The Effect of Water Quality Testing on Household Behavior: Evidence from an Experiment in Rural India

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Abstract. How does specific information about contamination in a household's drinking water affect water handling behavior? We randomly split a sample of households in rural Andhra Pradesh, India. The treatment group observed a contamination test of the drinking water in their own household storage vessel; while they were waiting for their results, they were also provided with a list of actions that they could take to remedy contamination if they tested positive. The control group received no test or guidance. The drinking water of nearly 90% of tested households showed evidence of contamination by fecal bacteria. They reacted by purchasing more of their water from commercial sources but not by making more time-intensive adjustments. Providing salient evidence of risk increases demand for commercial clean water.

INTRODUCTION

When people receive new information about health risks, they may change their behavior to protect themselves. However, the benefit of risk reduction is often less salient than the costs of behavior change, and therefore, information alone may be insufficient as a motivator. Rigorous experimental research has begun to shed light on this question.^{1–11} Recent field experiments have informed households in underresourced communities about microbial contamination in their drinking water and tested whether that information motivated a change in behavior. The emerging evidence is that, on average and in many different contexts, it may.^{9,12} We extend this body of knowledge by using an innovative study design to explore two related questions. First, when reacting to information about contamination, how do households trade off cash-intensive versus time-intensive risk avoidance strategies? Second, do response strategies vary across the socioeconomic distribution? We randomized credible and salient household-specific information about drinking water contamination to about one-half of 1,940 sample households in 44 villages in rural Andhra Pradesh, India; the other one-half of the sample served as a control group. The water quality information was provided through the use of test kits that detect hydrogen sulfide-producing fecal coliform bacteria. While waiting for their test results, householders were given specific suggestions of both cash- and time-intensive actions that could be taken to address a positive result.

METHODS

Intervention. This study tested the effect of an intervention that combined household-specific water quality information with messages about steps that households could take to improve it. At the end of a baseline survey about water, sanitation, and hygiene behaviors, approximately one-half of 1,940 study households (931 in all) had their drinking water tested for fecal contamination. Enumerators then read an informational handout to respondents that explained how to interpret test results and how to improve water quality; the handout was left with the respon-

dent household at the end of the visit. The following behaviors were recommended: (1) obtain drinking water from safe sources such as a community water supply (CWS) or bottled water; (2) chemically treat, boil, or use advanced filters; and/or (3) use a series of cheaper but more time-intensive compensatory strategies (like avoiding direct hand contact with water and keeping water out of the reach of children).

Tests of water from each treatment household's primary in-house drinking water storage container were conducted using H₂S test kits from HiMedia. The tests are inexpensive, costing less than \$0.50 per kit. The HiMedia test kits (HiMedia Laboratories Pvt Ltd., Mumbai, India) detect hydrogen sulfide-producing fecal coliform organisms and were modified to also detect *Escherichia coli* and *Salmonella typhimurium*. Contaminated water turns black within 48 hours; in addition, opening the bottle with such a positive (black) test result releases a strong odor that smells like rotten eggs. Intervention materials stated clearly that a positive test outcome implies contamination and a potential health risk, but it does not mean that consuming the water will necessarily make one sick.^{13,14} One kit was left with the tested household, and another kit was retained by study personnel.

Study design. The research used a randomized design to study the effect of information provision on treatment households. Power calculations suggested that a sample of approximately 50 households from each village would be more than sufficient to show a change in household behavior. Using a random number generator, we identified 25 households that would receive the water test and associated behavior change messages and another 25 households that would serve as controls.

Sampling frame. The villages in the study were chosen from communities that had participated in an earlier study in 2006 examining the impacts of advanced CWS systems in three districts of Andhra Pradesh.⁸ Study villages had (1) populations of at least 2,200 people, (2) a perennial surface water source that was not chemically contaminated, and (3) successful mobilization to finance a down payment for the investments in treatment infrastructure. Respondent households in this previous study were a representative sample of households with children under the age of 3 years. The evaluation of that intervention had revealed low sustained purchase of commercial safe water from the CWS centers and found that availability of CWS systems had no impact on health or water quality outcomes.⁸

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This study was conducted in 44 villages that had participated in the 2006 study. They were located in Krishna, Guntur, and West Godavari districts in central coastal Andhra Pradesh, India.

Survey implementation and interview procedure. Household survey instruments were designed based on existing questionnaires, literature reviews, and inputs from local advisors and study partners. Survey instruments were translated into Telugu and refined based on focus group discussions and pretests in villages in Andhra Pradesh. Trained enumerators and field supervisors with at least high school education carried out the field work. Baseline data collection and water testing took place in December of 2010, and the second round of surveys took place 1 month later in late January and early February of 2011.

The survey instrument consisted of questions and enumerator observations on water source availability; transport, storage, and handling; averting behaviors; exposure to sanitation and hygiene messages; and household demographics and socioeconomic characteristics. Survey responses were obtained from a male or female adult in each sample household. Informed consent was obtained from all respondents; survey protocols were approved by the institutional review board of Research Triangle Institute International.

Analysis. The randomized design of this experiment allows for straightforward analysis and reporting of survey results. Furthermore, the rich data from the previous intervention can aid and motivate more nuanced understanding of the evolving context in these communities. In the results, we present descriptive statistics for key household characteristics and behaviors as well as prior experience with water testing grouped by treatment assignment in the baseline survey in 2010. This comparison allows assessment of the quality of the randomization procedure. An array of characteristics is shown to be balanced between treatment and control groups, suggesting that our randomization algorithm produced exchangeable groups as intended.

We then analyze the impacts of our intervention on several key water and hygiene-related outcomes. These outcomes

include sourcing of water from a CWS as well as hygiene and safe water handling practices. We estimate impacts using a simple difference in means between treated and control households as well as the more conservative difference in differences (DiD) estimator that takes into account any baseline differences between these two groups that could have arisen solely as a result of chance. The DiD estimator is conservative because it subtracts the difference in means between treatments and controls at baseline (although this difference is zero in expectation) from the difference in treatments and controls at follow-up. This strategy is equivalent to a comparison of baseline to follow-up trends in the two groups, and therefore, it sweeps out the effects of any common changes over time that may be occurring in the background.^{3,8} It is obtained using the following linear regression, with relevant outcomes y_{it} on the left-hand side and indicators of treatment assignment T_i , a dummy 2011_{it} that is equal to 1 for the follow-up study wave and 0 during the initial study wave, and an interaction of the two variables on the right-hand side:

$$y_{it} = \beta_0 + \beta_1 \cdot T_i + \beta_2 \cdot 2011_{it} + \beta_3 \cdot T_i \cdot 2011_{it}.$$

Also, several outcomes are measured on an ordinal scale—for example, respondents were asked how often they wash their water vessels, with possible answers on a five-point scale (1 = every day, 4 = rarely, 5 = never). To analyze impacts on these outcomes, we use an ordered logit regression to compare the odds of moving between ordinal categories among control and treatment households. In those analyses, our DiD estimator represents a ratio of odds ratios.

RESULTS

Table 1 presents baseline statistics for the two experimental arms and tests for differences. Although only about 14 characteristics are shown in Table 1, we examined a total of 75 baseline characteristics (those characteristics not shown in Table 1 appear in Supplemental Table 1). Treatment households were not statistically different from control households

TABLE 1
Household characteristics and behaviors in the baseline

Household characteristic	Control	Treatment	Difference (95% CI)	P value
Demographics and socioeconomic indicators				
Children born 2001–2008	1.8	1.8	−0.02 (−0.08, 0.04)	0.48
Household members	4.8	4.8	+0.04 (−0.10, 0.18)	0.56
At least one adult in the household is literate	73.2	70.8	−2.5 (−6.0, 1.6)	0.24
At least one adult has ≥ 10 years of education	35.5	39.5	+3.9 (−0.4, 8.3)	0.08
Household expenditure is more than or equal to median expenditure	48.5	49.3	+0.7 (−3.8, 5.3)	0.76
Respondent believes its household is in one of the top 3 steps of a 6-step social status stairway	29.0	32.3	+3.2 (−0.1, 7.4)	0.12
Health knowledge				
Previously heard at least three types of public health messages	88.5	86.8	−1.7 (−4.5, 1.3)	0.29
Previously heard messages about water storage and handling	88.5	91.9	+3.4 (0.2, 5.6)	0.02
Water handling, storage, and treatment				
Uses modern filters	10.4	11.8	+1.4 (−1.3, 4.1)	0.32
Filters water through cloth	51.1	56.6	+5.4 (1.1, 9.7)	0.02
Does not treat water in house	23.7	22.6	−1.2 (−4.9, 2.6)	0.56
Stores water longer than 1 day	6.0	7.0	+1.0 (−1.2, 3.3)	0.36
Cleans storage vessel daily	86.3	86.2	−0.1 (−3.1, 3.0)	0.96
Washes hands after latrine	80.0	80.5	0.4 (−3.1, 4.0)	0.80
Lost in 2011 follow-up survey	4.0	3.7	−0.4 (−2.0, 1.4)	0.74
<i>N</i>	1,009	931		

With the exception of the rows labeled demographics and socioeconomic indicators (which indicates mean counts of adults and children in treatment and control households), each row represents a binary variable; each cell in control and treatment columns represents the percentage of households who have the characteristic indicated in the row title. The 1,940 households represented were all successfully interviewed at baseline in 2010.

HH = household.

TABLE 2
Difference in water sourcing between tested and control households at baseline and follow-up

	Fraction relying on each water source among treatment households minus fraction among control			
	At baseline	At follow-up	DiD	Sample average at baseline (%)
Commercial water supply	-0.6 (-3.3, 2.2)	4.7* (1.9, 7.5)	+5.3* (2.3, 8.3)	11
Private tap	1.4 (-2.6, 5.2)	-1.0 (-4.9, 2.8)	-2.4 (-6.7, 1.9)	25
Public tap	-3.9† (-8.3, 0.5)	-6.0* (-10.4, -1.7)	-2.2 (-6.9, 2.6)	43
Private well	1.6 (-1.0, 4.3)	0.2 (-2.3, 2.7)	-1.4 (-4.1, 1.3)	9.4
Public well	0.9 (-1.3, 3.1)	1.3 (-0.8, 3.4)	+0.4 (-1.9, 2.7)	6.1
Other (including missing)	0.6 (-1.3, 2.5)	0.9 (-1.6, 3.4)	+0.3 (-2.2, 2.7)	5

*Significant with $P < 0.05$.

†Significant with $P < 0.1$.

Each row represents a separate linear probability regression using regression equation 1 in the text. The sample underlying this table comprises the 1,940 households interviewed in 2010. The 76 households that were lost to follow-up are grouped into the other (including missing) category. The water sources represented in the rows are mutually exclusive and communally exhaustive, but the columns may not sum exactly to zero (and column 5 does not sum exactly to 100%) because of rounding. All coefficients and 95% CI limits (shown in parentheses) are multiplied by 100 to represent marginal effects in terms of percentage points.

in 70 of 75 characteristics (at the 10% confidence level). Apparent sample imbalances are not consistent across different measures of similar constructs—for example, control households were 2.5% more likely to have a literate adult (difference not statistically significant), although they were measured to be slightly less educated (significant at 10% confidence). We interpret this finding as an indication that the few statistically significant differences between the arms at baseline are merely rare results of simple chance. We conclude that the randomization was successful in establishing balance in terms of observed—and also unobserved—characteristics. Nonetheless, as an added precaution, we present the results of a DiD estimator to supplement our simple comparisons of changes in mean outcomes, and therefore, conservative readers can see the differential change in household behavior between the two arms during the month of follow-up.

The results that we present here represent an intent to treat (ITT) approach—comparing behavior change among the treatment group with the change among the control group regardless of the test result. In fact, the contamination test was positive in 88% of tested households. Given the overwhelming prevalence of contamination, we interpret these results as a reasonable lower bound on the impact of credible information on contamination. In analyses not reported here, we have also restricted our treatment group to only the 88% that tested positive; the patterns are consistent with those patterns that we report here, although the effects are somewhat stronger. The ITT results are much easier to interpret because they are not influenced by potential confounding factors that affect both test results and behavior change.

Tested households also received explicit advice on specific behaviors that they could undertake to reduce their risk of contamination. Most were time-intensive (for example, washing hands more frequently), but two were cash-intensive (purchasing water from commercial purification centers and purchasing more modern storage and transport containers).

Tables 2 and 3 illustrate the impact of the information on water sourcing. At baseline, about equal fractions of treatments of treatment and control households were purchasing water from commercial suppliers (95% confidence interval [CI] = -3.3 to 2.2; $P > 40\%$) (Table 2). This finding indicates that the randomization worked properly to establish similarity between the groups at baseline; however, by follow-up, nearly 5% more households were purchasing water from commercial suppliers (95% CI = 1.9–7.5; $P < 0.1\%$) for a total

DiD of 5.3% (95% CI = 2.3–8.3; $P < 0.1\%$). An alternative way to compute the same DiD would be to compare the differential time trends between the two groups (Table 3). Within the treatment group, the fraction of households relying on commercial suppliers rose by 3% (95% CI = 1.0–5.3, $P < 1\%$); among the control group, this fraction declined by 2.3% points (95% CI = -4.3 to -0.1, $P < 5\%$), and adding these values will recover the DiD (5.3%). Given that only 10% of households were purchasing such water at baseline, this finding represents an increase in the likelihood of purchasing treated water by a factor of 1.5. Consistent with these findings is the fact that tested households were more likely to change the mode of transport that they used to fetch water (results not shown). Table 3 provides a more complete picture of how treatment households adjusted their primary water sourcing between the waves—shifting away from (zero cash marginal cost) taps and private wells and to (costly) commercial safe water. In contrast, control households were shifting away from commercial safe water ($P = 0.05$). This pattern of shifting to cash-cheaper alternatives is consistent with other research that finds households diverting their efforts away from diarrheal disease-averting behaviors as the monsoon season wanes and perceived risk declines.^{7,15}

Households in the control and treatment groups showed much less evidence of differences in terms of cash-cheaper but more time-intensive adjustments. As shown in Table 4, treatment households were significantly more likely at follow-up to use a tap or ladle to extract water from storage containers and have tight screw caps on storage containers. Similarly, the DiD estimates show that such households

TABLE 3
Difference in water sourcing between tested and control households at baseline and follow-up: Changes in reliance on each water source between baseline and follow-up

	Treatment group	Control group
Commercial water supply	+3.1* (1.0, 5.3)	-2.2* (-4.3, -0.1)
Private tap	-2.6 (-5.5, 0.3)	-0.2 (-3.4, 3.0)
Public tap	-2.2 (-5.4, 1.1)	+0.0 (-3.5, 3.5)
Private well	-1.6 (-3.5, 0.3)	-0.2 (-2.1, 1.7)
Public well	-0.4 (-2.1, 1.3)	-0.8 (-2.3, 0.7)
Other (including missing)	+3.7* (1.8, 5.5)	+3.4* (1.7, 5.0)

*Significant with $P < 0.05$.

Each row represents a separate linear probability regression using regression equation 1 in the text. The sample underlying this table comprises the 1,940 households interviewed in 2010. The 76 households that were lost to follow-up are grouped in the other (including missing) category. The water sources represented in the rows are mutually exclusive and communally exhaustive, but the columns may not sum exactly to zero because of rounding. All coefficients and 95% CI limits (shown in parentheses) are multiplied by 100 to represent marginal effects in terms of percentage points.

TABLE 4
Difference in water handling and hygiene behaviors between tested and control households at baseline and follow-up

	Difference between groups (percent treatment – percent control households)		DiD	Sample average/median at baseline
	At baseline	At follow-up		
Ordinary binary outcomes*				
Treats water by any recommended method†	1.1 (–2.6, 4.8)	2.3 (–2.1, 6.7)	1.2 (–4.1, 6.5)	24%
Extracts water using ladle or tap	2.2 (–0.6, 5.0)	3.6‡ (1.3, 5.9)	1.4 (–2.0, 4.7)	11%
Storage vessel has tight screw cap	1.4 (–0.9, 3.7)	3.1‡ (0.6, 5.5)	1.7 (–1.4, 4.7)	11%
Categorical outcomes§				
Cleaning frequency: vessel used to fetch water (1 = daily; 5 = never)	1.02 (0.74, 1.41)	0.74‡ (0.57, 0.96)	0.73 (0.48, 1.10)	1 (daily); 91% of sample
Cleaning frequency: vessel used to store water (1 = daily; 5 = never)	1.01 (0.78, 1.32)	0.86 (0.68, 1.09)	0.85 (0.60, 1.21)	1 (daily); 86% of sample
Frequency of advanced filter usage (1 = daily; 5 = never)	0.85 (0.64, 1.13)	0.70‡ (0.49, 0.99)	0.81 (0.52, 1.28)	5 (never); 89% of sample
Number of occasions prompting hand washing (of five specific types of occasions)	1.12 (0.96, 1.32)	1.21‡ (1.03, 1.42)	1.08 (0.86, 1.35)	2 (of 5); 32% of sample

* Each row represents a separate regression; as in Table 2, the regressions for binary outcomes are linear probability models. All coefficients and 95% CI limits (shown in parentheses) are multiplied by 100, and they represent marginal effects in percentage point terms.

† Recommended methods include the use of chemical additives, modern filters like Aquaguard, or sustained boiling. This category specifically excludes filtering water through cloth.

‡ Significant with $P < 0.05$.

§ Each row represents a separate ordered logit regression. Reported coefficients are odds ratios, and the DiD is the ratio of the odds ratios in columns 2 and 3.

were 1.2% more likely to use recommended in-house treatment methods, were 1.4% more likely to avoid touching water with their hands (using a ladle or tap to extract water from the storage vessel), and reported more frequent cleaning of vessels for fetching and storing water. However, these DiD estimates were substantively small and statistically insignificant; the evidence overall, therefore, points to households reacting to the testing intervention by spending cash rather than time or personal effort.

Perhaps as intriguing as these differences was the consistent and strong pattern of decay in averting behaviors over time. Table 5 illustrates the between-wave trends in both treatment and control groups. It reveals a distinct pattern of decreased self-reported use of recommended risk reduction behavior between the two waves of the survey. However, the covering of drinking water storage vessels with a tight screw cap, a practice that was confirmed by enumerators and not dependent on self-reports, did not decay in the same way. This behavior increased by 2% (or a factor of 0.2) between survey waves among the treatment group (significant at 10% confidence), but it did not change between the waves for the control group. Although DiD is not statistically significant, as

shown in Table 4, the difference in means at follow-up (a less conservative measure of the treatment effect) is significant. This pattern would be consistent with treatment households spending cash on new vessels on learning that their water is contaminated, whereas control households simply continued using the vessels that they had.

DISCUSSION

Overall, analysis of the differences between treatment and control households over time in this study revealed that people receiving water tests increased their purchase of drinking water from commercial sources by a factor of 1.5 compared with controls (95% CI = 1.21–1.75; $P < 0.1\%$). More generally, there were large declines in reported protective behaviors over the 1 month between field visits, particularly among controls.

Commercial water is affordable but not negligibly costly by local standards—1 week's supply for the average household costs about 16 rupees or one-half of a day's wages for an average worker in these communities. However, more households on average were willing to incur these costs when they saw evidence that they were drinking contaminated

TABLE 5
Differential trends in water handling and hygiene behaviors between tested and control households

	Δ (Follow-up – baseline) among treatment group	Δ (Follow-up – baseline) among control group
Ordinary binary outcomes		
Treats water by any recommended method	–19.3* (–23.1, –15.6)	–20.5* (–24.3, –16.7)
Extracts water using ladle or tap	–2.8† (–5.4, –0.2)	–4.2* (–6.2, –2.1)
Storage vessel has tight screw cap	2.1 (–0.2, 4.5)	0.5 (–1.5, 2.5)
Categorical outcomes		
	Odds ratio: follow-up vs. baseline among treatments	Odds ratio: follow-up vs. baseline among controls
Cleaning frequency: vessel used to fetch water (1 = daily; 5 = never)	1.48* (1.09, 2.01)	2.00* (1.51, 2.65)
Cleaning frequency: vessel used to store water (1 = daily; 5 = never)	1.22* (0.95, 1.58)	1.46* (1.14, 1.87)
Frequency of advanced filter usage (1 = daily; 5 = never)	1.46* (1.07, 1.99)	1.77* (1.27, 2.48)
Number of occasions prompting hand washing (of five specific types of occasions)	0.26* (0.23, 0.32)	0.25* (0.21, 0.30)

* Significant with $P < 0.05$.

† Significant with $P < 0.1$.

This table represents an alternative presentation of the DiD values reported in Table 4; results come from the same regressions as those results reported in Table 4. All coefficients and 95% CI limits (shown in parentheses) are multiplied by 100, and therefore, they represent marginal effects in percentage point terms.

water, and they were more willing to incur these costs than to undertake cash-cheaper but more time-intensive behaviors like cleaning their vessels more frequently.

Diarrheal disease remains a major source of preventable morbidity and mortality.^{16,17} Many have asserted that effective interventions could use social marketing strategies that focus on information about water quality to promote preventive behaviors.^{3,8,18} Because microbial contamination is impossible to detect with the naked eye, the link from water to disease may not be salient enough to affect behavior. Information specifically tailored to individual households—like a direct test for contamination of a household's own water supply—may be striking in a way that general social marketing messages are not. This result points to the importance of imperfect or incomplete information as one explanation for the persistence of diarrheal disease in these communities.

It would be premature to say that the impact of information on water, sanitation, and hygiene behaviors is significant or long lasting. It would certainly be useful to build on studies such as this one with development of procedures for tracking households' water-related behaviors and the consequences of those behaviors for the quality of consumed water that are perhaps less subject to potential self-reporting biases (e.g., including non-intrusive observation of behaviors or water quality testing at follow-up). In particular, it is difficult to know whether declines in self-reported measures of protective behaviors across the entire sample were the result of seasonal adjustments or some other factors.¹⁹ Our DiD approach is likely, however, to sweep out biases arising from misclassification in the self-reports. In addition, our study does not provide data on the extent to which behavior change led to measurable improvements in water quality, which others have shown to be more difficult.¹¹ Nonetheless, those groups working to improve health by increased investments in preventive behavior should not overlook the impact that personally tailored information can have, at least in the short term. These results also suggest that the impact of information interventions is likely to interact with subsidies for the purchase of risk reduction technologies like commercially purified water.

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