content was above or below the national standard (50 ppb) which allows us to calculate the distance to the nearest known safe well from each well in our sample.[8][9] The specific arsenic content of the well is only known for the subset of wells whose tests results were delivered in April 2008. For each well we can therefore calculate the distance to the nearest well that is known to be safer. Note that, even though we do not have the complete set of arsenic levels for all wells in the village, the information in our data set should coincide with the information used by respondents in deciding where to fetch water, because the actual arsenic content of the BAMWSP tested wells is known neither to us nor to households in the study area. In fact, recall that BAMWSP did not communicate the exact arsenic level but only labeled tested wells using the red-green binary format. The average distance to the closest well below 50 ppb is 75 meters and the average distance to the nearest well with lower arsenic is 86 meters. All distances are measured as-the-crow-flies.

We also asked respondents about other households they knew whose wells were tested in the past. The variable "network size" captures how many neighbors the respondent was able to recall whose well they knew had previously been tested. On average, households knew one other household with an arsenic test (mean=1.3).

[7]In neighboring areas in Araihazar, Ahsan et al. (2006) estimated a 6% prevalence of clinically-diagnosed skin lesions in a sample of 11,746 individuals.

[8]Wells that are safe are given a distance of zero.

[9]There have been new wells dug since 2005 and some of those wells may have been tested by private companies. Private testing is rare, however, and no additional testing were done by BAMSWP or Columbia University in this area after 2005. So, although it is possible that there may be a few tested wells that are not in our sample, we do not expect there to be many. Hence, the closest safe well that is know to us is very likely to be the closest safe well that is known to the household.

An important component of the survey instrument was designed to measure perceptions about the health risks posed by arsenic. Beliefs about arsenic risk were elicited by posing a series of questions to the respondent about future events-asking respondents to express how likely they thought the described event would occur by counting physical objects. Each respondent was given 10 marbles and a plastic cup and asked to put more marbles into the cup if she felt the perceived event was more likely. After each question was asked, the cup was emptied so that the respondents started each question with 10 marbles and an empty cup.[10] This method was used to elicit respondents' beliefs about health risks from drinking arsenic from a generic hypothetical "unsafe well." Each respondent was asked to think of a well that had "just the amount of arsenic that the government says is unsafe." She was asked to think about a family that had been consuming arsenic-free water so far, but had switched to this hypothetical "unsafe" well on the day of the interview. The respondent was then asked about the chances that an adult from this family would develop skin lesions by drinking water from this well within alternative time horizons of 1 month, 1 year, 5, 10 or 20 years. She was also asked similar questions about the chances that an adult would develop "serious health problems," defined as health complications that would impede normal daily activities. The same questions were asked in the Wave I and Wave II surveys. In the baseline interview, these generic-well beliefs were elicited before the respondent was given her well test results.

In general, the beliefs data indicate that households understand the cumulative nature of arsenic risk. Mean levels of concern increase with time of exposure. Moreover, concern levels are relatively high for serious health consequences over long time horizons. The average subjective probability of an adult developing serious health consequences after drinking unsafe water for 10 years was 67% and over 20 years was 89%. In column 5 and 6, Table 1 also contains differences in means of observable characteristics among treatment and control households and the p-values of the tests of equality between groups. The tests, like all the regression estimates that will follow in the paper, are robust to the presence of intra-village correlation. Randomization was overall successful in balancing the 23 observed characteristics among experimental arms. The null of equality between arms is never rejected at the 5% level, and in only one case (mean value of food monthly consumption) at the 10% level.

Importantly, there are no statistically significant differences in arsenic levels between arms. The difference in mean arsenic levels between the two groups is 16.5 ppb (p-value 0.6). Even though the

[10] Similar methodologies for eliciting beliefs have been successfully adopted in other low-literacy context and are becoming more commonly used in surveys. See Delavande et al. (2010) for a survey of their use in developing countries.

mean arsenic levels are similar we may be worried about other differences in the arsenic distribution between treatment and control households. Figure 3 provides the distribution of arsenic for the two groups and the distributions look quite similar.[11] To test for equality of the distributions more formally, we divided arsenic levels into six bins and ran a Pearson's chi-squared test.[12] The p-value on the test is 0.52 indicating that we cannot reject the null hypothesis of equality of the arsenic distributions. The null is also not rejected if we test the equality of distributions only for unsafe wells (p-value=0.14).

3.2 Outcomes of the Intervention

The primary outcome of interest is whether households that receive the continuous risk message are more likely to move away from an unsafe source of drinking water. In the Wave II survey, households were asked whether they continued to use the well they had been given results for. If the respondent said her household was now getting drinking water from a different source, then the variable SWITCH was coded as a 1 and if the household was using the same well the variable SWITCH was coded as a 0. Of the 326 households using wells with arsenic greater that 50 ppb, 115 (that is, 35 percent) switched sources. Of the 207 households using wells with arsenic less that 50 ppb, only 15 (7 percent) had switched. When a respondent said they were using a new source, the survey enumerator actually went with the respondent to the new source. Thus, we feel confident that self-reported switching actually measures real changes in behavior. Indirect evidence supporting this view is also provided by earlier studies completed in areas proximate to our study locations, which showed significant declines in arsenic exposure (as measured through urinary arsenic concentration) in households who reported having abandoned the use of an unsafe well for drinking water (e.g. Chen et al. 2007).

An additional important question, which cannot be addressed with the binary switching outcome, is whether the gradient message affected the "quality" of switches, by enabling households to seek water from wells with the lowest level of arsenic. To examine this we would like to compare changes in arsenic exposure in gradient and bright-lines villages. However, in our sample we do not know the change in arsenic exposure for all households that switch water sources. The enumerator accompanied the respondent to the new source of drinking water and recorded any available information on arsenic. The records include the actual arsenic level (if the source was a well tagged with

[11] The levels of arsenic were truncated at 750 to allow for clearer comparisons of the distributions. Only three households were affected by this truncation and all three are in treatment villages.

[12] The intervals that delimit the bins are as follows: [0,0.1], (0.1,50), [50,100), [100,200), [200,400) and As> 400ppb.

a tin plate) or the color of paint on the well spout (if visible). Of the 125 households that switched wells between Wave I and Wave II, we know something about the arsenic level for 49 of them (just under 40%). Among those 49 wells we know the actual arsenic level of 25 and the color of the well for 24. We then categorize the switch as "beneficial", "harmful" or "unknown". If we know the arsenic level of the new well then we compare the arsenic level of the new and old well to determine whether the switch was beneficial or harmful. If we only know the color of the new well then we code the switch as beneficial if the old well had an arsenic level greater than or equal to 50 and the new well is painted green, while we code the switch as harmful if the old well had an arsenic level less than 50 and the new well is painted red. If the old well had an arsenic level greater than or equal to 50 and the new well is painted red then we categorize the switch as unknown (same if the old well was below 50 and the new well is green). Finally, we also categorize the switch as unknown if the household switched to a new well for which we have no information.

Even when we do not know the actual arsenic level of the new well, we might be able to make some inferences on whether the switch is health-beneficial. For example, if a household switches from a well at the 99^th percentile of the arsenic distribution, a move to a different well, even if the new well were chosen randomly, would very likely lower the household's arsenic exposure. Based on this intuition, we construct a simple village-specific model of arsenic in order to estimate changes in arsenic exposure for all households who switch to a new well. Changes in arsenic exposure were calculated directly for households for whom we knew the actual arsenic level of the new well. For households for whom we do not know the actual level, but do know the color, we assign to the new well the median level of arsenic in that village for that color. In other words, if the new well was red, we impute the median arsenic level for all wells in that village with arsenic above 50 ppb. If we know nothing about the new well we assign the well the median level of arsenic for the village. Thus, for every household that switched wells we have an estimate of the change in arsenic exposure. We use this estimate as an additional outcome.

4 Methods and Results

4.1 Well Switching Choices

We first use linear probability models to examine switching decisions. Our main regressor of interest is whether the household received the gradient message. We also include in our base specification the level of arsenic in the well, and we hypothesize that the higher the level of arsenic the more likely the household is to switch wells, consistent with the findings in Madajewicz et al. (2007) and Opar et al. (2007). We also include an interaction term between gradient and arsenic level that allows for the effect of the gradient message to vary over different levels of arsenic. In theory, our risk communication message could affect the frequency of switching among households that use wells with any positive level of arsenic. Indeed, one of the motivations for the emphasis on the gradient in arsenic risk was to encourage people using "safe" wells to lower their arsenic exposure further. However, we find very little switching among households using wells with less than 50 ppb arsenic (safe wells). Specifically, there are only 15 of 207 households (7%) with arsenic less than 50 ppb that switch sources. Of these 15 switches, only 3 claimed to have switched wells for reasons related to arsenic (2 households in bright-lines villages and 1 household in a gradient village). Thus, even though treatment could have an effect in that part of the arsenic distribution, our data lack sufficient power to test for the existence of such an impact. We therefore focus on explaining switching behavior among households who were using an unsafe well at baseline, who are anyway the most exposed and therefore relevant population. Our specification is given by:

$$SWITCH_{iv} = \beta_0 + \beta_1 GRADIENT_v + \beta_2 \ln(As_{iv}) + \beta_3 GRADIENT_v \times \ln(As_{iv}) + \beta_4 X_{iv} + \varepsilon_{iv}, \quad (1)$$

where $SWITCH_{iv}$ is a binary variable that takes a value of 1 if the household i in village v switched wells after being informed about the (unsafe) status of the well in April 2008, $GRADIENT_v$ is the binary variable that takes a value of 1 if the household is in a village that was assigned to the gradient message, As_{iv} is the arsenic level of the household's tested well, X_{iv} is a vector of covariates and ε_{iv} is the error term.[13]

The interaction term in equation (1) allows for the effect of treatment to differ across the arsenic distribution. In principle, differences in arsenic levels could be correlated with different forms of unobserved heterogeneity, if households were sorting on arsenic level. In locations proximate to our study areas, Madajewicz et al. (2007) find no evidence of correlation between arsenic and several observed covariates. In Table 2, we show how tubewell arsenic levels, or a dummy for "unsafe well" (that is, As $>$ 50 ppb), correlate with a series of household characteristics. There is a weak relationship between household characteristics and both unsafe status and the precise arsenic level. The R-squared on the regression is only 0.03 in both regressions and we cannot reject the null hypothesis that all slopes are equal to zero in both models. The monthly amount spent on food is statistically significant in the unsafe regression, although the coefficient is small. Increasing

[13]One concern about linear probability models is that it may produce predicted probabilities that are outside the unit-interval. For the switching model, all of the predicted probabilities are within the unit interval.

monthly food expenditure by 3,000 Takas (about one standard deviation) decreases the probability of using an unsafe well by 6%. In the model on arsenic levels, the age of the head of household is statistically significant, but again relatively small. Increasing the age of the head of household by 1 year increases the arsenic level by only 1 ppb. Overall, the poor fit of a model including many important observed covariates provides little evidence of sorting on arsenic and we conclude that the interaction of gradient and arsenic can be treated as exogenous.

The results of the impact of the gradient message on well switching can be found in Table 3. The first column contains the base specification that includes the gradient variable, the level of arsenic in the well, and the interaction of gradient with the arsenic level. For households in the bright line group, the probability of switching increases the higher the level of arsenic in the well. An increase in arsenic from 50 to 100 ppb is associated with a 19 percentage points increase in the probability of switching to an alternative source. The effect of the risk message intervention is more complicated. The coefficient for the gradient message itself is positive and significant, but the interaction with the (log of) arsenic level is significant as well. The model predicts that households just at the safety threshold of 50 ppb were 22 percentage points more likely to switch with the gradient communication mode relative to those in the bright line group. However, with a high arsenic level of 200 ppb, the difference in predicted switching rates reverses sign and becomes -0.22. The value of arsenic where these two effects cancel out (so that the effect of the gradient message is exactly zero) is 101 ppb. Given that the median value of arsenic (for the unsafe part of the distribution) is 138 and the mean is 181, the effect of the gradient message is then *negative* for most households.

Because the estimates may be partly the result of the choice of a specific simple parametric model, we also evaluate the impact of the gradient message using non-parametric methods. We estimate switching rates conditional on arsenic using non-parametric locally linear regressions (Fan 1992). We choose a relatively small bandwidth (equal to 50 ppb) in order to highlight the data-driven shape of the regressions. For each regression, we also display 90% confidence bands estimated using 250 bootstrap replications. We use block-bootstrap to reflect the clustered nature of the data, so that in each replication we re-sample clusters of village-specific observations rather than households. For each point on a grid of arsenic levels, we construct the lower and upper bounds of the 90% confidence band by selecting respectively the 5th and 95th percentile from the bootstrap distribution of 250 point-specific estimated regressions.[14]

[14] The bands are very similar if we estimate the upper and lower bounds by adding and subtracting 1.645 times the

The non-parametric regression of switching decisions as a function of arsenic for bright-lines and gradient villages are shown in the top two panels of Figure 4. In areas where the bright-lines message was used, switching rates are close to zero at arsenic levels close to the safe threshold of 50 ppb, and only become substantially larger than 20% for arsenic levels above 100 ppb. Switching rates then increase visibly with arsenic levels up to 160 ppb and then stabilize around 40-50%. The shape of the regression is significantly different in gradient villages. First, almost half of households are estimated to switch for arsenic levels close to 50 ppb, which actually represents the peak over the arsenic range in the graph. Second, we find no evidence of increased switching for higher levels of arsenic. On the contrary, the regression suggests *declining* switching rates for high levels of arsenic. The stark difference between the two lines is highlighted in panel C of Figure 4, where we display both regressions. Finally, in the bottom-right panel D, we display the difference between the gradient and binary regressions together with 90% confidence bands. The difference shows a marked declining pattern relative to arsenic levels. Although estimation error is large enough that we cannot reject the null of equality over most of the arsenic range, the difference is positive, large (about 40 percentage points) and statistically significant in a neighborhood of the safety threshold of 50 ppb and negative, large (about 35 percentage points) and significant for high arsenic levels around 250 ppb.

Overall, the non-parametric estimates are consistent with the OLS results in Table 3 and again suggest that the different risk communication messages led to strikingly different behavior among users of moderately unsafe and very unsafe wells. To ensure that these results are robust we try several other parametric specification and the results can be found in columns 2-4 of Table 3. In the second column, we show that the inclusion of several observed household characteristics leaves the results essentially unchanged. This robustness check is important, because although randomization should balance observed and unobserved covariates across the whole sample, the balance is less likely to hold along all parts of the arsenic distribution in a small sample. If that is the case, the treatment interaction may actually measure differences in covariates. Columns 7 to 10 of Table 1 compare the means of observed covariates among gradient and bright-line households separately for households using moderately unsafe or highly unsafe wells. There are, in fact, a number of statistically significant differences in mean levels of observed covariates once we restrict the sample to these categories. Among users of moderately unsafe wells, the mean level of arsenic for gradient households is five ppb lower than for bright-line households (p-value = 0.063). However,

As-specific standard deviation of the 250 bootstrap estimates.

the magnitude of the difference is small. The null of equality is also rejected at the 10% level for literacy, number of females in the household, fraction of children enrolled in school, well network size and availability of a sanitary latrine. Among users of highly unsafe wells, we find that statistically significant differences for medical expenditure (lower in bright-line households) and also in arsenic levels, where the mean is on average 79 ppb *higher* in wells from gradient communities. Note that if anything this latter fact should have expected to lead to a relative increase in switching, while we find that gradient households using highly unsafe wells are less likely to change source of drinking water relative to others in bright-line communities.

We also examine whether differences in prior subjective arsenic-related health risk perceptions from arsenic could explain the treatment effect findings. In column 3 of Table 3 we include two measures of risk perceptions. The first is a short-term measure which is the average of the respondents' answers to questions about the likelihood that an adult would experience "serious health problems" from drinking water from a generic unsafe well over a one month and one year period. The second measure is a long-term measure which is the average of the respondent's answers to questions about the likelihood that an adult would experience "serious health problems" from drinking water from a generic unsafe well over a 10 year and 20 year period. We also include both of these terms interacted with the log of arsenic. Only one of the risk measures is statistically significant—households with higher levels of concern about the long-term health effects of arsenic and who have higher levels are arsenic are more likely to switch. However, including these perception measures in the regression does not change the pattern of the intervention impacts.

The inclusion of additional covariates addresses potential differences in observed characteristics, but we might still be concerned about unobserved heterogeneity at the village level. Since we cannot use village-level dummy variables in a model with village-level treatments, we explore this possibility in other ways. First, we look at geographic patterns of switching behavior among respondents using an unsafe well at baseline. Figure 5 presents the percentage of households that switch by village, where the orange circles represent treatment villages and the blue circles represent control villages. The larger the circle, the higher the percentage of households using an unsafe well at baseline that switched to a new well. Switching does happen across the study area, but there a few areas where high levels of switching appear to be spatially clustered. To control for unobservable covariates that might determine switching behavior in some spatially correlated way, we include strata dummy variables. This will capture most of the spatial clustering that we can see visually on the map. These results are presented in column 4 of Table 3. The estimated effect of the intervention remains substantially unchanged, although both the relevant coefficients are closer to zero relative to the basic model in column 1.

Overall, then, with respect to switching decisions, it appears that receiving a message emphasizing the gradient between arsenic exposure and arsenic risk and encouraging the selection of a well with lower levels of arsenic does not have a uniform effect. Receiving the gradient message increased the likelihood of switching only for a small set of households with moderately unsafe arsenic levels (50-100 ppb). For households using water from these wells, switching rates are 35 vs. 23% for the gradient and bright line communication mode respectively. That is, switching rates are about 50% higher in gradient relative to bright-lines areas, although the difference is not significant at standard levels (p-value = 0.276). Among households with higher arsenic exposure, the rates are instead 28 vs. 47% in the two groups, that is, they are about 49% *lower* in gradient relative to bright-lines areas, and the difference is significant at the 5% level (p-value = 0.016). This pattern is robust to specification choices.

4.2 Change in Arsenic Exposure

Even though we find that less switching happened at higher arsenic levels in gradient villages, it is still possible that, conditional on switching from an unsafe well, households in these villages chose safer alternatives relative to switchers in bright-line areas. Table 4 contains a summary of "beneficial", "harmful", and "unknown" switches in gradient and bright-lines villages, where the switch "types" are described in Section 3.2. There are more beneficial switches in bright-lines villages, but the percentage of all switches that are beneficial is roughly the same in gradient and bright-lines villages (25% in gradient versus 28% in bright-lines). A Person's chi-squared test cannot reject the null hypothesis that there is no difference in switching patterns by intervention (p-value of 0.41). Furthermore, using our estimated changes in arsenic exposure (see Section 3.2), the average decrease in arsenic exposure among switchers in gradient villages was 70 ppb and in bright-lines villages the average decrease was 91 ppb. However, this 21 ppb differences is not statistically significant (p-value of 0.44 adjusting for clustering at the village level). We also examine the pattern of switching among moderately unsafe households (50-100 ppb) and very unsafe households. While the percentage of beneficial switches among the very unsafe households in bright-lines villages was slightly higher than among gradient villages (34% versus 30%), this difference is not statistically significant.

To more explicitly estimate the effect of the gradient message on change in arsenic exposure, we estimate regression models similar to (1), but with change in arsenic as the dependent variable, and including only information from households who stopped using an unsafe well. Column 1 in Table 5 contains regression results for a model where the change in arsenic level (a positive change indicate a decrease in arsenic exposure) is regressed on gradient, (log) arsenic and their interaction. In column 2, we also estimate a specification that includes a full set of control variables and strata dummies. In both specifications, the effect of the gradient message is small and not statistically significant. The point estimate for the gradient variable in the full specification is 56 ppb and the p-value is 0.79, while the point estimate of gradient interacted with log of arsenic is -12 with a p-value of 0.78.

While there are many switches for which we do not have precise changes in arsenic exposure, overall we cannot reject the hypothesis that switches were equally health-beneficial in the two experimental groups.

5 Interpretation of Observed Behavioral Responses

The results described so far have shown that the more complex gradient message had the desired effect of increasing switching rates relative to the standard bright-lines format only for moderately unsafe levels of arsenic. Among users of very unsafe wells, the simpler bright-lines message appeared to be more effective at promoting switching. This pattern of results survives several specification checks and additional hypothesis tests and is therefore hard to dismiss as purely spurious. In this section we use specifically collected data on arsenic-related knowledge and risk perceptions to test several possible explanations for the pattern of switching responses.

5.1 Differences in Risk Perceptions at Baseline

The first hypothesis for these findings is that, immediately after the test results were conveyed, households' understanding or perception of the safety of the well water differed across the distribution of arsenic, as a function of the communication mode. In particular, we examine whether respondents from households in the bright lines group are less likely to recognize their well as unsafe when the arsenic is in the moderately unsafe range, but more likely to do so when the arsenic concentration increases. We do not find much support for this hypothesis. Shortly after communicating the arsenic level, the surveyors asked whether the respondent considered the well's water safe to drink. The results, in Table 6, show several clear patterns. First, a sizeable number of respondents do not appear to understand or believe the information just delivered to them. Of a total of 533 households, only 326 (61%) correctly assessed whether their well was safe or unsafe based on the actual arsenic level we had just given them and the Bangladesh standard of 50 ppb which had also just been presented. Second, the concordance between test results and responses is significantly stronger when we delivered "good news": more than 80% of respondents (=(78+92)/(96+111)) correctly identified their well as "safe" when the result indicated an arsenic level below 50 ppb, while only 48% (=(15+20+63+58)/(52+57+118+99)) immediately recognized the water source as unsafe when the arsenic level is above the threshold. Third, the proportion of respondents who mistakenly identified unsafe wells as safe is much lower among users of highly unsafe wells (35% of households with As $>$ 100) relative to users of moderately unsafe wells (65% of households with 50 $\leq$ As $\leq$ 100). Fourth, conditional on actual safety, the communication mode does not appear to have influenced perceptions much, although among users of unsafe wells, the bright lines message led to a slightly lower fraction of wells correctly identified as unsafe relative to the gradient message (46 vs. 50%). However, the difference is small enough that the null hypothesis that the distribution of responses is independent of the communication mode (conditional on actual safety status) is not rejected at standard levels. Finally, the figures in columns 3 and 4 show that the probability of a correct safety assessment is also very similar between experimental groups when we only look at households whose well-arsenic is between 50 and 100 ppb. Thus, the results in Table 6 suggest that the large gap in switching rates between gradient and bright lines messages among users of moderately unsafe wells does not appear to be explained by differences in understanding or perception of well safety immediately following result delivery.

Similarly, the communication mode had only a marginal impact on the self-reported likelihood of a switch to a safer source of drinking water within a year (not reported in the table). The likelihoods were recorded immediately after the question about the perceived safety status of the well, by asking the respondent "in your opinion, how likely are you to switch to a safer source of drinking water over [the next year]?" Perceived probabilities were elicited using physical objects as described in Section 3. Among households with a moderately unsafe well, the mean perceived probability of moving to a safer well was only 15 and 18% for the gradient and the bright lines communication mode, respectively.[15] As a reminder, these figures considerably underestimate the actual switching rate among households in the gradient group (35%), while they are close to the

[15]Similar questions were also asked with a 1, 3 and 6-month horizon. As expected, predicted switching rates were even lower at these shorter time intervals.

actual figure for the bright lines group (23%). The perceived likelihood of switching remains very low when we look at households exposed to water with As > 100 ppb, for which the figures are 15% and 21% for gradient and bright lines, respectively. Note also that, at these latter exposure levels, the immediate stated intentions do reflect the reality, documented at follow-up, that a smaller fraction of households changed source among those who received the gradient message.

5.2 Differences in Risk Perceptions at Follow-up

In reality, it is likely that the immediate respondent's reactions to the provision of information is only a noisy representation of all the elements taken into account by households when making decisions about where to fetch drinking water. The test results are likely to be discussed with other family members (especially the male head), and both comprehension and risk perceptions are likely to change as a consequence. For this reason, we next consider knowledge and perception data collected during the follow-up survey, completed 7-9 months later. A first notable observation is that, despite the information provision, more than 90% of respondents still do not know the exact threshold for safety (row A in Table 7), regardless of actual well safety status or communication mode. Indeed among the 533 panel households, 480 respondents literally said they did not know the threshold, while only 23 recognized the correct figure. Separate questions then asked how the respondent would choose where to drink if given the choice of two wells both labeled "unsafe" (row B) or "safe" (row C). Overall, we find that the gradient message, against our expectations, did not lead to better decision making: for users of both moderately and highly unsafe water, a *higher* fraction of respondents incorrectly stated that it makes no difference, because all (us)safe well are equally (un)safe, although the differences are not statistically significant. As an aside, note also that indifference is expressed more frequently in the choice between two safe wells (about 60-70% of cases, row C) than in the choice of wells with As > 50 ppb (about 40-50%, row B). Taken together, the findings in rows A to C provide some mild evidence in favor of the hypothesis that the more complex gradient message "confused" people leading to worse choices.

Next, additional and more pertinent information is provided by direct questions about the perceived safety of the tested water (row D). Almost all respondents recognize correctly the "safe" status of wells whose water indicated arsenic concentrations below 50ppb. However, a large number of respondents incorrectly identified as safe water from wells above the threshold. Consistent with the higher switching rates among users of moderately unsafe water who received the gradient message, we find that the unsafe status is correctly identified by 60% of respondents, while this happens in only 44% of the cases in the bright lines group. The difference is significant at the 10% level (p-value= 0.074). This result is perhaps not surprising, given that, without the emphasis on the gradient, users of moderately unsafe wells may be led to think that their water source is close enough to be safe that no mitigation is necessary. Again consistently with the patterns apparent from Figure 4 (see also row E in Table 7), the fraction of respondents who correctly identify the unsafe status among users of highly unsafe wells is instead lower when the gradient message was used, although the difference in this case is very small (70 vs. 76%) and not significant.

Overall, perceptions about safety status measured at follow-up are then broadly consistent with the unexpected switching patterns we have described. An important caveat, however, is that we cannot exclude that such consistency can be at least partly ascribed to ex-post rationalization. That is, some respondents may state or actually convince themselves that an unsafe well does not pose a health risk as a way to justify the choice to keep using it. On the other hand, if at all present, such ex-post rationalization was not a universal phenomenon. In fact, we find that among the 215 households who were still using an unsafe well at follow-up, 133 (62%) recognized that the well water was unsafe to drink. The proportion is almost identical between the two arms: 64% with bright lines and 60% with gradient.

5.3 Discouragement

Another possibility is that inactivity among users of highly unsafe wells is due to discouragement: the emphasis on the gradient may have induced some of these users to believe that past exposure had already been so heavy to make a switch to a safer source pointless, despite the explicit suggestion to move contained in the gradient message.[16] However, such hypothesis is largely inconsistent with the figures in Table 7. First, respondents in the gradient group are actually less likely to recognize that the choice between two unsafe wells is a choice of consequence for their health (row B, columns 5 and 6). Second, as we have mentioned, such respondents are also less likely to recognize the water as unsafe, although the difference relative to bright lines is very small. Finally, information on the reasons for not switching to a safer source collected at follow-up is also not consistent with this hypothesis. A majority of the 137 users of highly unsafe wells justified the choice not to switch on grounds of safety perceptions and distance, and not on the basis of other concerns. The proportion

[16] Until recently, medical studies suggested that all-cause mortality and certain cancer risks may take decades to decline after exposure to arsenic has dropped, Chang et al. (2004), Yang et al. (2005), Argos et al. (2010). However, by tracking a large cohort over 7 years in Araihazar, Chen et al. (2010) found that substantial reductions in exposure were associated with a 60% reduction in the risk of death from cardiovascular disease relative to a control group.

is indeed even higher (68%) in the gradient relative to the bright lines group (58%). Although our data do not separately indicate whether "other" included responses such as "it is too late for risk mitigation", these results overall do not support discouragement as a compelling explanation for the lower switching rates among users of highly unsafe wells in the gradient group.

6 Conclusions and Discussion

The cluster randomized controlled trial described in this paper was designed to test if providing households with more detailed information on the gradient between arsenic exposure and arsenic risk could induce more households to switch well sources than the standard bright-lines "safe/unsafe" risk presentation. We find evidence of this effect only for households using moderately unsafe wells (arsenic between 50 and 100 ppb), where the observed switching rates are 50% higher (35 vs. 23%), although not statistically significantly so, in areas where the gradient communication mode was used relative to bright-line communities. However, for users of wells with higher arsenic concentrations (where the bulk of the arsenic distribution is, also encompassing its mean and median), the effect of the gradient message is to decrease switching. For wells with arsenic levels above 100 ppb the fraction of users moving to an alternative source is 40% *lower* (28 vs. 47%) in areas where we used the gradient relative to locations where the standard bright-line message was adopted. This latter difference is statistically significant at the five percent level.

Even though there was less switching in gradient villages, it could still have been the case that the switching that did happen led to greater reductions in arsenic exposure. We examined whether there were any differences in the estimated level of arsenic exposure reduction and found no evidence that switching in gradient villages resulted in greater reductions in arsenic exposure relative to switching in bright-lines villages.

The pattern of switching behavior is remarkably consistent and robust to specification checks. While we cannot fully explain the pattern, it is broadly consistent with data collected on perceptions of risk from arsenic. Immediately following provision of results there is no statistical difference in risk perceptions among the bright lines or gradient groups for users safe, moderately unsafe, or very unsafe wells. By the follow-up survey, seven to nine months later, differences in risk perceptions had developed. In particular, gradient households in the moderately unsafe range were more likely to perceive that the water from their well was unsafe compared to households with similar arsenic levels who received the bright lines message. Among users of very unsafe wells this pattern was reversed (but not statistically significant). While some of this change in risk perceptions could be ex-post rationalization, we offer evidence that this does not explain all of the differences in perception. Taken together these results suggest that conveying information about the continuous nature of arsenic risk may not lead to increases in health-improving behaviors and may actually have the opposite effect for the most at-risk population, at least in the short-term (less than one year).

There are three important caveats for our findings. First, the bright-lines safe/unsafe message is prevalent throughout Bangladesh and certainly households in Araihazar had been accustomed to hearing information about arsenic in the safe/unsafe format. While our findings, that the gradient message did not result in greater rates of health-improving behavior among the most exposed households, may well hold for Bangladesh, it may not hold in other settings where the bright-lines message is not already dominant.

Second, our intervention was limited in scope. Presentation of the gradient in arsenic risk was limited to oral information given to respondents when the test results were displayed. The test result plates themselves focus largely on the safe/unsafe message and these plates were the same in both gradient and bright-lines households. A more sophisticated presentation of the gradient in risk, perhaps gradients of colors or a bar that represents the level of arsenic in the well relative to others in the village, may have greater impacts.

Third, we examine switching choices over a relatively short time horizon. The time between our baseline and follow-up surveys was less than one year. In other work (Soumya et al. 2010) we find that switching away from unsafe wells does not always happen in the short-term after results are provided. Soumya et al. (2010) find significant numbers of households that switch off unsafe wells more than two years after they are first informed that they are using an unsafe well. The effect of gradient information may take time to have an impact.

Our results are consistent with previous work on health labeling and risk communication which has found that these information-based programs may be least effective among higher risk individuals, although we have argued that in our context arsenic risk is largely exogenous to the household. Our intervention was successful at inducing a large relative increase in switching from unsafe wells among users of moderately unsafe sources, but the opposite was true for higher exposure. Given the vast magnitude of the arsenic contamination problem in Bangladesh, as well as in other parts of the world, further research is clearly needed in order to develop more effective health risk communication strategies.

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Figure 1: Tubewell and Test Result Plate

The picture shows an example of the black-and-white plate used to communicate results: the plate indicates the well I.D., the year when the water sample was taken, the arsenic level and a hand holding a drinking cup, in this example crossed because the arsenic level (336ppb) is above the safety threshold. The smaller, stainless steel, plate visible above the black-and-white one indicates the well I.D. and was attached to the well in 2005, at the time of the water sample collection.

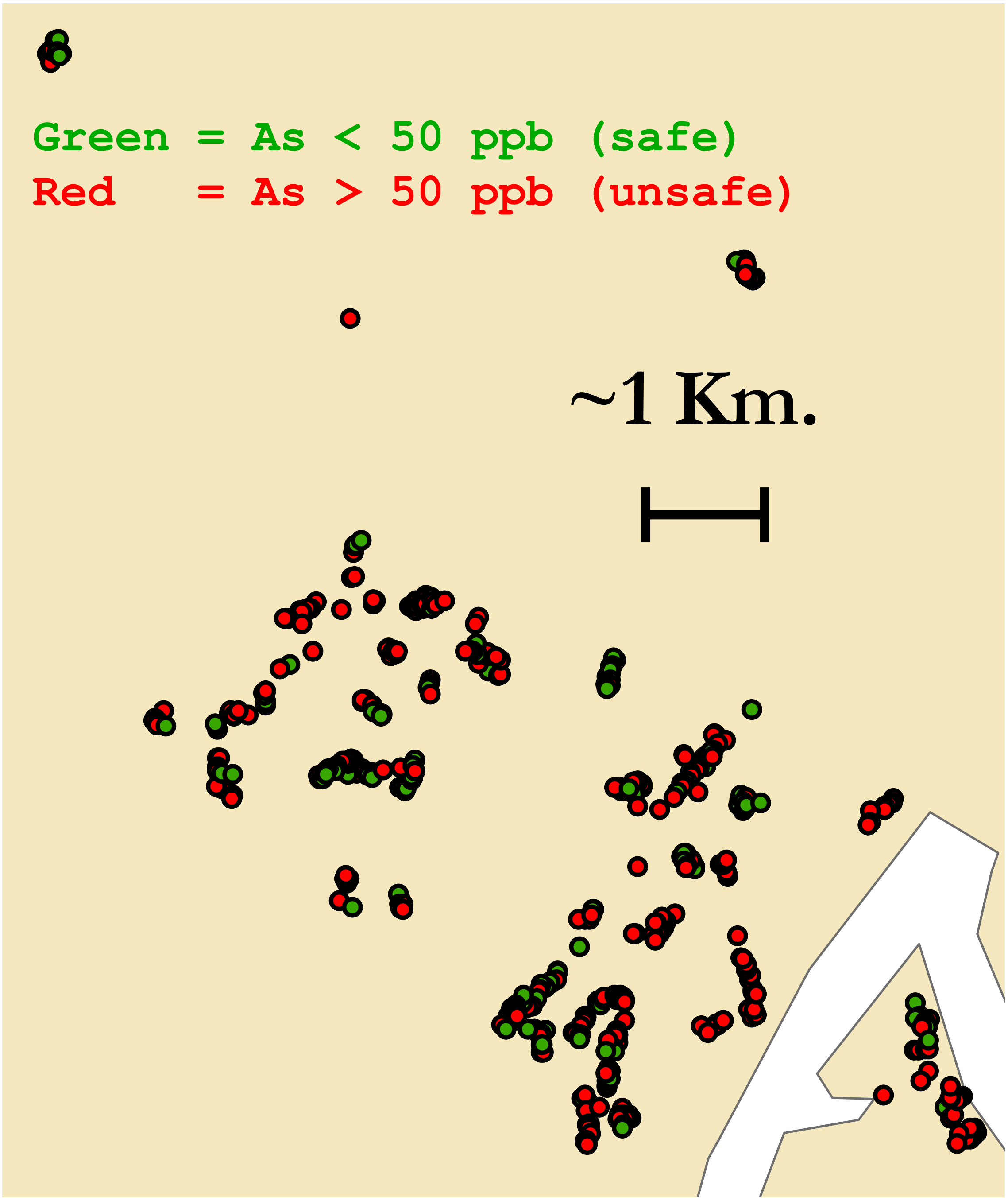

Figure 2: Spatial Distribution of Arsenic in Study Area

The picture shows an example of the plate used to communicate results: the plate indicates the well I.D., the year when the water sample was taken, the arsenic level and a hand holding a drinking cup, in this example crossed because the arsenic level (336ppb) is above the safety threshold.

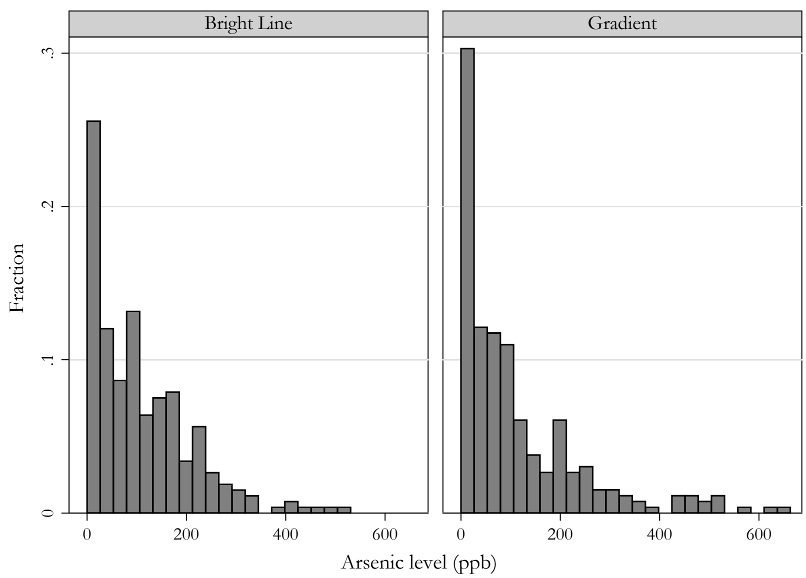

Figure 3: Histogram of Arsenic Levels by Treatment

Histograms exclude 3 observations for which the arsenic level was above 750ppb.

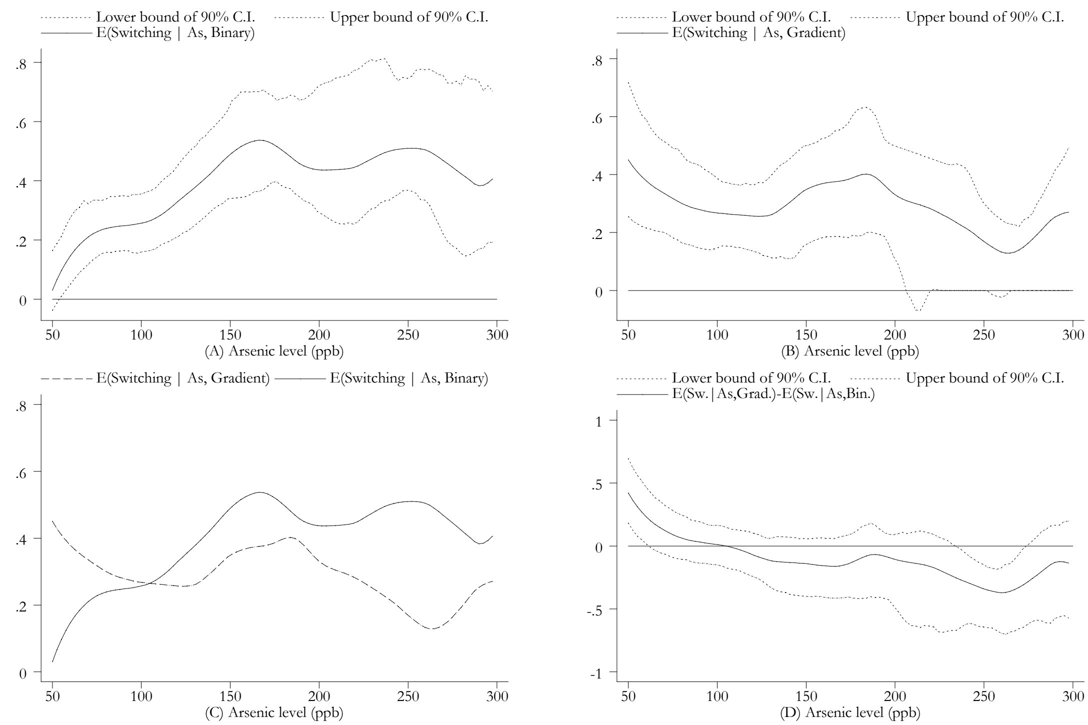

Figure 4: Histogram of Arsenic Levels by Treatment

Source: Author's estimates from Wave II (post-intervention) data. We estimate all regressions using non-parametric locally linear regressions (Fan 1992), with a bandwidth equal to 50ppb. The top two panels show switching rates conditional on arsenic levels for unsafe wells in the bright line (graph A, $n = 170$) and the gradient (graph B, $n = 156$) experimental arm respectively. The two graphs are overlapped in panel C. Panel D shows the estimated vertical distances between the two graphs, with 90% confidence bands estimated using block-bootstrap replications. We construct the bands by selecting respectively the 5th and 95th percentile from the bootstrap distribution of 250 point-specific estimated regressions.

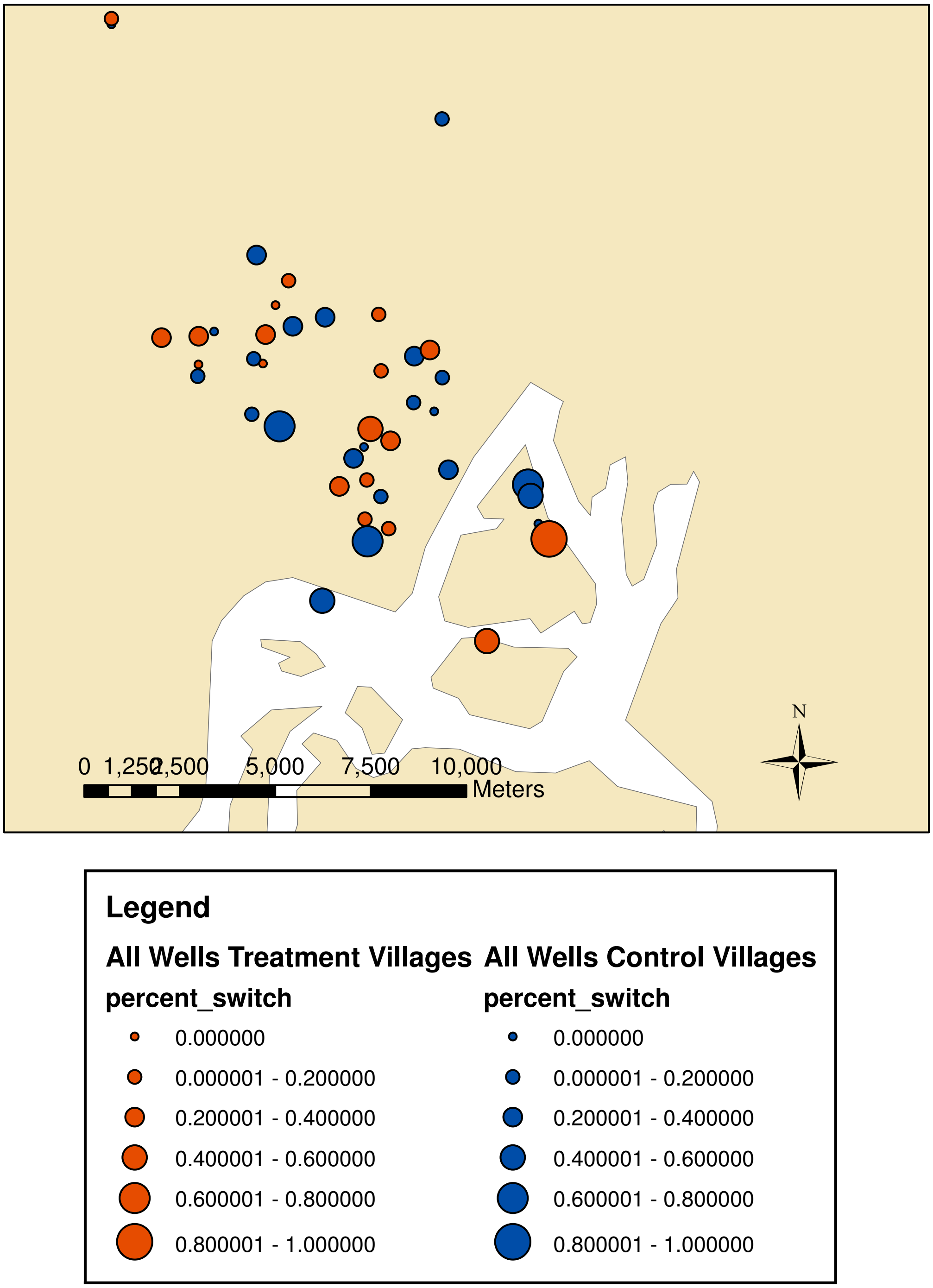

Figure 5: Spatial Distribution of Households Switching Off Unsafe Wells

Source: Author's estimates from Wave II (post-intervention) data.

Table 1: Baseline Summary Statistics and Randomization Tests

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
					Difference between experimental arms (Gradient − Bright-line)[3]					
					All		Moderately unsafe $50 \leq As \leq 100$		Highly unsafe $As > 100$	
	Obs	Mean	Median	Std Dev	Mean	p-value	Mean	p-value	Mean	p-value
Well Arsenic Level	533	116	80	149	17	0.60	-4.9	*.063	79	**.029
As > 50 ppb	533	0.61	1	0.49	-0.06	0.62	N/A	N/A	N/A	N/A
# Household members	533	5.30	5	2.50	0.09	0.75	-.12	.82	-.11	.77
Household head: age	525	46	45	14	0.25	0.88	1.2	.64	1.8	.36
Household head: Can read/write	521	0.39	0	0.49	-0.02	0.62	-.12	*.096	0	.99
Household head: secondary education or above	515	0.21	0	0.41	-0.02	0.74	-.091	.2	-.043	.46
Household head: woman	525	0.19	0	0.39	-0.05	0.15	-.1	.12	.012	.8
Number of adult females	533	1.70	1	0.89	-0.11	0.25	-.22	*.088	.012	.94
Number of children	533	3.10	3	1.60	-0.05	0.78	-.035	.91	.1	.7
% members age > 10 who can read/write	533	0.55	0.5	0.33	-0.02	0.68	-.043	.42	-.016	.75
% of 6-14 in a household in school	375	0.76	1	0.36	-0.02	0.61	-.12	**.019	-.035	.64
Network size	533	1.30	1	1.50	-0.12	0.45	-.82	***.0016	.21	.4
Value of food consumed: monthly[1]	530	5073	4333	3339	507	*0.07	32	.94	262	.48
Total expenditure: monthly	527	5942	5000	3227	371	0.16	129	.81	378	.34
Typical income: monthly	495	7672	6000	7193	515	0.40	331	.73	1132	.3
Expenditure on medicines: monthly	510	543	250	1227	-159	0.13	-38	.66	-240	**.037
Uses sanitary latrine	533	0.80	1	0.40	0.00	0.98	.14	*.081	.022	.73
Pakka house or pakka walls (good quality)	533	0.11	0	0.31	-0.01	0.83	.03	.55	-.063	.26
% members with symptoms of arsenic poisoning	533	0.01	0	0.07	0.00	0.69	-.0032	.3	.014	.32
Any member with symptoms of arsenic poisoning	533	0.04	0	0.19	0.02	0.56	-.019	.3	.059	.25
Mean # days of illness last year (ages 6 to 70)[2]	532	19	13	22	-0.23	0.91	4.4	.33	-3.1	.29
Household owns well	527	0.7	1	0.46	-0.019	0.6	0.045	0.54	-0.075	0.18
Distance to nearest well below 50 ppb	529	75	21	219	55	0.40	-13	.62	166	.22
Distance to nearest safer well	531	86	47	137	-8.10	0.58	-49	.13	12	.55
Average concern about short-term arsenic risk	513	1.2	1	0.74	0.087	0.35	0.24	0.14	0.052	0.74
Average concern about long-term arsenic risk	510	7.8	8	1.6	0.098	0.64	0.52	0.13	-0.077	0.81

Source: Author's calculations from baseline survey (Spring 2008) data.

1: All income and expenditures are derived from simple, one-shot questions. The recall period is given for each question in the table. All monetary units are in Bangladesh Takas (BDT) with an official exchange rate of approximately 68 BDT per 1 U.S. Dollar and a purchasing power parity exchange rate of 22.64 BDT per dollar.

2: Number of days lost to work or school in the last year.

3: The figures in columns 5, 7 and 9 show the mean difference between treatment groups for the whole sample and respectively for moderately and highly unsafe wells. The figures in columns 6, 8 and 10 show the p-value for a test of equality of means for the relevant sample. Tests are robust to intra-cluster correlation of residuals. Asterisks indicate significance at the 1 (***), 5 (**) or 10 (*) percent level.

Table 2: Tubewell Arsenic Levels and Household Characteristics

	(1) Unsafe ($As > 50$)	(2) Arsenic level
# Household members	0.019	0.165
	[0.016]	[3.604]
Household head: age	-0.002	-1.139
	[0.002]	[0.396]**
Household head: Can read/write	0.059	6.934
	[0.060]	[22.866]
Household head: secondary education or above	-0.095	-51.097
	[0.076]	[31.544]
Household head: woman	0.006	-29.9
	[0.070]	[19.765]
Number of adult females	0.003	3.514
	[0.041]	[10.112]
Number of children	0.011	2.915
	[0.034]	[11.416]
% members age> 10 who read/write	0.015	21.478
	[0.091]	[29.934]
Network size	-0.02	8.174
	[0.017]	[7.175]
Value of food consumed: monthly (1,000s)	-0.016	-1.831
	[0.005]**	[1.176]
Total expenditure: monthly (1,000s)	-0.004	0.127
	[0.009]	[2.770]
Uses sanitary latrine	0.072	-0.246
	[0.064]	[15.787]
Pakka house or pakka walls (good quality)	0.017	3.177
	[0.072]	[18.547]
Mean # days of illness last year (age 6 to 70)	0	-0.108
	[0.001]	[0.234]
Average short-term concern for arsenic risk	-0.042	-3.363
	[0.043]	[10.489]
Average long-term concern about arsenic risk	0.03	0.229
	[0.021]	[6.628]
Number of observations	0.442	159.524
	[0.217]*	[67.444]*
R-squared	484	484
Observations	0.03	0.03
# clusters	42	42
F-test of the regression	2.13	1.9
p-value	0.026	0.05

Source: Author's calculations from baseline survey (Spring 2008). Standard errors in brackets are robust to intra-cluster correlation. Asterisks indicate significance at the 1 (***), 5 (**) or 10 (*) percent level.

Table 3: Effect of Communication Mode on Switching Decisions

Dependent variable: SWITCH	(1)	(2)	(3)	(4)
Gradient	1.429	1.245	1.164	1.021
	[0.361]**	[0.412]**	[0.392]**	[0.332]**
ln(Arsenic)	0.267	0.242	-0.035	-0.177
	[0.050]**	[0.045]**	[0.307]	[0.296]
ln(Arsenic) × Gradient	-0.306	-0.268	-0.251	-0.217
	[0.069]**	[0.082]**	[0.077]**	[0.067]**
# Household members		0.032	0.039	0.03
		[0.018]	[0.019]*	[0.021]
Household head: age		0.002	0.001	0.001
		[0.002]	[0.002]	[0.002]
Household head: Can read/write		0.148	0.158	0.15
		[0.091]	[0.085]	[0.084]
Household head: secondary education or above		-0.252	-0.283	-0.27
		[0.084]**	[0.087]**	[0.086]**
Household head: woman		0.025	-0.013	-0.017
		[0.068]	[0.060]	[0.058]
Number of adult females		-0.078	-0.069	-0.101
		[0.058]	[0.061]	[0.062]
Number of children		-0.017	-0.028	-0.013
		[0.032]	[0.036]	[0.040]
% members age> 10 who read/write		-0.066	-0.066	-0.069
		[0.124]	[0.114]	[0.104]
Network size		0.001	0.005	0.007
		[0.023]	[0.023]	[0.021]
Value of food consumed: monthly (1,000s)		0.018	-0.005	0.007
		[0.022]	[0.023]	[0.020]
Total expenditure: monthly (1,000s)		-0.013	-0.005	-0.006
		[0.017]	[0.017]	[0.016]
Uses sanitary latrine		-0.145	-0.185	-0.162
		[0.064]*	[0.070]*	[0.068]*
Pakka house or pakka walls (good quality)		-0.08	-0.037	-0.055
		[0.114]	[0.118]	[0.119]
Mean # days of illness last year (age 6 to 70)		0.001	0.001	0.001
		[0.001]	[0.001]	[0.001]
Owns well		0.062	0.042	0.034
		[0.058]	[0.056]	[0.054]
Distance to nearest safe well		0	0	0
		[0.000]	[0.000]	[0.000]
Average short-term concern for arsenic risk			0.311	0.321
			[0.421]	[0.442]
Average short-term concern × ln(Arsenic)			-0.042	-0.052
			[0.086]	[0.090]
Average long-term concern about arsenic risk			-0.218	-0.3
			[0.246]	[0.246]
Average long-term concern × ln(Arsenic)			0.04	0.058
			[0.049]	[0.048]
Constant	-0.926	-0.809	0.716	1.18
	[0.251]**	[0.296]**	[1.541]	[1.505]
Stratum dummies included	326	308	297	297
Observations	0.05	0.13	0.15	0.22
R-squared	42	41	41	41
Number of clusters (villages)	0.05	0.13	0.15	0.22

Source: Author's calculations from Wave I and Wave II data. All estimates are Linear Probability Models where the dependent variable is a dummy equal to one if the household switched to a different source of drinking water after the communication of the test results. Standard errors in brackets are robust to intra-cluster correlation. Asterisks indicate significance at the 1 (***), 5 (**) or 10 (*) percent level.

Table 4: Beneficial and Harmful Switches by Intervention and Arsenic Level

		$As < 50$ (safe)		$50 \leq As \leq 100$ (moderately unsafe)		$As > 100$ (highly unsafe)	
		Bright Line	Gradient	Bright Line	Gradient	Bright Line	Gradient
Beneficial	obs	0	0	3	5	18	8
	%	0.00	0.00	25.00	26.32	33.96	29.63
Harmful	obs	2	2	0	1	0	1
	%	2.22	40.00	0.00	5.26	0.00	3.70
Unknown	obs	7	3	9	12	35	18
	%	77.78	60.00	75.00	68.42	66.04	66.67

Source: Author's calculations from Wave II survey. Well switching is classified as beneficial if the household moved to a well with a lower level of arsenic or from a red well to a green well. Switching is classified as harmful if the household switched to well with a higher level of arsenic or from a green well to a red well. Unknown switches include switches for which we do not know anything about the arsenic content of the new well and switches from a red well to a new red well or from a green well to a new green well.

Table 5: Effect of Communication Mode on Estimated Reduction in Arsenic Exposure among Switchers

Dependent variable: Estimated change in As	(1)	(2)
Gradient	105.531	55.883
	[194.595]	[209.624]
ln(Arsenic)	175.374	27.773
	[25.063]**	[121.664]
ln(Arsenic) × Gradient	-20.828	-12.203
	[40.166]	[42.629]
# Household members		-3.385
		[5.820]
Household head: age		0.273
		[0.921]
Household head: Can read/write		-22.285
		[19.737]
Household head: secondary education or above		38.478
		[25.910]
Household head: woman		-22.174
		[30.654]
Number of adult females		-1.661
		[12.883]
Number of children		-7.94
		[9.183]
% members age> 10 who read/write		21.461
		[37.634]
Network size		-0.845
		[6.012]
Value of food consumed: monthly (1,000s)		3.549
		[11.150]
Total expenditure: monthly (1,000s)		3.781
		[7.819]
Uses sanitary latrine		-35.581
		[21.793]
Pakka house or pakka walls (good quality)		28.072
		[33.769]
Mean # days of illness last year (age 6 to 70)		-0.603
		[0.204]**
Owns well		-39.774
		[14.126]**
Distance to nearest safe well		0.026
		[0.037]
Average short-term concern for arsenic risk		149.04
		[179.169]
Average short-term concern × ln(Arsenic)		-25.317
		[35.642]
Average long-term concern about arsenic risk		-118.906
		[100.774]
Average long-term concern × ln(Arsenic)		22.829
		[20.376]
Constant	-786.873	54.211
	[121.364]**	[561.401]
Stratum dummies included	No	Yes
Observations	111	103
R-squared	0.57	0.69
Number of clusters (villages)	34	34

Source: Author's calculations from Wave I and Wave II data. All estimates are obtained with OLS, including only households who switched from an unsafe well, and the dependent variable is the reduction in arsenic exposure estimated as described in Section 3.2. Standard errors in brackets are robust to intra-cluster correlation. Asterisks indicate significance at the 1 (***), 5 (**) or 10 (*) percent level.

Table 6: Immediate Perceived Safety of Tested Well

Is your well's water safe to drink?		$As < 50$ppb (safe)		$50 \leq As \leq 100$ppb (moderately unsafe)		$As > 100$ppb (highly unsafe)		All	
		(1) Binary	(2) Gradient	(3) Binary	(4) Gradient	(5) Binary	(6) Gradient	(7) Binary	(8) Gradient
Don't know	obs.	10	12	2	1	9	11	21	24
	%	10.42	10.81	3.85	1.75	7.63	11.11	7.89	8.99
No	obs.	8	7	15	20	63	58	86	85
	%	8.33	6.31	28.85	35.09	53.39	58.59	32.33	31.84
Yes	obs.	78	92	35	36	46	30	159	158
	%	81.25	82.88	67.31	63.16	38.98	30.3	59.77	59.18
Total	obs.	96	111	52	57	118	99	266	267
	%	100	100	100	100	100	100	100	100
H_0: Binary=Gradient (p-values)		0.9232		0.6925		0.5003		0.9248	

Source: Author's calculations from baseline survey. The figures show the responses to the question "[d]o you consider the water from your tube well to be safe to drink?", asked shortly after the delivery of the test results.

Table 7: Perceived Safety of Tested Well at Follow-up

			$As < 50$ppb (safe)		$50 \leq As \leq 100$ppb (moderately unsafe)		$As > 100$ppb (highly unsafe)	
			(1) Binary	(2) Gradient	(3) Binary	(4) Gradient	(5) Binary	(6) Gradient
(A)	Does not know 50ppb threshold	%	.95	.96	.98	.95	.97	.93
(B)	Thinks all "unsafe" wells the same	%	.44	.38	.40	.54	.42	.53
(C)	Thinks all "safe" wells the same	%	.53	.64	.60	.67	.58	.74
(D)	Tested well water is unsafe to drink	%	.04	.00	.44	.60	.76	.70
(E)	Switched to a different source	%	.094	.045	.23	.33	.45	.27
(F)	P(health risk within 1m/5y)		.03	.018	.099	.13	.15	.16
(G)	P(health risk within 10/20 years)		.12	.078	.30	.40	.43	.47

Source: Author's calculations from follow-up survey. $n = 533$.
A: % respondents who do not recognize that the Government of Bangladesh considers water with As concentration > 50ppb unsafe to drink.
B and C: % respondents who, if given a choice between two unsafe (B) or safe (C) wells, states that it does not matter which one is chosen as source of drinking water.
D: % respondents who thinks that the well water tested at baseline is unsafe to drink.
E: % households who switched to a different source of drinking water between baseline and follow-up survey.
F: mean of six household-specific average subjective probabilities of developing health conditions in the short term as a consequence of drinking the tested water (risk of skin lesions within 1 month and within 1 or 5 years and risk of "serious health conditions within the same time frames).
G: mean of four household-specific average subjective probabilities of developing health conditions in the long term as a consequence of drinking the tested water (risk of skin lesions within 10 or 20 years and risk of "serious health conditions within the same time frames).