Can Information Alone Change Behavior? Arsenic contamination of groundwater in Bangladesh*

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Abstract

We study how effectively information alone induces people to incur the cost of avoiding a risk to health. Arsenic contamination of the groundwater in Bangladesh provides an unfortunate natural experiment. We find that the response to specific information about the safety of one's well is large and rapid; having an unsafe well raises the probability that the individual changes to another well within one year by 0.5. The estimate of the impact of information is unbiased, because arsenic levels are uncorrelated with individual characteristics. Evidence suggests that a media campaign communicates general information about arsenic as effectively as does a more expensive door-to-door effort.

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1. Introduction

As many as one billion people in the world drink unsafe water (WSCC, 1999). Over two million deaths from diarrhea are estimated to have occurred in 1998, mainly among children (WHO, 1999). People drink unsafe water because they are not informed about the risks to their health and because they lack access to safe water. Policy interventions which provide information are likely to be cheaper and easier to implement than ones which provide water. Therefore, it is important to know if and when information alone can induce people to seek safe water on their own.

We study the effect of providing information on people's reaction to high concentrations of arsenic in their drinking water in Bangladesh. First, we determine the magnitude of the effect which specific information about levels of arsenic has on people's decision whether or not to seek safe water. Second, we compare the amount of information people have about the threat which their water supply poses after two different types of information campaigns, a door-to-door one and one based on the media.

One-third or more of the wells in Bangladesh have concentrations of arsenic above the Bangladeshi safety standard of 50 micrograms per liter.[1] Since wells supply drinking water for about 90% of the population, at least 37 million people are consuming unsafe water. (British Geological Survey, 2001) The exposure to arsenic is an unintended consequence of a successful information campaign in the 1980s, during which UNICEF convinced people to switch from drinking surface water to drinking groundwater. The reduced incidence of water-borne diseases contributed to a major decline in infant and child mortality, but exposed people to arsenic in the groundwater of which UNICEF was not aware.[2]

Long-term exposure to arsenic causes a variety of serious health problems whose gestation periods vary from 5 to 15 years for the early effects to 20 years or more for various types of cancer.[3]

[1] The WHO lowered its standard for safe concentrations from 50 to 10 micrograms in 2001.
[2] Infant and child mortality declined from 211 per 1000 in 1980 to 104 per 1000 in 1997 (World Development Report, 2000/2001). Changes in medical treatment over this period, e.g. oral rehydration therapy, as well as improvements in access to medical care and nutrition certainly mattered. However, the decline is almost twice as large as the average decline for low-income countries during this period. (World Development Report, 2000/2001)
[3] See for example Chang et al (2004), Chiu et al (2004), Hopenhayn-Rich et al (1996), Lokuge et al (2004), Moore et al (1997).

Since the majority of the population has been using wells since the early 1990's, the country may now be in the early stages of an epidemic described by Smith et al in the WHO Bulletin (2001) as "… the largest case of mass poisoning in history."

We provided two types of information to households in our study area, Araihazar district. We tested each well in the area, labeled it as safe or unsafe with a sign designed for a mostly illiterate population and communicated the result to those who use the well. We also organized information sessions about the dangers of drinking water from unsafe wells. Households in Araihazar and in four control areas, in which we provided no information, also received information about the dangers of arsenic from messages on TV, radio and in newspapers placed by the government contemporaneously with our information campaign.

The most striking result of our analysis is the behavioral response to information provided by the well test. Having an unsafe well increases the probability that a household seeks drinking water from a different well over the probability that she does so if her well is safe by 0.5. Sixty percent of people whose original well is unsafe change to another well, while only 14% of people whose original well is safe change, and only 8% of people change in control areas. People whose wells are safe or who do not know the status of their well may change for reasons other than arsenic, such as a well malfunction. Ninety-one percent of people in Araihazar can correctly state whether the well they were using before the well test is safe or not, while few people in control areas claim to know the status of their well.[4] Therefore, the change in behavior in Araihazar is clearly a response to information about one's well.

The identification of the effect of information on behavior exploits the fact that concentrations of arsenic appear to be the outcome of a natural experiment. The above result could be biased if households whose wells are unsafe are switching for reasons other than arsenic, and those reasons are correlated with whether or not their wells are unsafe or with whether they know that their wells are unsafe. This does not seem to be the case. The arsenic is naturally occurring, not an industrial pollutant. Evidence on the process by which arsenic dissolves from the soil into the water suggests that it is unlikely to be correlated with household characteristics.[5] We show that, within villages, levels of arsenic are not correlated with observable characteristics of respondents, such as education or income, which may also influence the decision to change to another source. Therefore, our result should accurately describe the effect of information about one's own well on the behavior of a randomly chosen household.[6]

Since 91% of people correctly state whether their original well is safe in Araihazar, having an unsafe well is almost the same as knowing that the well is unsafe. Ninety-four percent of those who are not correct about the status of their wells have safe wells, therefore the response to the perceived status of the well is larger than is the response to the actual status.

We are describing what people do within six to twelve months of receiving information. The options available within this time frame are mainly other existing wells, the great majority of which are privately owned by households. Arsenic concentrations vary greatly within hundreds of feet, therefore a household whose well is unsafe often has neighbors whose wells are safe.[7] Alternatively, the household can install a new well or switch to an existing community well.

The response to well tests suggests that information alone may result in a rapid and large change in behavior to avoid a risk to health. The response appears to have reduced exposure to arsenic according to data from public health researchers which indicates that those who changed have considerably reduced concentrations of arsenic in their urine.[8] The size and rapidity of the response are surprising, since the consequences of drinking unsafe water are not visible yet. Only 1% of people in our sample have symptoms and only 6% know someone who does. Furthermore, the response contrasts with most examples reported in the economic literature, which emphasize that behavior changes slowly in response to accumulation of information and the example of other people’s behavior changing.[9] The context in our

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[4] We do not know whether the people in control areas who claim to know are correct.
[5] See for example Harvey (2001), McArthur et al (2001), Nickson et al (2000).
[6] We discuss two caveats in section 4.
[7] Van Geen et al (2002)
[8] The data was collected by a team led by Joseph Graziano and Habibul Ahsan.
[9] Munshi and Myaux (2002), Conley and Udry (2002), Foster and Rosenzweig (1995), Besley and Case (1994), Munshi (2004), Jalan et al. (2004)

paper is different from those described in the literature, therefore an important question which requires further research is under what conditions the large and rapid response we observe can be expected.[10]

The second point in this paper is that the media campaign may be a more cost-effective way of disseminating general information about arsenic than our door-to-door campaign even though only about 66% of people own a radio or a TV and only about 15% read newspapers. The probability that a person residing in a control area is aware of the possible presence of arsenic in the water is smaller by .16 than is the probability for a resident of Araihazar. However, the probability that people know that diseases caused by arsenic are not contagious is larger by .06 in control areas, while there is no difference in the probability that people know that boiling water does not remove arsenic. The small difference in awareness of arsenic may not justify the cost of the door-to-door effort which is orders of magnitude larger than the cost of the media campaign. However, the media campaign should be supplemented with well tests, since without the crucial information which they provide behavior does not change.

We provide a tentative estimate of a lower bound on the willingness to pay for a reduction in exposure to arsenic. We base it on the increased amount of time which people walk for water after changing to another well.

The remainder of the paper proceeds as follows. Section 2 presents a simple model which underlies the empirical work. Section 3 describes the project and the data. In Section 4, we discuss the methodology and the results which estimate the effect of knowing the status of one's own well on the decision whether to change to another source of water. In Section 5, we analyze the difference between the effect of the door-to-door campaign and the media campaign on how much information people have. In Section 6, we present a tentative estimate of willingness to pay. Section 7 concludes.

2. Model

We model an individual's choice of her health outcome in order to motivate the subsequent empirical analysis. The model is not designed to capture the full complexity of how individuals allocate

[10] Unfortunately, the transition from surface water to wells in Bangladesh has not been sufficiently well documented

resources to maintaining their health.[11] Rather, it highlights the decision whether or not to avoid a source of pollution and addresses how one might measure the willingness to pay for avoiding the source of pollution. Thus, it provides a basis for the empirical analysis of whether people change to another source of water and how costly this change is to them.

We focus on actions which an individual can take to affect her health. We measure the individual's health as the number of days of work or school missed because of illness. The number of days missed is h(d,b), where d is the effective exposure to arsenic, and b is the amount of medical intervention sought to reduce the effects of arsenic. Effective exposure to arsenic, $d(a,s_q,s_t)$ depends on a, the amount of arsenic in the water the individual consumes, s_q, the quantity of safe water which the individual purchases, and s_t, the quantity of safe water which the individual obtains by spending more time, e.g. by walking further for water. The distinction between s_q and s_t is simply a way of introducing into the model the fact that obtaining safe water may have cost components which have different prices associated with them, as will become clearer below. We can write the number of days missed as $h(a,s_q,s_t,b)$.

The quantity of safe water which an individual purchases may be thought of as water from a new well, which must be installed and maintained, or from a well owned by someone else, who has to be compensated for the use of the water, or from a community well, access to which requires some contribution to the community. If the source is someone else's well or a community well, then an individual has to spend time to avoid arsenic by walking further for safe water. In general, a new source may require both monetary compensation and an investment of time.

An individual maximizes her one-period utility subject to an income constraint.[12] The maximization problem is

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to the best of our knowledge to provide a useful comparative study.

[11] The model is essentially the version of Grossman's (1972) model presented in Freeman (1993).

[12] The allocation of resources to health is an inter-temporal decision and Grossman (1972) treats it as such. However, the complication added by an inter-temporal dimension does not yield insights which we are able to examine empirically.

$$\max_{s_q, s_t, b, f, X} U(X, f, h)$$
$$s.t. \qquad I + p_w(T - f - h - s_t) \geq X + p_{s_q} s_q + p_b b$$

In this problem, X is a private good purchased by the individual, f is leisure time, T is the total amount of time available, p_w is the wage, p_{s_q} is the price of a safe source of water and p_b is the price of the medical services. The expression $(T - f - h - s_t)$ represents the total amount of time spent earning an income.

The first-order conditions for the amount of safe water and the amount of time spent walking for safe water are

$$\frac{\partial U}{\partial h} - \lambda p_w = \frac{\lambda p_{s_q}}{\partial h / \partial s_q} \qquad (1)$$

and

$$\frac{\partial U}{\partial h} - \lambda p_w = \frac{\lambda p_w}{\partial h / \partial s_t} \qquad (2)$$

where λ is the Lagrange multiplier on the budget constraint. The first-order condition for the choice of the amount of medical intervention to mitigate the effects of arsenic is

$$\frac{\partial U}{\partial h} - \lambda p_w = \frac{\lambda p_b}{\partial h / \partial b} \qquad (3)$$

We will estimate the determinants of the decision whether or not to switch to a safe source of water, which is essentially the combined demand function for s_q and s_t; two components of the demand for safe water which have different prices, p_{s_q} and p_w respectively. The demand function for s_q which can be obtained from the above maximization problem would be $s_q(I, p_w, p_{s_q}, p_b, a)$ and similarly for s_t. In the empirical part, we will treat this as one demand function for s, a source of safe water.

The model above also allows us to derive an expression for willingness to pay (WTP) for avoiding arsenic, which relates WTP to information observable in our data. Taking the total derivative of the health function with respect to arsenic yields

$$\frac{dh}{da} = \frac{\partial h}{\partial s_q}\frac{\partial s_q^*}{\partial a} + \frac{\partial h}{\partial s_t}\frac{\partial s_t^*}{\partial a} + \frac{\partial h}{\partial b}\frac{\partial b^*}{\partial a} + \frac{\partial h}{\partial a}$$

where the asterisks denote the utility-maximizing choice of the given variable in response to a change in arsenic. Rearranging terms yields

$$\frac{\partial h}{\partial a} = \frac{dh}{da} - \frac{\partial h}{\partial s_q}\frac{\partial s_q^*}{\partial a} - \frac{\partial h}{\partial s_t}\frac{\partial s_t^*}{\partial a} - \frac{\partial h}{\partial b}\frac{\partial b^*}{\partial a}$$

Multiplying both sides by the rearranged first-order condition (1),

$$-\frac{p_{s_q}}{\partial h / \partial s_q} = p_w - \frac{\partial U / \partial h}{\lambda}$$

and rearranging terms yields

$$w_a = p_w \frac{dh}{da} + p_{s_q}\frac{\partial s_q^*}{\partial a} + p_w \frac{\partial s_t^*}{\partial a} + p_b \frac{\partial b^*}{\partial a} - \frac{\partial U / \partial h}{\lambda}\frac{dh}{da} \qquad (4)$$

where w_a is the marginal WTP for a reduction in exposure to arsenic. The left-hand side is equal to the marginal WTP, because one can show that marginal WTP is equal to the marginal rate of substitution between pollution and any other input which determines health, multiplied by the price of that input. The reason is essentially that cost minimization in the production of health requires that the values of marginal products of all inputs be equal.

The first four terms in expression (4) are observable in principle. They can be approximated with information about observed changes in illness due to exposure to arsenic, expenditures on safe water, the value of time spent walking for safe water and expenditures on medical assistance. Applying data to expression (4) should yield an underestimate of the marginal WTP. The last term is based on unobservable preferences and it is positive, since $\frac{\partial U}{\partial h} < 0$, therefore it will tend to make the true marginal WTP higher than the measured one.

Our data allows only a partial estimation of what expression (4) suggests. We estimate the WTP for a change in one's source of water. The reason is that, despite our best efforts, we do not know to which well the household changed for enough households. Therefore, we do not know the change in arsenic levels. In fact, not all households changed to wells which are safe. However, we know from the change in urinary arsenic concentrations collected by the public health team that exposure declined by a large amount. We estimate the WTP for the average change in arsenic resulting from a change in the source of water due to exposure to a high concentration of arsenic.

Second, we estimate two components of WTP, the value of additional time spent walking for water as a result of the change to another source and the value of this and all other costs of the new source as reflected in the difference between household expenditures of those households who change and those who do not among those who have unsafe wells. We do not estimate the effect of changing on saving behavior.

3. The Project and the Data

The project is a joint effort by three different disciplines, geo-chemistry, public health and economics to study the arsenic problem in Bangladesh and to help design policy responses. The study, launched in March 2000, focuses on a small section of the Araihazar district 20 km south-east of Dhaka. The study region has a population of 70,000 and contains 6000 wells. We also conducted surveys in four sub-districts in four other districts in the country in order to provide a control for the analysis in Araihazar. The other subdistricts are Jessore Sadar in Jessore district, Nikli in Kishoreganj, Tangail Sadar in Tangail and Ghior in Manikganj.

In Araihazar, we provided two main pieces of information, the results of well tests and general information about the health consequences of drinking water which has unsafe levels of arsenic. The geo-chemistry team tested every one of the 70,000 wells in the area and labeled each well with a picture denoting whether the well is safe or not, understandable to the 55% of the population who cannot read or write, and the level of arsenic in the well, accessible only to the literate. Contemporaneously with the well tests, the public health team was interviewing 11,746 individuals, each of whom was a member of a married couple, interviewing both members of a couple for 4,803 couples. Interviewers told respondents whether the well which they primarily use for drinking water is safe or not and what is the level of arsenic in it. They also conducted a health exam, which included a urine and blood sample, and told each respondent if they had symptoms of an arsenic-related illness. In their data, 6% of people have symptoms.

After the public health interviews, a team of three educators communicated information about arsenic through skits, songs and conversation with the audience. They traveled from neighborhood to neighborhood, and held meetings once a reasonable number of people assembled. The materials were designed for an illiterate audience. The information included health problems which arise from drinking water contaminated with arsenic, the fact that these are not contagious, the fact that commonly known treatments of water, such as boiling, do not remove arsenic, and an explanation of the labels on the wells. The education campaign did not include much information about safe sources of water other than the suggestion to switch to a well which is safe, an exhortation to those with safe wells to allow others to use them and a warning against changing to surface water unless people planned to boil it. The meetings were conducted during normal working days and during working hours. 31% of the people in our sample attended one of these education meetings.

The data for this paper is based on a survey which we carried out six to twelve months after the education campaign plus the information about the well which the household was using before receiving information. For each household interviewed after the information intervention, we know the well which they were using and whether or not they had heard of the arsenic problem before our project began from the public health survey.

We interviewed 2680 individuals who responded to the public health survey which conducted a health exam. The sample for that survey consisted of randomly chosen couples at each well in the area, totaling a little over one-half of all married couples. We randomly selected 2000 wells and then randomly chose one of the couples from the public health sample who use that well. We could not interview the couple at every well, nor could we always interview both members of the couple. Our sample consists of 1089 married couples, 414 married women and 87 married men.

We asked five categories of questions. The first were background questions about the household and each of its members. Then we asked a series of questions about what the respondent knows about the arsenic problem. The third set of questions asked the respondent about the source of water which they currently use and why they did or did not change to a different source. We then asked about the respondent's membership in a variety of social networks. Finally, we collected detailed information about household expenditures on food and non-food items, savings and remittances in order to construct a measure of household income and information about assets. Throughout the paper, the sum of all monthly expenditures serves as our measure of household income. Table 1 presents descriptive statistics of selected variables.

Contemporaneously with the end of the above survey, we collected information in control areas, in which we did not provide any information. We interviewed 200 married couples in Jessore Sadar and 100 each in Tangail Sadar, Nikli and Ghior. Jessore Sadar includes one of the largest cities in Bangladesh, Jessore. In this area, we selected 3 city neighborhoods, 4 mixed urban/rural neighborhoods and 3 villages. All were chosen randomly from a list of neighborhoods and villages. We interviewed 20 couples randomly chosen in each neighborhood or village. In all other areas, we randomly chose 5 villages from the list of all villages and randomly chose 20 couples in each village.

In each case, we were working with a non-profit, non-government organization (NGO) which was planning to test wells in the area and to conduct an information campaign.[13] We conducted the surveys before the information campaigns began. In two cases there may have been overlap towards the end of the survey. However, only 6% of respondents in control areas report having learned about arsenic from a NGO education campaign, while 76% report having learned the information from the media. In Araihazar, on the other hand, 97% of respondents report learning the information from our project staff.

UNICEF had tested a small subset of wells in each area, therefore we have an idea how severe the arsenic problem is in each of them. However, the great majority of wells had not been tested.

In each control area, we collected the same categories of information as were part of the survey in Araihazar. The one difference is that we did not have information about the well which the household was using six to twelve months earlier so we asked each respondent to recall whether they had changed to a different source of water in the last twelve months. The point was to determine what was the change in awareness and behavior in these areas over the time period which we were studying in Araihazar and what the source of information was in the absence of our intervention.

Neither Araihazar nor the control areas were chosen entirely randomly. Araihazar was chosen for its accessibility from the capital, Dhaka. The control areas are much farther away from Dhaka. They were chosen from among areas in which our partner NGOs were planning to implement arsenic programs in the future. Table 2 compares a number of characteristics of households in Araihazar to the average for the control areas and to each area. Araihazar does not differ from the average for the control areas in terms of monthly per capita household expenditure. However the average Araihazar household has less per capita wealth in assets than does the average household in the control areas. On average, people in the control areas have two more years of education than do people in Araihazar. The differences in assets and education are statistically significant. If education is correlated with unobservable characteristics of the area which make people more informed, then the coefficient on the effect of our information campaign may be biased downward in a comparison of awareness between Araihazar and control areas. On the other hand, one might expect that the proximity of Araihazar to the capital would bias our results toward finding a bigger effect of our information campaign on people's awareness than is really due to the campaign. We will actually find that the difference in awareness between Araihazar and the control areas is very small. We discuss whether the result could be biased in more detail in section 5.

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[13] The testing and information campaigns were funded by UNICEF. We are deeply grateful to UNICEF and the four NGOs, BRAC, The NGO Forum for Water and Sanitation, EPRC and Unnayan Samannay for their cooperation in

4. Effect of information on behavior

We first study the choice of a source of water as a function of the level of arsenic in the well which the respondent was using prior to the information campaign. This is not exactly the demand for a safe source of water, but rather the reduced form of the demand and supply equations. If we may think of the supply of safe water as being fixed in the short run, determined by the distribution of arsenic, then we do estimate the demand for safe sources of water. However, in reality, for each respondent, the supply is likely to depend on factors which either also determine demand or which are unobservable, such as the compensation required for using another well and the respondent's status in the community, which affects the neighbors' willingness to allow the respondent access to their wells.

The alternative sources of water available to people whose wells are unsafe are constrained by the short period of time which has elapsed since information was provided. The great majority of wells in Bangladesh are privately owned by households and another household's private well is the most readily available option, since arsenic concentrations are very variable over short distances. Van Geen at al (2002) report that close to 90% of households in our study area live within 100 meters of a safe well, even though only 46% of wells are safe. People can also install a new well or change to a community well.

We estimate the effect of information about arsenic in one's well on the equilibrium decision whether or not to change to another well using only Araihazar data. The primary reason is that no more than 11% of respondents in control areas know the status of the well they were using 12 months ago, i.e. at the time at which wells were tested in Araihazar. Also, we cannot check whether those who claim to know are correct because in some cases people do not know who tested the well and in others documentation is not available from the institutions which tested the wells.

Araihazar data is sufficient to obtain a very general estimate of the effect of information about levels of arsenic in the well on the choice of well. As long as whether the well is safe or unsafe and whether the household knows the status of the well are orthogonal to household characteristics which may

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this research.

affect the decision to change then the estimate based on Araihazar alone is valid for all households, those outside of Araihazar as well.

We supply evidence that arsenic is not correlated with observable characteristics, at least within villages, in table 3.[14] The first two columns show means of various characteristics for respondents whose wells are safe and those whose wells are unsafe, as well as the p value for the mean comparison test. Respondents whose wells are unsafe on average have slightly lower household expenditures, lower assets, and they are slightly older. However, in the regression reported in column 3, in which we include village fixed effects, whether or not a well is safe is correlated only with age.[15] The chi squared test for whether the coefficients on all independent variables except the village fixed effects are zero has a p value of 0.19, i.e. we cannot reject the null that all these coefficients are zero. Therefore, arsenic concentration is not correlated with observable household characteristics within villages, and all of our analyses will be within-village ones.

Further evidence that arsenic is not correlated with characteristics of respondents or of the neighborhoods they live in is that the chemical process which determines whether the naturally-occurring arsenic dissolves from the soil into water does not suggest a reason for such a correlation to the best of our knowledge.[16] The arsenic is not a pollutant released by industry or agriculture. The one potential relationship to patterns of human activity is based on the fact that the amount of arsenic released is related to the presence of oxygen in the soil. More permeable soils are somewhat associated with lower levels of arsenic.[17] Soil permeability is not generally desirable for cultivation of rice, which is the main crop in our study area. If places with high arsenic are worse for the cultivation of rice, one might expect to see a relationship between arsenic and occupation and perhaps arsenic and income and/or assets, at least for land-owning households. This may explain why arsenic is correlated with income and assets *across*

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[14] The table reports results for the binary outcome whether the well is safe or not. The same results hold for the continuous level of arsenic.
[15] One possible explanation is that, in Araihazar, older wells tend to have higher levels of arsenic controlling for depth, which suggests that volume of water drawn may affect arsenic levels. However, scientists have not found more direct evidence of this mechanism.
[16] Please see footnote 4 for references.

villages. However, neither of these relationships exists in the data *within villages*. Furthermore, even in data across villages, the relationship does not provide a link between arsenic in the well which the respondent uses at the house and the respondent's income or assets, because houses are sufficiently far from fields that there is little relationship between the soil in one's field and the soil around one's well.

There are two factors which may be correlated with the status of one's well and which may therefore result in a different response to information about the well in areas other than Araihazar. The first is the health of the members of the household. In Araihazar, few people have already developed arsenic-related diseased. Fewer than 1% of the people in our sample have arsenic symptoms, and the number of days of work or school missed due to illness is uncorrelated with arsenic. The response to unsafe wells may be different for households in which someone is already ill.

Second, characteristics of the distribution of arsenic in the area may affect a household's decision. For example, if neighbors influence each others' behavior then the percentage of neighbors who have unsafe wells in the area may affect the probability of people changing to another well. We control for the effect of area characteristics partly by including percentage of unsafe wells and the average arsenic in those wells among neighbors who live within 100 meters. However, if the percentage of unsafe wells in our entire study area affects the probability of a change in behavior in the area, then we are not fully controlling for the potential effect of area characteristics.

4.1 Methodology

We estimate the following probit regression

$$f(y|\mathbf{a}_{ij}, \mathbf{w}_{ij}, \mathbf{x}_{ij}, \mathbf{v}_j) = \left[\Phi(\mathbf{a}_{ij}\boldsymbol{\theta}, \mathbf{w}_{ij}\boldsymbol{\gamma}, \mathbf{x}_{ij}\boldsymbol{\alpha}, \mathbf{v}_j\varphi)\right]^y \left[1 - \Phi(\mathbf{a}_{ij}\boldsymbol{\theta}, \mathbf{w}_{ij}\boldsymbol{\gamma}, \mathbf{x}_{ij}\boldsymbol{\alpha}, \mathbf{v}_j\varphi)\right]^{1-y} \quad (5)$$
$$\mathrm{y} = 0,1$$

where *f* is the density function of the binary outcome *y* given the vector of independent variables and Φ denotes the standard normal cumulative distribution function. The binary outcome is whether the respondent changes to another well or not. The vector, $\mathbf{a}_{ij}$, describes the arsenic concentration in the well

[17] Personal communication with Alexander van Geen.

used by individual i in village j before the information campaign and in that individual's neighbors' pre-information wells. It consists of whether or not the individual's well is safe, the level of arsenic, and the interaction between the binary variable and the level of arsenic, the percentage of that individual's neighbors who live within 100 meters of him/her whose wells are unsafe, and the average level of arsenic in those neighbors' wells. The vector, $\mathbf{w}_{ij}$, consists of characteristics of that person's pre-information well, for example the person's relationship to the owner of the well and the distance to the well. The vector, $\mathbf{x}_{ij}$, consists of individual characteristics such as education, income, age, gender. The vector, $\mathbf{v}_{j}$, is a vector of village fixed effects. We control for various household characteristics, even though if arsenic is truly exogenous within villages then we should not have to include anything other than village fixed effects.

We also estimate the effect of individual characteristics on whether or not the individual changes to a safe well separately for those whose wells are safe and those whose wells are unsafe. The objective is to determine who is more likely to seek safe water. We separate the sample by the status of the well, since reasons for changing when your well is safe may be quite different from reasons for changing when the well is unsafe.

4.2 Results

The most remarkable result which we document is that 60% of the 1522 households in Araihazar whose pre-information-campaign wells are unsafe change to a different well.[18] The difference from the percentage who change in control areas, where 8% change, is so large that it cannot be due to unobservable differences between the areas alone. Furthermore, only 14% of households whose wells are safe change in Araihazar. This figure is the same order of magnitude as the percentage who change in control areas. The evidence strongly suggests that the change in the behavior of those households whose wells are unsafe is motivated by the information about their wells. Households whose wells are safe or who do not have information about their wells may change for other reasons, such as the well malfunctioning or the quality of the water in the well deteriorating.[19]

[18] 54% of wells in Araihazar are unsafe.
[19] Opar et al (2004) documents broken wells.

The regression reported in the first column of table 4 confirms what the descriptive evidence suggests; that an unsafe well has a large effect on the probability that an individual changes to another well over and above the probability that she changes if her well is safe. Having an unsafe well increases the probability of changing to another well by 0.52 if we do not control for any individual characteristics but include village fixed effects and by 0.5 if we do control for a broad range of characteristics as well as village fixed effects.

We present the results using a regression discontinuity framework in Figure 1. The bar graph illustrates the change in the percentage of people who switch to another well immediately around the unsafe threshold of 50 micrograms per liter. Arsenic concentrations in micrograms per liter are on the x axis and percentage of people who change is on the y axis. If the worry remains that arsenic is correlated with unobservable characteristics which affect behavior, then the characteristics of those whose arsenic concentrations are just under 50 should be quite similar to characteristics of those whose arsenic concentrations are just over 50. The graph illustrates that the behavior of these two groups is nevertheless dramatically different. The fraction of those whose arsenic is between 40 and 50 who change is around .2, while for those whose arsenic is between 50 and 60 the fraction is .5. Note that here we are not controlling for village fixed effects. Even without these, the effect of information on behavior is clear.

We explain behavior with actual arsenic concentration in the well, not what the household believes it to be. Ninety-one percent of people can correctly state whether the well which was tested as part of the information campaign was safe or not. If we replace the actual arsenic with whether people think the well was safe or not, we obtain a higher probability of switching in response to information. Those who are wrong about the status of the well are overwhelmingly more likely to have had a safe well; out of 180 people who are wrong 11 had unsafe wells and 169 had safe wells.

The change in behavior appears to have considerably reduced exposure to arsenic. The public health researchers are in the process of writing up results which show a large reduction in urinary arsenic among those respondents who changed to another well.

The change in behavior is remarkable, since people do not yet have personal experience which tells them that the water is unsafe. Only 6% of people in Araihazar know of someone who has either fallen ill or died as a result of arsenic exposure. In addition, changing to another source of water is far from costless. We discuss the costs in detail in section 6.

As we noted in the introduction, the large and rapid change in behavior is contrary to evidence in other studies which suggests that behavior changes only very slowly even in the presence of convincing information. Admittedly, existing studies consider rather different contexts. For example, Munshi and Myaux (2002), who focus explicitly on the question how quickly people's behavior responds to new information, consider the speed with which people begin to use contraceptives in Bangladesh. Adoption of contraceptives in the Bangladeshi culture requires a change in strong social norms and in the bargaining power within households. Changing to a different source of water in our context does not.

We also analyze who among the respondents with unsafe wells is more likely to change. We only summarize the effects which are statistically significant.[20] A troubling result is that people are no more likely to change to another source of water when their wells are very unsafe than when they are somewhat unsafe until the level of arsenic reaches 300µg. Somewhat arbitrarily, we consider four levels of arsenic concentration, between 50µg and 100µg, larger than 100µg, larger than 200µg and larger than 300µg. Only levels of arsenic over 300µg increase the probability of changing, even though long-term exposure to concentrations of 250µg is far more dangerous than is exposure to levels of, for example, 55µg.

Family networks appear to play a large role in the decision whether or not to change to another well. The probability that people who own their well switch to a different source is 0.22 less than is the probability that people who use wells owned by non-relatives switch. The probability that someone who uses a well owned by a relative within the family compound, called a bari, switches is 0.14 less. Both of these results hold when we control for the distance to the well and the distance to the nearest clean well.

[20] The table is available from the authors.

Thus the ownership variables are picking up an effect other than distance. Furthermore, people are more likely to switch to another well when more of their relatives live in the area.

Most people whom we interviewed claim that anyone is welcome to use their well for any length of time, free of charge, and they typically offer the explanation that Islam dictates that people should offer strangers free access to water. However, those who have safe wells report that 93% of other people using their wells are relatives. People seem to be reluctant to use the wells of neighbors who are not relatives or they may not feel welcome to do so.

Surprisingly, the only effect of household expenditure and assets is that respondents in the second quartile of assets are slightly more likely to change relative to respondents in the bottom quartile; increase in the probability of switching is .11. The result suggests that people in the bottom quartile of assets, but not expenditure are disadvantaged in terms of access to safe water.

Secondary and higher education increase the probability of changing relative to no education, but primary education does not.[21] The respective increases in probability are .15 and .18. Education could affect the evaluation of the risk imposed by drinking contaminated water conditional on being informed, and thereby affect behavior. Also, education could affect one's social status and thereby access to others' wells. Jalan et al (2004) find that education has a large effect on the decision to adopt some method for purifying drinking water. They interpret education as a proxy for how informed people are. In our sample, there is almost no variation in how informed people are about the safety of their wells, therefore the effect of education is conditional on being informed about the safety of the well.

Of those who change to another well, 63% change to a neighbor's private well, 24% install their own new wells and 13% change to an existing community well. Those who install their own new wells tend to be wealthier, since this is the most expensive alternative. The concern is whether using a neighbors' well, the option chosen by the majority, is a long-term solution to the problem. We will show in section 6 that people who changed walk substantially longer distances for their water. Furthermore, anecdotal evidence suggests that many well owners and many of those using someone else's well are not comfortable with the arrangement. Other options exist but they will require collective action on the part of communities and/or public provision for those who are not wealthy enough to install their own new wells.

5. Effect of information on knowledge

We want to determine whether the door-to-door information campaign carried out in Araihazar contributed to the amount of general information which people have about the arsenic problem over and above the government media campaign. The Bangladeshi government began to inform people through the TV, radio and newspapers about the dangers associated with drinking water contaminated with unsafe levels of arsenic contemporaneously with our information campaign. Both households in Araihazar and in the control areas were exposed to the information transmitted through the media.

We consider whether people in Araihazar are more aware that the arsenic problem exists than are people in control areas. Then, we look at two more specific outcomes, whether or not people know that boiling water does not remove arsenic from it and that diseases caused by arsenic are not contagious**.** Misinformation on the first point leads to exposure to high levels of arsenic. Wrong information on the second point causes considerable hardship for those who show signs of arsenic-related diseases. Reports that men divorce women who have skin ailments caused by arsenic and that these women are often banished from their homes and villages are quite common.

5.1 Methodology

We estimate the joint effect of our entire intervention on how informed people are in Araihazar. In other words, we do not separate out the different components of the intervention. Rather the key independent variable is a binary variable which takes the value one if the person resides in Araihazar and 0 if she resides in a control area.

The three outcomes of interest are binary. We estimate the probability that an individual is informed using a probit model like the one in expression (5) with the appropriate substitution for the

[21] Primary education consists of years 1 – 5, secondary 6 – 10, and higher of years 11 and up.

dependent variable. In this case, arsenic does not appear on the right-hand-side. Two independent variables which do appear but were not present in (5) are the indicator for Araihazar and a vector of measures of an individual's access to different media sources, in particular radio, television and newspapers.

We also estimate in two separate probit regressions the determinants of being informed for residents of Araihazar and for residents of control areas. These regressions include village fixed effects. Since we have two respondents for most households, the error terms of these observations may be correlated. In the estimation we allow errors to be clustered by household.

5.2 Results

5.2.1 General information about arsenic

The house-to-house intervention in Araihazar has a small effect over and above the media campaign on awareness that arsenic may be present in well water. Tables 5a and 5b present the descriptive statistics. In 2003, 99% of the respondents in Araihazar were aware of arsenic contamination, while 84% of people in control areas were aware.[22] Table 6 presents the marginal effects represented by the coefficients in the probit regression results. The probability that a resident of Araihazar is aware that arsenic may be present in the well water, in column one of Table 6, is higher by 0.16 than is the probability for a resident of a control area and the effect is statistically significant.

As Tables 5 a and b show, in Araihazar, 52% of people know that boiling water does not remove arsenic and 43% know that diseases caused by arsenic are not contagious. The respective percentages in control areas are 62% and 60%. Column three of Table 6 shows that, controlling for observable differences between individuals in Araihazar and in control areas, the probability that a resident of the control areas knows that arsenic-related diseases are not contagious is 0.09 higher than it is for a resident

[22] Only 51% of the residents of Araihazar had heard of arsenic in 2000.

of Araihazar. There is no significant difference between the probabilities of knowing that boiling water does not remove arsenic.

We cannot entirely rule out the possibility that the lack of difference in outcomes between Araihazar and the control areas is due to unobservable differences between the areas rather than to the fact that our intervention is no more effective than the media campaign. Nor can we entirely rule out the possibility that outcomes in Araihazar would look even worse if we could control for unobservable differences. As we noted earlier, Araihazar is closer to the capital than are the control areas. On the other hand, the control areas have a higher average level of education, and higher educational attainment may be correlated with area characteristics which cause people to be more informed. One of the control areas, Jessore, includes one of the largest cities in Bangladesh and the population there on average has four more years of education than in Araihazar. Comparing Araihazar to this area alone still yields the result that the probability that people in Jessore are aware is 0.1 less. Educational attainment in Tangail is most similar to Araihazar. The probability that people there are aware is 0.007 less than in Araihazar.

The media information campaign seems to convey general information as effectively as does our door-to-door campaign. This is striking for several reasons. First, our project had a very intensive presence in Araihazar. People saw project staff walking around most days, they spoke to researchers who were testing wells, researchers who were conducting physical exams and interviewers in a series of interviews. Furthermore, the presence of foreigners working for a famous U.S. university makes a big impression on people in rural Bangladesh. Second, ownership of televisions and radios is far from universal and only about 15% of people read newspapers. The comparison suggests that word-of-mouth may be playing an important role in conveying information.[23]

We do not have sufficient information to conduct a careful cost-benefit comparison of the two information campaigns. However, consider the following illustration of the difference in costs. The cost of wages required to bring information door-to-door throughout the country once would be 17 million

[23] We examine this hypothesis in another paper.

taka, or about $300,000 at the exchange rate for the year 2002, 59 taka/$. The effort would last a year. This ignores all other costs involved.[24] Even if we imagine that a TV, radio or newspaper reporter who covers the arsenic story in a one-hour segment four times during the year earns $50,000 per year, which is an extremely high wage by Bangladeshi standards, the difference in labor costs is enormous. Note that only four hours' worth of the yearly salary of $50,000 should be counted toward the campaign, and the media story reaches the entire country four times a year, while the door-to-door campaign reaches everyone once. The difference in impacts would have to be considerable to justify the difference in costs.

The determinants of being informed are not very different in Araihazar and in control areas, except for the effect of the media. We summarize only the effects which are statistically significant.[25] Seventy-six percent of people in control areas report that they learned about arsenic from the media, 72% of them from the TV. In Araihazar, 97% of respondents report learning about arsenic from our project staff. These results confirm that information is coming from different sources in Araihazar and in control areas, despite the lack of a difference in how informed people are.

TV is a particularly effective medium for reaching women. Women listen to the radio less than men do and almost no women read newspapers. However, women watch TV more than men do. The observation is particularly important in the case of information about water, since in Bangladeshi society obtaining water is the women's role.

Perhaps the most striking results are the importance of education and lack of importance of income and wealth. The coefficients on all levels of education and especially higher levels are very large. Level of education is likely to be correlated with unobservable characteristics which affect how informed a person is. However, being informed about a health risk may also be a significant return to education. Wealthier people are not better informed, once education is controlled for.[26]

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[24] It is not unreasonable to assume that production costs would be the same for the two campaigns, though the cost of materials, transportation, daily expenses, etc. is likely to be much higher for the door-to-door campaign.
[25] The table is available from the authors.
[26] The result does not change when we remove media variables, which may proxy for wealth, from the regression.

There is a considerable literature on the role of social networks in disseminating information. We offer some suggestive evidence. We find that relatives and participation in religious groups affect the probability of being informed, and differently for men than for women. Men benefit from interaction with relatives, while such interaction seems to have a negative effect on the probability that women are informed. Women benefit from interaction with non-relatives. The reason may be that women who interact often with relatives and have many relatives are ones who observe purdah more strictly.[27] Women who interact more with non-relatives may have more diversified social networks. Both men and women who participate in religious groups or attend religious services tend to be less informed.[28]

5.2.2 Information specific to a respondent's well

The significant difference in outcomes between Araihazar and control areas is the result of the fact that our project tested and labeled every well in Araihazar and communicated the well test result to the users of the well. This is a crucial piece of information without which behavior cannot change. Our intervention is the source of information about wells in Araihazar, since only 4% of people had tested their wells at the time of the preliminary survey in 2000 and not all of these had correct results. Only 11% of people in control areas say that the wells they were using 12 months ago had been tested, but we cannot verify whether they are correct about the status of their wells.

Twenty-one percent of people in Araihazar know the precise level of arsenic in the well which they were using before the information campaign, i.e. just how unsafe the well is and therefore how large is the risk which it poses. No one has this information in the control areas.

The media campaign may not be inducing people to test their wells either because tests are not available or they are too expensive or because the urgency of the threat communicated by the media is different from that conveyed by our intervention. The media inform people that local offices of the Department of Public Health and Engineering (DPHE) will provide a free well test to anyone who requests one. We do not know how many requests DPHE offices receive and how responsive they are.

[27] Purdah is the Islamic custom which dictates that women should not interact with strangers or with men, even male relatives.

6. Willingness to pay for a safe source of water

As we discussed at the end of Section 3, we estimate two components of the willingness to pay for a change in one's source of water. Changing to another well is not costless. Those who change to someone else's well have to walk farther for water. The time is likely to have an opportunity cost in terms of foregone income, housework, or leisure. Furthermore, use of someone else's well may require either explicit payments or implicit compensation in the form of helping to maintain the well or otherwise assisting the owner of the well.[29] Those who install their own wells pay for the cost of installation and maintenance.

We estimate the effect changing to another well on the added time that respondents spend walking for their water and, separately, on household expenditure. The former analysis captures the amount of time foregone in order to seek safe water. The latter also captures other costs, by reflecting the total reduction in household expenditure incurred to seek safe water. The former should be a subset of the latter, since the latter should reflect earnings foregone due to additional time spent walking for water. However, it may not be a subset if labor markets are imperfect. This is of particular concern since women walk for water and employment opportunities for women in rural Bangladesh are very limited. Women who cannot earn additional income may walk further to obtain a cheaper source of water and the time they use to do so may not appear in reduced income.[30] In this case, the WTP may actually be a sum of the value of additional time spent walking and any effect on expenditure, where the latter reflects the monetary costs of the source.

The two components do not include other dimensions of WTP and therefore they are lower bounds. They ignore the opportunity cost of time lost due to illness or medical visits and the cost of seeking medical remedies. People in Araihazar do not have to incur these yet, therefore they would not be

[28] These results are merely correlations. Social network variables are likely to be endogenous.
[29] Respondents deny that payments are required, but almost all cite an Islamic injunction against demanding payment for drinking water, therefore they are unlikely to admit if such payments actually take place. Most respondents report that they compensate the owner in ways other than an explicit payment for water.

reflected in reduced expenditure. The expectation of what these costs may be in the future would affect their willingness to pay. These costs may have fairly complex components such as the expected monetary and psychological cost to parents of their children suffering delayed or permanently stunted development due to exposure to arsenic. Our estimates also ignore costs which are reflected in reduced savings rather than expenditures and they do not account for the disutility of being ill.

6.1 Methodology

We present the empirical model for the effect of changing to another well on additional time spent walking for water. The regression model for the effect on a household's monthly per capita expenditure is identical except for the dependent variable. The model is the following,

$$t_{ij} = s_{ij}\kappa + \mathbf{x'_{ij}}\boldsymbol{\alpha} + \mathbf{w_{ij}}\boldsymbol{\gamma} + \mathbf{v_j}\varphi + \varepsilon_{ij} \tag{6}$$

$$s_{ij} = a_{ij}\delta + \mathbf{x'_{ij}}\boldsymbol{\alpha} + \mathbf{w_{ij}}\boldsymbol{\gamma} + \mathbf{v_j}\varphi + \nu_{ij} \tag{7}$$

$$\begin{aligned} s_{ij} &= 1 \quad \text{if i in village j changes to a different source of water} \\ &= 0 \quad \text{otherwise} \end{aligned}$$

The dependent variable, t_{ij}, is the difference between the length of time respondent i in village j walks for water now and the length of time she walked to the well she used before the information campaign. It is zero for those respondents who did not change to another well. The variable, a_{ij}, is the indicator for whether the pre-information well was safe or not. The difference between $\mathbf{x_{ij}'}$ and $\mathbf{x_{ij}}$ in section 4.1 is that $\mathbf{x_{ij}'}$ does not include household expenditure. The vector, $\mathbf{v_j}$, are the village fixed effects. The error terms are ν_{ij} and ε_{ij}. We assume that the errors are correlated. Other variables are as defined in section 4.1.

The error terms, ν_{ij} and ε_{ij}, may be correlated. One's motivation to seek a safe source of water may be correlated with unobservable characteristics, e.g. entrepreneurial spirit or utility derived from health, which may also affect one's relationship with the neighbors and/or one's status in the community and therefore the distance to nearest available safe well. When expenditure is the left-hand-side variable, there is also a simultaneity problem caused by the fact that wealthier households are more likely to be able to afford their own new source of water.

[30] Time spent by household members earning income and attending to household chores is fungible to some extent,

Whether or not one's original well is safe serves as an instrument for changing to a different well. As we discussed in section 4, the level of arsenic in the well is unlikely to be correlated with any unobservable household characteristics within villages. When expenditure is the dependent variable, arsenic may not satisfy the exclusion restriction if some members of households exposed to high levels of arsenic suffer health problems which impact expenditure. In this case, any negative impact of changing to a different source may actually be the negative effect of the health shock on expenditure. However, we will not find a significant effect on expenditure; a result which cannot be due to this bias.

The instrumental variable estimator is a difference-in-difference estimator. We estimate the difference in time spent walking for water between those households who changed to a different source and those who did not among those households exposed to unsafe levels of arsenic minus this difference among those households who are not exposed to unsafe levels of arsenic. Recall that households who have safe wells may change to a different well for other reasons, and we do not want to include the cost of this action in the cost of the household's response to arsenic.

The coefficient of main interest, κ, is the effect of changing on those households whose decision was affected by whether or not they are exposed to unsafe levels of arsenic.[31] We expect the effect to be positive for the added time spent walking and negative for expenditures.

We estimate the model using two-stage least squares, therefore we are using a linear probability model for the first stage when the endogenous variable is changing to another well. We only include the households in Araihazar. As before, we estimate robust standard errors since they may be clustered by household and we include village fixed effects.

6.2 Results

The mean time spent walking for water before the information campaign was .13 minutes and the median was 0 minutes. Only 5% of respondents walked more than 1 minute, with 6 minutes being the

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therefore if the women spend more time obtaining water, other household members may work fewer hours.
[31] Angrist et al 1996

longest time. After the information campaign, the mean time is 1 minute, the median is still 0, but 32% of the sample walk 1 minute or more and the maximum time is 20 minutes.

We report the results of the regression which estimates the effect of changing to a different well on additional time spent walking in the first column of Table 7. Changing to another well on average raises the time the respondent spends walking one way for water by 2.39 minutes, which is an increase of 2.26 minutes over the mean time of .13 minutes. Considering that women walk to bring water several times a day, an increase of almost 5 minutes on the round trip is very large, especially relative to the amount of time they had to devote to the activity before.

A lower bound on respondents' willingness to pay for a reduction in exposure to arsenic could be obtained by valuing the increase in the daily amount of time spent walking for water at an appropriate wage. As discussed above, women obtain the water, and their employment opportunities are very limited. A market wage would be highly inaccurate. We do not know the number of hours women devote to housework, therefore we cannot estimate a shadow wage from a household production function. The following exercise is purely illustrative. The average male wage in our data is about 30 taka per hour. Assume that women walk for water once for every meal, i.e. 3 times a day, and value their time at half the male wage. Then the willingness to pay is 113 taka per month per respondent.

Changing to a different well does not have a significant impact on household expenditure in a regression which includes village fixed effects. It does have a significant impact in a regression in which we do not include village fixed effects and in a regression in which the variables are village averages, i.e. in which we consider inter-village variation in the variables but not intra-village variation. However, arsenic may not be a valid instrument in the inter-village analysis since average village arsenic is correlated with average village expenditures and therefore it may be correlated with unobservable village characteristics which influence income.

The fact that the opportunity cost of time spent walking does not appear in reduced expenditure may suggest that labor markets are indeed imperfect and/or a liquidity constraint is binding, so people can pay for a new source of water with time but not money. However, it may also mean that people are drawing down savings rather than reducing expenditures.

7. Conclusion

Our principal finding is that information alone can rapidly induce a large number of people to change their behavior in order to avoid a risk to health, even if the change in behavior is costly. We provide specific information about the safety of people's wells. Having an unsafe well increases the probability that the person will change to another well within six to twelve months of receiving information by 0.5. The response to information is particularly striking since few people were sick from arsenic before they changed and switching to a different source of water is costly.

We also compare the effect of a house-to-house delivery of information to the effect of information provided through the media on how much people know about the arsenic problem. The crucial role of our intervention has been to provide information specific to one's well, without which people do not know whether they should seek a different source of water. Ninety-one percent of people in our study area know whether their well is safe, while at most 11% know in control areas.

On the other hand, the media has communicated general information about the risk which arsenic poses as effectively as has the door-to-door campaign despite the fact that only two-thirds of households own a TV or a radio. Furthermore, the media are a considerably cheaper method of mass communication.

Interventions which aim to improve access to safe water should consider who among those whose wells are unsafe has not changed to a different source. Somewhat surprisingly those in the lowest income quartile do not seem to have less access to safe water, but those in the lowest quartile of assets do. People who have not changed are less educated. Furthermore, those who are using wells belonging to relatives are less likely to change. Apparently, people are reluctant to use wells whose owners are not kin.

The contrast between our results and prior literature raises an important question for future research; under what circumstances is a large and rapid change in behavior in response to information likely to occur? One potential explanation, which we are exploring in another paper, is the influence which neighbors have on each others' behavior. If such influence is strong, even if only a few people are convinced of the need to act, their behavior may spread through the entire community. Such strong effects may help design less expensive information campaigns which target only a few people in a group.[32]

Explaining the effect we observe also requires understanding which components of our intervention were crucial in eliciting the behavioral response. For example, would a media campaign together with the delivery of a well test result yield the same outcome, or did other parts of our intervention such as the repeated surveys and the daily contact between residents and project staff promote a sense of urgency about the problem? The geochemistry team is documenting the percentage who change to another well in areas in which only well tests were conducted by the Bangladesh Arsenic Mitigation Water Supply Project in addition to the media campaign. Their data may help to shed light on the question.

A number of questions remain for future research. Future surveys will reveal whether the change in behavior which we document is a long-term or a temporary one. An important question is whether relatives or any other social networks help people gain access to safe water, thereby providing insurance in crises such as the arsenic one. Also, we want to understand the long-term impact of the decision to change on welfare. The change in behavior may have consequences other than avoiding diseases caused by arsenic, such as reduced schooling for children, worse nutrition, etc. Finally, we want to determine whether information can lead to more complex behavioral responses. Neighbors' wells are not likely to offer a long-term solution. Access to safe water in the medium and long run is likely to require collective action to drill wells into deeper aquifers which are free of arsenic, to pipe water from safe wells, and/or to clean up surface water. The question arises whether an information intervention is sufficient to catalyze collective action.

[32] See for example Katz and Lazarsfeld (1955) for a sociological discussion of this idea.

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Table 1: Descriptive statistics for Araihazar

Variable	Mean	Std. Dev.	Min	Max
Arsenic level (micrograms/liter)	108	119	5	879
Well is safe (takes value 1 if arsenic < 50)[a]	0.43	0.50	0	1
Age of respondent	37	11	16	80
Respondent is female	0.56	0.50	0	1
Number of people in household	5.8	2.3	2	24
Can read and write	.45	.50	0	1
Highest grade completed was at primary level	0.24	0.43	0	1
Highest grade completed was at secondary level	0.22	0.42	0	1
Highest grade completed was at higher level	0.03	0.17	0	1
Attend religious services: 1-never, 2-few times/year, 3-every month, 4-every week, 5-every day	2.83	1.51	1	5
# relatives in the area	17	17	0	250
Changed to another well for drinking water	0.40	0.49	0	1
Distance to original well (minutes walking)	.13	.5	0	6
Distance to new well (minutes walking)	1.05	2.26	0	20
Change in walking time due to change of well	0.93	2.26	-5	20
Distance to nearest safe well (minutes walking)	4.15	5.00	0	85

[a] Seventy-seven percent of wells in Araihazar have arsenic concentrations which exceed the stricter WHO standard of 10 micrograms per liter.

Table 2: Comparison of Araihazar and control areas

	Araihazar	Control areas	Ghior	Jessore	Nikli	Tangail
% of high arsenic wells[a]	56.8	34.9	30.4	26.4	12.9	63.3
Years of education*	3.18 (0.07)	5.34 (0.15)	4.5 (0.30)	7.26 (0.21)	2.83 (0.27)	4.88 (0.35)
Monthly per capita income (taka)	1,363 (32.13)	1,336 (55)	1,162 (134)	1,473 (82)	927 (57)	1,560 (159)
Per capita assets* (taka)	73,097 (4,188)	136,781 (8,659)	81,171 (12,270)	151,617 (11,840)	53,476 (5,121)	246,383 (32,068)
Days of work or school missed due to illness last year*	13.82 (0.66)	17.07 (0.91)	10.43 (1.49)	18.23 (1.37)	19.02 (1.69)	24.91 (5.59)
Fraction use own well*	0.34 (0.009)	0.63 (0.02)	0.35 (0.03)	0.89 (0.02)	0.21 (0.03)	0.73 (0.03)
Fraction use well in bari*	0.47 (0.01)	0.13 (0.01)	0.34 (0.03)	0.07 (0.01)	0.06 (0.02)	0.1 (0.02)
Fraction use community well*	0.01 (0.002)	0.11 (0.01)	0.04 (0.01)	0.02 (0.007)	0.48 (0.04)	0.06 (0.02)
Hours watch television per month*	27.06 (0.75)	35.03 (1.3)	22.84 (2.08)	56.24 (2.45)	17.15 (1.92)	23.58 (1.7)
Hours listen to radio per month*	8.63 (0.37)	18.69 (0.9)	15.61 (1.78)	25 (1.71)	18.22 (1.98)	10.28 (1.1)
Days read newspaper per month*	2.48 (0.14)	7.11 (0.36)	3.87 (0.63)	12.05 (0.66)	1.94 (0.43)	6.06 (0.77)
Number of observations[b]	2680	997	199	397	201	200

Table contains means of each variable for each area. Figures in parentheses are standard errors of the sample mean estimate.

* variables whose means are different for Araihazar and for control areas at a level of statistical significance of 0.05 We have not conducted a mean comparison test for levels of arsenic.

[a] The percentage for Araihazar is from our own data. It is based on tests of every one of the 6000 wells in our study area, which is a small portion of the Araihazar district. Percentages for control areas come from UNICEF and are based on a sample of wells from each district: 11,000 wells in Ghior, 35,000 in Jessore, 10,000 in Nikli and 20,000 in Tangail.

[b] This is the total number of observations we have in each area. Not all of these observations were used to calculate the mean for each variable since different variables have different numbers of missing values.

Table 3: Determinants of whether a well is safe or not

	Mean for those with safe wells	Mean for those with unsafe wells	Dependent variable Is well safe or not?[ab] Probit
Years of education	3.23	3.13	-
	p value for mean test	0.48	
Primary education (=1 if yes)	-	-	.04 (.032)
Secondary education	-	-	.06 (.038)
Higher education	-	-	.005 (.011)
Monthly household expenditure (taka)	8399	7230	-
	p value for mean test	0.002	
2^{nd} quartile of expenditure (binary)	-	-	.003 (.037)
3^{rd} quartile of expenditure (binary)	-	-	.03 (.042)
4^{th} quartile of expenditure (binary)	-	-	.002 (.046)
Assets (taka)	533,660	376,352	-
	p value for mean test	0.06	
2^{nd} quartile of assets (binary)	-	-	.03 (.037)
3^{rd} quartile of assets (binary)	-	-	.03 (.041)
4^{th} quartile of assets (binary)	-	-	.03 (.045)
Own baseline well (=1 if used one)	.36	.33	.06
	p value for mean test	0.12	(.049)
Baseline well in bari (=1 if used one)	.45	.48	-.02
	p value for mean test	0.22	(.043)
Number of relatives	18	16.6	-.0007
	p value for mean test	0.03	(.0007)
Days missed because of illness	13.44	14.04	-.0002
	p value for mean test	0.66	(.0004)
Age	36.5	37.3	-.003**
	p value for mean test	0.06	(.0017)
Village fixed effects	-	-	Yes
N	-	-	2107
Pseudo R^2	-	-	.23
p value for Chi^2 test	-	-	.00

Third column reports marginal effects calculated from probit regression. Standard errors are in parentheses. Other independent variables in the regression in the third column are how often attend religious services, how far walk to baseline well, household size. Their coefficients and the differences in means are not significant.

[a] Using binary categories for education, expenditures and assets in regression does not affect results. Continuous education, expenditures and assets are also not significant. The specification simply allows for non-linear effects.

[b] The chi squared test for the H_0 that coefficients on all independent variables except the village fixed effects are zero has a p value of 0.19, i.e. we cannot reject the null.

* denotes significance at 0.1. ** denotes significance at 0.5. Robust standard errors, clustered by household.

Table 4: Response to information that well is unsafe

	Dependent variable	
	Whether or not changed (=1 if yes) FE, no controls	**Whether or not changed[a] (=1 if yes) FE, controls**
	Probit	**Probit**
Well is safe (=1 if safe)	-.52**	-.49**
	(.047)	(.053)
Level of arsenic	.0007**	.0008**
	(.0002)	(.0002)
Safe * arsenic	.005**	.004*
	(.002)	(.002)
Other controls	No	Yes
Village fixed effects	Yes	Yes
N	2243	1943
Pseudo R^2	.24	.26
p value for Chi^2 test	.00	.00

Table reports marginal effects calculated from probit regression. Standard errors are in parentheses.
[a] Other independent variables are education, household expenditure, assets, whether used own baseline well, whether used baseline well in bari, how long walked to baseline well, days missed due to illness, number of relatives, how often attend religious services, household size, age.
* denotes significance at 0.1. ** denotes significance at 0.5.
Robust standard errors, clustered by household.

Table 5a: Information overall and by gender in Araihazar

	Percent who know		
	Overall	Women	Men
Arsenic may be present in well water	99%	99%	99%
Know whether own well safe or not	91%	94%	88%
Arsenicosis is not contagious	43%	40%	47%
Boiling does not remove arsenic	52%	55%	49%

Table 5b: Information overall and by gender in control areas

	Percent who know		
	Overall	Women	Men
Arsenic may be present in well water	84%	85%	82%
Know whether own well safe or not*	NA	NA	NA
Arsenicosis is not contagious	60%	57%	63%
Boiling does not remove arsenic	62%	61%	64%

* 11% of people claim that their wells have been tested and they know the status of the well, but we do not know whether their perception of the status is correct.

Table 6: Effect of information campaign in Araihazar on being informed

	Dependent variable		
	Is aware of arsenic (=1 if yes)	**Knows that boiling does not remove arsenic (=1 if yes)**	**Knows that arsenicosis is not contagious (=1 if yes)**
	Probit	**Probit**	**Probit**
Resident of Araihazar (=1 if yes)	.16**	-.02	-.06**
	(.020)	(.028)	(.028)
Other controls	Yes	Yes	Yes
Village fixed effects	No	No	No
N	2986	3000	2998
Pseudo R^2	.40	.07	.09
p value for Chi^2 test	.00	.00	.00

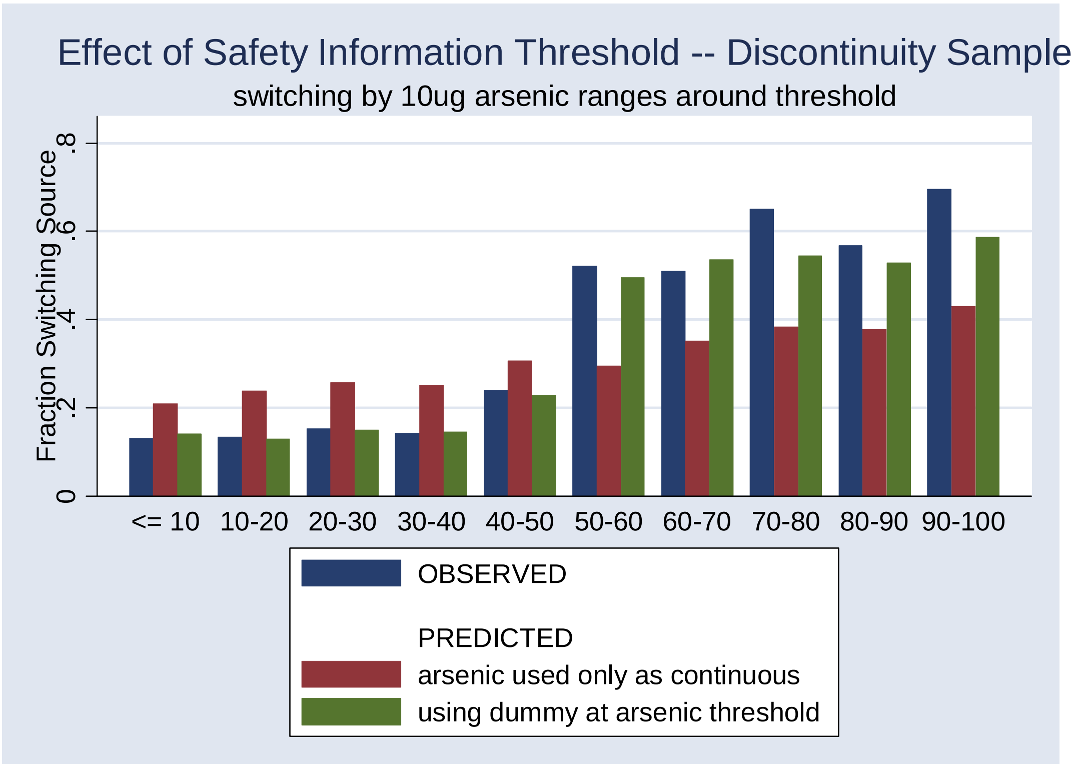
Table reports marginal effects calculated from probit regression. Standard errors are in parentheses.
The other controls in the regressions are household size, age, gender, education, income, assets, religious attendance, number of relatives in area, how many hours watch TV and listen to radio, how many days read newspapers.
** denotes significance at 0.05 or less. * denotes significance at 0.01 or less.

Table 7: Impact of changing to a different well on additional time spent walking for water and on monthly household expenditures

	Dependent variable: time to current well minus time to baseline well	Dependent variable: log of per capita monthly expenditure	Dependent variable: whether or not changed (FIRST STAGE)
	IV	**IV**	**OLS**
Whether or not changed (=1 if yes)	2.39** (.256)	0.03 (.65)	-
Whether or not well is safe (=1 if yes)	-	-	-.46** (.026)
Other controls	Yes	Yes	Yes
Village fixed effects	Yes	Yes	Yes
N	2350	2358	2358
R^2	.15	.22	.30
p value for F test	.00	.00	.00

Standard errors are in parentheses.
Other controls in the regressions are household size, age, education, number of days missed due to illness, whether used own baseline well, whether used baseline well in bari, monthly household expenditure, assets.
** denotes significance at 0.05 or less. * denotes significance at 0.01 or less.
Robust standard errors, clustered by household.

Figure 1



Each interval of arsenic concentrations has three bars. The first bar is the observed percentage who change. The second bar is the percentage of those who change predicted with arsenic as a continuous variable. The third bar is the percentage who change predicted with the binary variable whether the well is safe or not, which reflects the information used by people.

Appendix

A.1 Time line of our project

Year 2000:	Baseline survey documents all wells in the study area and asks a random sample of people whether they have heard of arsenic
Years 2001 – 2002:	1) Project tests and labels all wells 2) Contemporaneously with #1, public health team conducts physical exams, communicates well test result, and asks what they know of arsenic for a random sample of married couples. People have not begun to switch to other wells yet, but they have been exposed to project staff for over a year, thereby learning about arsenic. 3) Following the public health interviews, a team of educators travels around the area, summons as many people as will come to a meeting in each neighborhood and conveys a number of facts about arsenic poisoning. Meetings are on weekdays, during the day. 4) Six to twelve months after the team of educators has been to a particular area, we conduct a survey of a random sample of those individuals interviewed by the public health team in #2. We document whether they have changed to another well, how much they know about the arsenic problem and collect socio-economic data. All socio-economic data, including income, is from this survey.
Year 2002:	Surveys of households in control areas occur before NGOs have started their information campaigns. No systematic well tests have been done except those conducted by UNICEF on a small sample of wells, which were chosen independently of our sample. We ask questions about the well which people were using 12 months ago, i.e. at the time when well tests were being conducted in Araihazar and what they knew about arsenic then. We also ask whether people have changed to another well during the last twelve months, what they know about arsenic now, and collect socio-economic data.

A.2 Health effects of arsenic[33]

The general term for health problems due to arsenic is arsenicosis. The effects of arsenic are cumulative. Up to a point, effects can be reversed if exposure to arsenic ceases. However, eventually even complete elimination of exposure cannot reverse the changes in health.

Keratosis has the earliest onset, with a gestation period of 5 to 15 years. It has a number of symptoms. The most common ones are a darkening of the pigmentation of the skin, and a hardening of the skin on the palms and the feet. As the hardening progresses, the flesh eventually cracks, gangrene may set in, and the victim often loses her limbs. The spots of darkened pigmentation may eventually become cancerous.

Continued exposure to arsenic can affect most organs in the body. It can lead to liver, lung, kidney and bladder malfunctions. It can cause hypertension, strokes and heart disease. Eventually, it leads to a number of types of cancer.

Arsenic exposure can also lead to developmental problems in children. It can cause permanent learning disabilities.

[33] Please see footnote 3 for references relevant for this section.