The Importance of Being Informed: Experimental Evidence on the Demand for Environmental Quality

JYOTSNA JALAN
E. SOMANATHAN

Indian Statistical Institute
New Delhi, India

October 2004

South Asian Network for Development and Environmental Economics (SANDEE)
PO Box 8975, EPC 1056
Kathmandu, Nepal

SANDEE Working Paper No. 8 - 04

Published by the South Asian Network for Development and Environmental Economics (SANDEE), PO Box 8975, EPC-1056 Kathmandu, Nepal.
Telephone: 977-1-552 8761, 552 6391 Fax: 977-1-553 6786

SANDEE research reports are the output of research projects supported by the South Asian Network for Development and Environmental Economics. The reports have been peer reviewed and edited. A summary of the findings of SANDEE reports are also available as SANDEE Policy Briefs.

National Library of Nepal Catalogue Service:

Jyotsna Jalan and E. Somanathan
The Importance of Being Informed: Experimental Evidence on the Demand for Environmental Quality

(SANDEE Working Papers, ISSN 1813-1891; 2004 - WP 8)

ISBN: 99933-826-7-1

Key Words
1. Environmental quality
2. Drinking water
3. Information
4. Awareness
5. Experiment

The South Asian Network for Development and Environmental Economics

The South Asian Network for Development and Environmental Economics (SANDEE) is a regional network that brings together analysts from different countries in South Asia to address environment-development problems. SANDEE's activities include research support, training, and information dissemination. SANDEE is supported by contributions from international donors and its members. Please see **www.sandeeonline.org** for further information about SANDEE.

Comments should be sent to E. Somanathan, Indian Statistical Institute, 7 Shaheed Jit Singh Marg, New Delhi 110016, India. E-mail: som@isid.ac.in

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

To what extent does information affect the demand for environmental quality? A randomly selected group of households in Gurgaon, India was informed whether (or not) their drinking water had tested positive for fecal contamination using a simple test kit costing less than $0.50. Households that were initially not purifying their water, and were told that their drinking water was contaminated, were 11 percentage points more likely to begin some form of home purification in the next 7 weeks than households that received no information. By way of comparison, an additional year of schooling of the most educated person in the household, is associated with a 4.4 percentage-point rise in the probability of initial purification, while a move from one wealth quartile to the next is associated with a 15 percentage-point rise. Households that received a "no contamination" result were not significantly different in their behavior from households that were not informed about their water quality. These results indicate that the issue of under-provision of information needs to be addressed when estimates of the demand for environmental quality are used for welfare or policy analysis.

Keywords: Environmental quality, drinking water, information, awareness, experiment.
JEL Codes: I12, O10, Q53, Q56

The Importance of Being Informed: Experimental Evidence on the Demand for Environmental Quality

Jyotsna Jalan and E. Somanathan

1. Introduction

In the late 1840's, Ignaz Semmelweis, a Hungarian physician working in the Lying-In hospital in Vienna, showed that the high death rate among women giving birth in the hospital was due to the transfer of a toxic substance from the hands of medical students who had worked on cadavers and then attended to the women in the maternity ward. This knowledge was used to dramatically lower the death rate by having the students wash their hands with a disinfectant before attending to patients. A few years later, another physician, John Snow, showed that the cholera epidemic that hit London was transmitted by contaminated water.

By the late 1870's, the germ theory of disease had been put on a firm empirical footing (Nester et. al., 1998). Nevertheless, more than a century later, 70 percent of those surveyed in a village in rural Bolivia thought that diarrhea was a normal occurrence in childhood (Quick et. al., 1997), while 45 percent of those surveyed in a suburb of Delhi in the study reported here did not include drinking contaminated water among the possible causes of diarrhea.

These stories illustrate two points: first, that relevant information helps people protect themselves from environmental hazards such as infectious disease, and second, that despite this, such information spreads slowly through conventional avenues like school education.

The economics literature has laid more emphasis on wealth than on information as a determinant of the willingness to pay to protect oneself from environmental and health hazards.[1] Just how quantitatively significant is the role of information in this regard? In this paper, we examine this question in the context of drinking-water quality. This is an extremely important issue in the developing world where there are 1.7 million deaths and 54 million disability adjusted life years lost annually due to unsafe water, sanitation and hygiene. Furthermore, 90 percent of the deaths are those of children (WHO, 2002).

We conducted a randomized experiment in Gurgaon, a suburb of Delhi, in which we tested approximately 1,000 randomly selected households' drinking water for the presence of bacteria of fecal origin. About 60 percent of the water (before any home purification) tested "dirty" i.e., positive for the presence of fecal bacteria.[2] By way of comparison, in the United States, if even a single sample of tap water tests positive for fecal coliforms, then the local water authority is in violation of federal regulations issued under the Safe Drinking Water Act.[3] These regulations also stipulate that local authorities inform individual households about any violation of the standards in their jurisdiction. In India, on the other hand, tap water is unregulated and the results of any water quality tests conducted by government authorities are generally not made public (McKenzie and Ray, 2004).

---

[1] As exemplified in the literature on the Environmental Kuznets Curve surveyed in Borghesi [1999].

[2] Throughout the paper, we use the term “clean” to indicate that the water tested negative for the presence of fecal bacteria and the term “dirty” to mean that the water tested positive for the presence of fecal bacteria.

[3] *Source*: http://www.epa.gov/safewater/mcl.html

In the second round, we informed a randomly selected group of about half the households in our sample of their water test results. Returning about seven weeks later, we found that households who were told that their water was "dirty" (indicating the likelihood of fecal contamination) and were initially not doing any home water purification were 11 percentage points more likely to have begun doing so as compared to households who had not been informed of the test result.[4]

How should we evaluate the size of this effect? Jalan et. al. (2003) using National Family Health Survey data for urban Indian households found that the probability of home water purification rose by 5-12 percentage points when moving from one wealth quartile to the next, while it rose by 1(1.4) percentage points with a year's increase in schooling of the most educated male (female) member of the household. Likewise, we find, using the cross-section from the first round of our survey in Gurgaon, that an additional year of schooling for the most educated member of the household is associated with a 4 percentage-point rise in the probability of purification while a move from one wealth quartile to the next is associated with a 15 percentage-point rise.

Even one-time targeted information of this nature can have considerable effects on awareness. Whether such awareness will ultimately lead to a significant decline in the incidence of water-borne disease is another question beyond the scope of this paper. However, what the experimental results do indicate is to the extent that the failure of public authorities to provide safe water is due to lack of demand (whether by way of political expression or lack of willingness to pay for improvements), regular water testing and public information campaigns can help mitigate this problem at a relatively low cost.

More generally, measuring the demand for environmental quality and attempting to draw welfare and policy conclusions from it without addressing the issue of under-provision of information can lead to significant underestimates. It is not surprising, given the public-good aspect of information about environmental risks, that it is underprovided.

As yet, little attention has been paid to this issue in the literature. The only experimental study of which we are aware is not from a developing country. This is Smith et. al.'s (1995) study of mitigating behavior in response to different information booklets on cancer risks from radon gas given to a sample of US households in New York state by the Environmental Protection Agency. They found that radon readings and the manner of presentation of information about the health risks of radon influenced the decision to take mitigating action.

Antle and Pingali (1994) studied pesticide use in rice farming in the Philippines and found that insecticides were heavily over-used because farmers were not sufficiently aware of their adverse chronic (long-term) health effects. These are not easily perceptible, unlike acute (immediate) effects. It is notable that this conclusion applies to private profitability with health effects being valued by their productivity losses alone.

With regard to drinking-water quality, apart from Jalan et. al. (2003) mentioned above, Roy et. al. (2004) found, controlling for income, that the elasticity of water purification expenditure of households in Kolkata, India with respect to years of schooling of the most educated member of the household was approximately unity. Dasgupta (2004)and McConnell and Rosado (2000) found that in Delhi and an urban area of Brazil respectively, education of the household head was statistically significant in the decision to purify water, although they do not report the

[4] Although public provision of safe water may be a more effective way to prevent disease, we measured home treatment because it is the only response we can expect from households in the short term and is easy to implement. In fact, among environmental goods, we chose to study clean drinking water not only because of its intrinsic importance but also because private mitigating actions that can be easily recorded are available to households.

size of the effects (these not being their main concern). This is suggestive of the role of information that is examined more closely below.

The following section describes the experiment and the sampling design. Section 3 provides details about the data and reports some summary statistics. Section 4 presents the theoretical framework and the results from the experiment. Section 5 concludes.

2. The Experiment

Our study area is the city of Gurgaon, in the state of Haryana in India and a suburb of the national capital, New Delhi.[5] We chose Gurgaon because we wanted a residential urban area where the water supply to households was not of uniform quality, where there was some heterogeneity among the population in terms of their general awareness of sanitation and health issues, and that was sufficiently compact so as to make for easy implementation of the survey.

In July and August 2003, we conducted a pilot survey of the quality of water supplied to residential households in randomly chosen areas of Gurgaon. We used water-testing kits that test for the presence or absence of bacteria of fecal origin. While most fecal bacteria are not themselves pathogenic, their presence shows that pathogens may be present since most water-borne pathogens are of fecal origin. Direct tests for the presence of pathogens are expensive and so testing for fecal coliform bacteria is the standard method of testing for exposure to waterborne disease worldwide (WHO, 1997). Our test kits were purchased from TARA, a non-profit development organization based in Delhi. More than 90 percent of the approximately 30 samples from the pilot survey were contaminated.

Once we had identified our sampling frame, we used 2001 census data at the enumeration block (EB) level to create a wealth index based on the first principal component of a number of indicators.[6] We excluded all those EB's where at the time of the 2001 census house-listing, there were fewer than 50 census buildings. Old Gurgaon includes 240 EB's in the municipality, 19 EB's in Sukhrali village and 28 EB's in Gurgaon village.[7] After categorizing the EB's into wealth quintiles, we used EB maps provided by the census bureau for our house lists. Our objective was to choose a random sample of 1,000 households, stratified by wealth, from all EB's so as to over-sample households from the middle three quintiles and under-sample from the top and bottom quintiles.[8] Our final sample consisted of 60 and 70 households respectively from Sukhrali and Gurgaon villages representing the lowest wealth quintile, and 870 households (120 from the top quintile and 250 each from the middle quintiles) from Gurgaon municipality.[9]

[5] There are two sections in Gurgaon - new Gurgaon, an area that has witnessed rapid growth over the last decade and old Gurgaon which has been in existence for four to five decades. Our sampling frame includes only old Gurgaon for which the 2001 census maps were readily available.

[6] This was created in the same way as the household-level index described in Section 3 below. The variables included in the wealth index are: Predominant material of the floor, wall, and roof, condition of house, ownership status, number of dwelling rooms within the house, drinking water source, lighting source, whether kitchen, bathroom, latrine are within the house, type of waste-water outlet house is connected to, type of fuel used for cooking, whether household possesses a radio/transistor, television, telephone, bicycles, scooter/motorcycle/moped, car/ jeep/ van, and whether the household avails of banking services.

[7] The latter two were once villages but are now in the middle of urban Gurgaon.

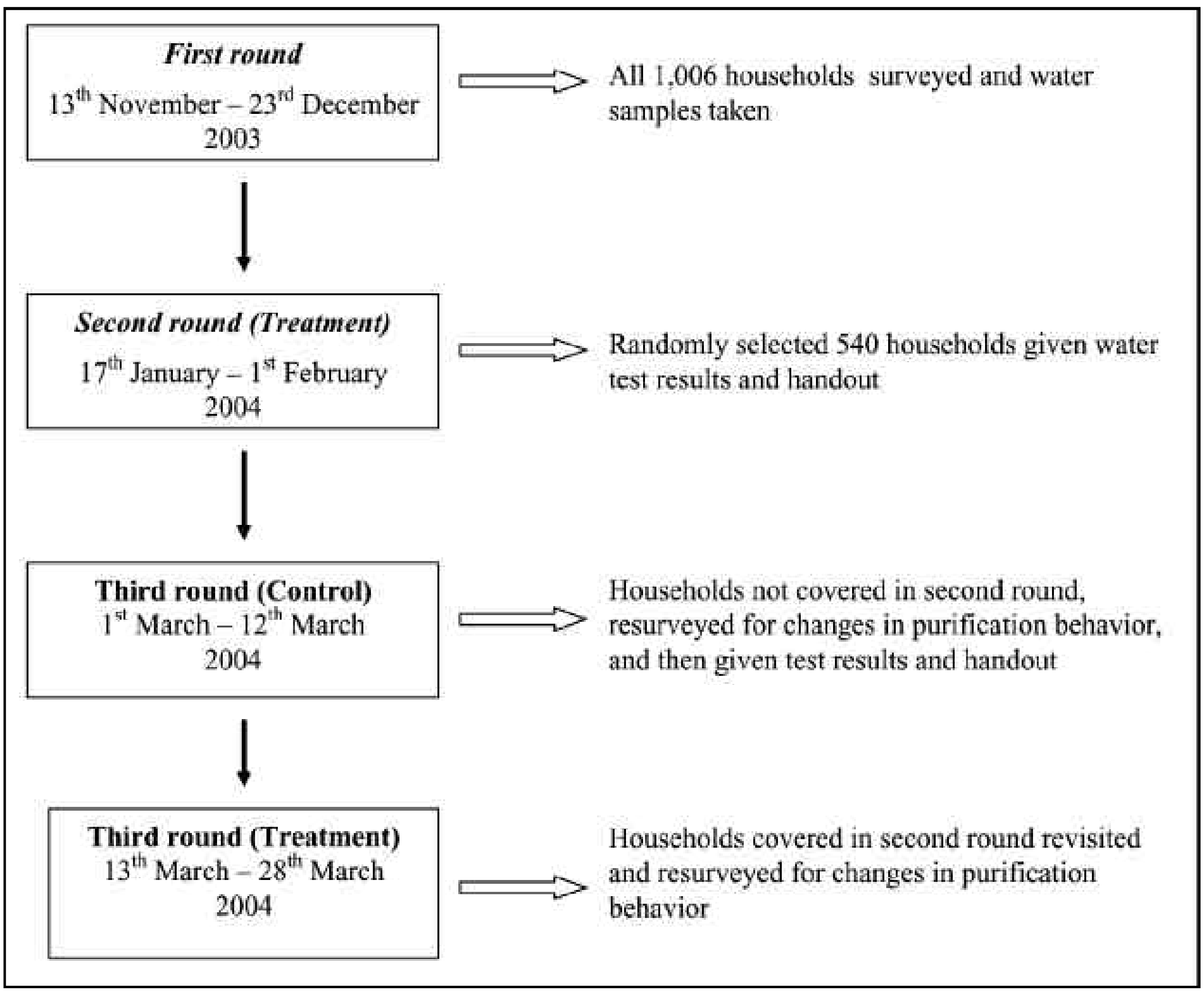
[8] We adopted this sampling strategy because the poor may be constrained by wealth from acting upon the information they would receive during the experiment while most of the wealthy might already have adopted home water purification.

[9] Two possible substitutes were included for each household in the sample. 296 households were actually substituted, 50 because no respondent was available, 76 because they did not wish to be surveyed, and 171 because the house could not be located from the map or was a commercial establishment.

Between November 13 and December 23, 2003, we conducted the survey and gathered information on household demographics, source and quality of the households' drinking water, whether they used any purification method, and general awareness of the household about health and sanitation issues. The awareness module was administered first with households being told that the survey was about health and awareness so that their responses would not be influenced by questions on water.[10] A time-line of the survey is given in Figure 1.

At the end of each interview, a sample of each household's drinking water, both unpurified and purified (if any) was collected in testing bottles and resealed immediately after collection. Each bottle contained a slip of filter paper impregnated with nutrients, the major one being peptone. The bottles were kept in an incubator at body temperature for 48 hours after which, if they contained fecal bacteria, they would produce hydrogen sulfide, which would create iron sulfide, a black precipitate, otherwise remaining clear.[11]

Figure 1: Time-line of Survey Process



---

10 A copy of the household survey questionnaire is available from the authors.

11 The use of the incubator was convenient because we had a large number of samples, but is not required. Hydrogen sulfide tests have been shown to agree with other tests at rates ranging from 71 to 100 percent in different studies, with only one study showing a disagreement rate greater than 20 percent (Sobsey and Pfaender, 2002).

During the second round (January 17-February 1, 2004,) we wanted to administer the treatment to approximately half of the originally selected sample. However, we were concerned that randomizing at the household level could potentially contaminate our control group because of the possible proximity of treatment and control households. So we divided the sample into *S* wards (which are aggregations of EB's) of which a subset *s* was randomly chosen as treatment units. All sampled households in a treatment ward were given the treatment. *s* was chosen so that the number of households in the treatment group was close to half the full sample. We revisited 520 households from our original sample of 1,000 households.

Households in the treatment group were given their test results and a handout (see Appendix 1 for details) explaining the results. Each household was also given its water sample bottle(s) and told that if the contents of a bottle were black, then its water was likely to contain germs. The remainder of the handout suggested that the households could, if they wished, adopt one of a number of purification methods in use in Gurgaon as appropriate for their budget. The respondent's attention was drawn to the different methods, a brief remark about their effectiveness in removing pathogens, and their cost. Information on safe water storage and handling practices were also included in the handout.

In the third and final round (March 1-28, 2004), we revisited all sampled households. There was some attrition from our original number of sampled households due to relocation to another address. Our final complete sample (i.e. three rounds of data for the treatment group and two rounds for the control group) consisted of 965 households indicating a sample attrition of 4 percent. There were no statistically significant differences between the observed characteristics of the households that dropped out and those that remained in the sample. Nor was there a statistically significant difference in the proportion of drop-outs from the treatment and control groups.

We surveyed households (see Appendix 2 for this questionnaire) to see whether they had changed their water purification behavior in any way. Households in the control group were visited first, and were given their test results and the handouts that the households in the treatment group had received earlier in the second round. This meant that households in the treatment group were surveyed approximately eight weeks after they were given the information about their water quality and the handout.

3. Data and Descriptive Statistics

Tables 1 and 2 report several descriptive statistics on information gathered during the first round for the whole sample (column 2) and for treatment (T=1 in column 3) and control (T=0 in column 4) groups. The tables also report the test statistics (column 5) for the difference in means across the treatment and control groups. The numbers in these tables indicate that the randomization produced relatively balanced treatment groups. That is, means of observable characteristics are very similar across groups and none of the differences are statistically significant at the 5 percent level.

In Table 1 we report statistics on the quality (as measured by our water test results) of water supply in Gurgaon. Two points are striking in this table: contamination rates of unpurified water are high - 61 percent of unpurified water tested "dirty" i.e., positive for the presence of fecal bacteria. Secondly, private purification methods (including boiling) are not very effective in reducing the contamination rates -55 percent of home-purified drinking water tested "dirty".

Table 1: Quality of Water Supply in Gurgaon

	All group	Treatment group (T = 1)	Control group (T = 0)	Difference in means test between T=1 & T=0
Percent of households where unpurified water tested positive for presence of fecal bacteria	60.62 (1.6)	61.77 (2.2)	59.40 (2.3)	.0237 (.031)
Number of observations	965	497	468	—
Percent of households where purified water tested positive for presence of fecal bacteria	54.55 (2.5)	59.30 (3.5)	49.75 (3.6)	.0955** (.050)
Number of observations	396	199	197	—

Notes: Numbers in parentheses are standard errors.
* indicates significance level of 5 percent or lower.
** indicates significance level between 5 and 10 percent.

A fecal contamination rate of 61 percent is high relative to developed countries, where fecal contamination levels of tap water are typically zero, but is comparable to some parts of India for which only fragmentary information is available. According to the Sukthankar Committee report to the Government of Maharashtra, bacteriological contamination was found in 10 percent of water samples from municipalities over the state in 1999, with the figure for Mumbai being 14 percent, while a survey in Kolkata in 2003 found that 63 percent of taps had high levels of fecal contamination (McKenzie and Ray, 2004). The reasons for such high levels include inadequate sanitation, sometimes large numbers of animals in urban areas, and leaky public water supply and sewage systems. In Gurgaon, as in most of urban India, water is supplied intermittently for a couple of hours in a day, and not continuously. As a result, pipes are not always pressurized and (illegal) private pumps attached to the main lines suck in possibly contaminated water.

Of the 186 households whose water tested "clean" before purification, in 72 (38.71 percent) cases the water tested "dirty" after purification. These numbers suggest that considerable contamination is taking place within the household, this being partly a consequence of the necessity of storing water within the home, a need which arises because of the intermittent supply.[12] However, at least one study has shown that within-household fecal contamination of stored water is less infectious than pathogens introduced from outside the household (VanDerslice and Briscoe, 1993).

Given pervasive externalities from disease prevention and the likelihood of re-contamination of stored water within households, a continuous pressurized publicly treated water supply may be more effective in reducing disease than home treatment would. We however, focused our study on home treatment because it is the only easily measurable response we can expect from households in the short term. In any case, it is also of interest to ask how much the demand for safe water changes with the inexpensive information we provide so that the public provision of safe water may be better financed.

About 6 percent of households had at least one case of diarrhea in the month preceding the survey. However these percentages cannot be assumed to reflect the situation throughout the year because there are seasonal variations in the incidence of diarrhea in India with most cases occurring during the summer months between May

[12] Within-household fecal contamination of drinking water is a commonly observed phenomenon in developing countries (Wright et. al., 2004).

and August. Dasgupta (2004), using hospital records for the years 1996-1998 from poor localities in neighboring Delhi, reports that only 1 percent of the annual number of recorded diarrhea cases were observed in the months of November and December while the months of June, July, and August accounted for 69 percent of total cases. We did not find a statistically significant difference in the incidence of diarrhea between households that had contaminated drinking water and those that did not.[13]

Nearly three-quarters of the 41 percent of households using some form of purification in the first round (Appendix Table 1) were using methods (boiling, electric filters, or bottled water as a substitute) believed to remove all germs if properly used.[14] The average annual household expenditure on purification in the sample was Rs 253 (Rupee 1 » US 2 cents). It was Rs 625 among households that used some form of purification (See Appendix 3).[15] Using the latest available household consumption expenditure numbers for urban Haryana (NSS Report No. 484, December 2003), these purification expenditure numbers suggest that an average household in Gurgaon was spending less than .04 percent of its total annual expenditure on water purification methods.[16]

Gurgaon households are better educated and wealthier than the average urban Indian household. According to the 2001 census, literacy rates for males and females (in the 7+ age group) in urban India are 80 percent and 73 percent respectively. Assuming that all those who have completed one year of schooling are literate, the corresponding percentages for our sample are 93 and 86 respectively. Likewise, the percent of households possessing consumer durables like a television, telephone, two-wheeler or four-wheeler are higher than the average for urban India. In urban India, 64 percent of households have a television while in Gurgaon 97 percent do. The analogous numbers for telephones, two-wheelers, and four-wheelers are 23 and 79, 25 and 75, and 6 and 36 respectively (Source: Census 2001 and Gurgaon sample survey).

But, despite these above average education and wealth statistics, when asked what causes diarrhea, only 55 percent of the households mentioned drinking contaminated or dirty water, and strikingly, only 7 percent mentioned infection (Table 2), indicating a low level of awareness about the health hazards associated with poor drinking water quality.

We created wealth and awareness indices using the first principal component of appropriate variables. That is, the weights used on each of the variables were such that the linear combination captured the greatest amount of information common to all variables. The wealth index for the *i* th household was thus defined as:

$$w_i = \sum_j f_j a_{ij} \quad \forall i=1,..,N$$

---

[13] Owing to circumstances beyond our control we could not conduct the survey during the summer months when diarrhea would be more common and differences in its incidence more likely to be detectable.

[14] 53 households who said that they were purifying their water but failed to give us a sample of their purified water during the first round of the survey were assumed to be not purifying their drinking water. All regressions were run making the opposite assumption as well. The results are very close to our favored specification and so are not reported separately.

[15] Expenditures were calculated by annualizing fixed costs where necessary.

[16] The average per capita consumer expenditure in Haryana was Rs.13,500 and the average household size was 4.8 members.

where a_{ij} is the standardized (mean zero and standard deviation one) variable j for household i, and f_j is the "scoring factor" for the j^{th} asset. ($f1$,…, fn) maximizes the sample variance of w subject to the constraint $\sum f_j^2 = 1$. A higher value of the index indicates more wealth or a more aware household. We created dummy variables for households having values of these indices higher than the median.

Table 2: Awareness Characteristics of Households in Gurgaon

	All group	Treatment group (T = 1)	Control group (T = 0)	Difference in means test between T=1 & T=0
Maximum years of education among adult male household members	11.97 (.107)	11.90 (.155)	12.03 (.147)	-.1286 (.213)
Maximum years of education among adult female household members	10.93 (.141)	11.15 (.188)	10.71 (.211)	.4418 (.282)
Percent including "contaminated drinking water" among the causes of diarrhea	55.23 (1.60)	55.94 (2.23)	54.49 (2.30)	.0145 (.03)
Percent including "infection" among the causes of diarrhea	7.15 (.83)	8.05 (1.22)	6.20 (1.12)	.0185 (.02)
Percent including "clean water provision" among actions govt can take to prevent diarrhea	40.00 (1.58)	38.83 (2.19)	41.24 (2.28)	-.0241 (.03)
Percent including "sanitation provision" among actions govt can take to prevent diarrhea	35.13 (1.54)	34.00 (2.13)	36.32 (2.23)	-.0232 (.03)
Percent dipping their hands in the storage container when taking water out of it	29.20 (1.46)	29.18 (2.04)	29.06 (2.10)	.0012 (.03)
Number of observations	965	497	468	—

Notes: Numbers in parentheses are standard errors.
*indicates significance level of 5 percent or lower.
** indicates significance levels between 5 and 10 percent

The variables included in the wealth index were: possession of a refrigerator, radio, computer, television, phone, washing-machine, bicycle, two-wheeler, four-wheeler, whether household owns the house it lives in, whether household possess land other than current residence, whether the house has a permanent structure, whether there is a separate kitchen and whether there is an air-exhaust outlet in the kitchen.

The (binary) variables included in the awareness index were: respondent listed contaminated water among the causes of diarrhea, mentioned infection among the causes of diarrhea, respondent stated diarrhea can be prevented by purifying water, respondent thinks the government can prevent diarrhea by providing clean water, respondent thinks government can prevent diarrhea by providing proper sanitation, and household uses a safe method to draw their drinking water from a storage container.

In Appendix Table 2, we report marginal effects from probit regressions of whether or not a household adopts any drinking water purification method on a number of explanatory variables for each of the two wealth categories. Awareness does not raise the probability of purification for households in the lower (i.e., below median) wealth category but does so by 3 percentage points for those above median wealth. The effects of wealth and education are also higher among households above median wealth.[17]

[17] These regressions should be interpreted as being descriptive rather than as a causal analysis of the data.

4. Model and Results

The household will not be purifying its water initially if

$$D(p^0) - c(w) + v < 0 \ldots\ldots (1)$$

where D denotes the utility differential between purification and no purification, p^0 denote a household's prior probability that its water is unsafe or contaminated, w denotes the household's wealth, $c(w)$ the utility cost of purification and v is an error term. The household will switch to purification if :

$$D(p) - c(w) + u > 0 \ldots\ldots (2)$$

where the distribution of u is conditional on (1), and p equals p^0, p^+, or p^-, depending on whether the household was in the control group and so did not receive a test result, received a positive result (i.e. water is "dirty"), or received a negative result (i.e. water is "clean") respectively. Other things equal, we expect p^0 and, therefore, also p^+ and p^-, to be increasing in awareness, and c to be decreasing in w.[18]

We can express the above as follows:

$$\triangle y = 1 \quad \text{if } D(p) - c(w) + u = x'ß + u > 0,$$
$$= 0 \quad \text{otherwise,}$$

where $$x'ß = a + ß_1(+ve) + ß_2(-ve) + ß_3(+ve)*wu + ß_4(+ve)*a_u \ldots (3)$$

In equation (3), $\triangle$y is the difference in the indicator variable for purification between the third and first rounds, (+*ve*) denotes a positive test result indicating contamination and (-*ve*) denotes a negative test result indicating no contamination, w_u is a dummy for households having wealth greater than the median, and a_u is a dummy for households having awareness greater than the median. The discussion above leads us to expect that $ß_1$, $ß_3$, and $ß^4 > 0$. We also estimate a model in which the dependent variable is the change in purification expenditure. Given that all the regressors in equation(3) are dummy variables, linearity imposes no restriction on the functional form, and hence the coefficients are simply the differences in conditional means.

We estimated equation(3) conditioning on households who were not initially purifying because this is the population of primary interest.[19] We want to know how their willingness to pay for safe water (as revealed by their purification choices) will respond to information. This will also provide a benchmark to public authorities about the extent to which households' willingness to pay to finance improvements in water quality increase with information provision. We also estimate a similar model, conditioning on initial purification to see whether households stop purifying in response to a "clean" water test result, a possibility suggested by the fact that $p^- < p^0$.

[18] Let $l = Pr(+ve \mid \text{contamination})$ be the probability of a "dirty" water result conditional on the water being contaminated and $\mu = Pr(-ve \mid \text{no contamination})$ be the probability of a "clean" water result conditional on the water being not contaminated. The posterior probability of unsafe water conditional on a positive test result is:

$$p+ = Pr(\text{contamination} \mid +ve) = \frac{\lambda p^0}{\lambda p^0 + (1-\mu)(1-p^0)}$$

and the posterior probability of unsafe water conditional on a "clean" water result is:

$$p^- = \Pr(\text{contamination} \mid -ve) = \frac{(1-\lambda)p^0}{(1-\lambda)p^0 + \mu(1-p^0)}$$

So if $l > 1 - \mu$ and $1 > p^0 > 0$, which we assume, then $p^+ > p^0$, and if in addition $\mu > 1 - l$, which we also assume, then $p^- < p^0$. Furthermore, it is clear that both p^+ and p^- are increasing in p^0.

[19] This conditioning also implies that $\triangle y = 1$ if a household switches from being a non-purifier to a purifier and zero otherwise.

Equation (3) is estimated using least squares and coefficients are reported in Table 3. All standard errors have been corrected for clustering at the ward level.

The first row shows that households who were told that their water is "dirty" are on average, 11 percentage points more likely to start purifying than those in the control group confirming our expectation above that $p^+ > p^0$. This difference is statistically highly significant. Of the 29 who were told that their water was "dirty" and started purification, 19 chose one of the three most expensive methods: boiling, using an electric filter, or buying bottled water, while only 4 of the 11 from the control group that started purification chose one of these three methods. Households who were told that their drinking water was probably not contaminated were not statistically significantly different in changing their purification behavior relative to the control group.

The difference b_3 in the response of households belonging to the upper and lower wealth categories to a "dirty" water test result is strongly significant. Households in the upper wealth category are nearly 16 percentage points more likely to start purification. It is not surprising that richer households are more likely to make protective expenditures in response to information. This result parallels the finding from the cross-sectional probit regressions based on the first-round survey that awareness is associated with a higher probability of purification for those above median wealth but not for those below median wealth (Appendix Table 2). The wealth effect in Table 3 can also be seen in Figure 2.

Table 3: Effects of Treatment on Purification and Expenditures of Households not Initially Purifying their Drinking Water

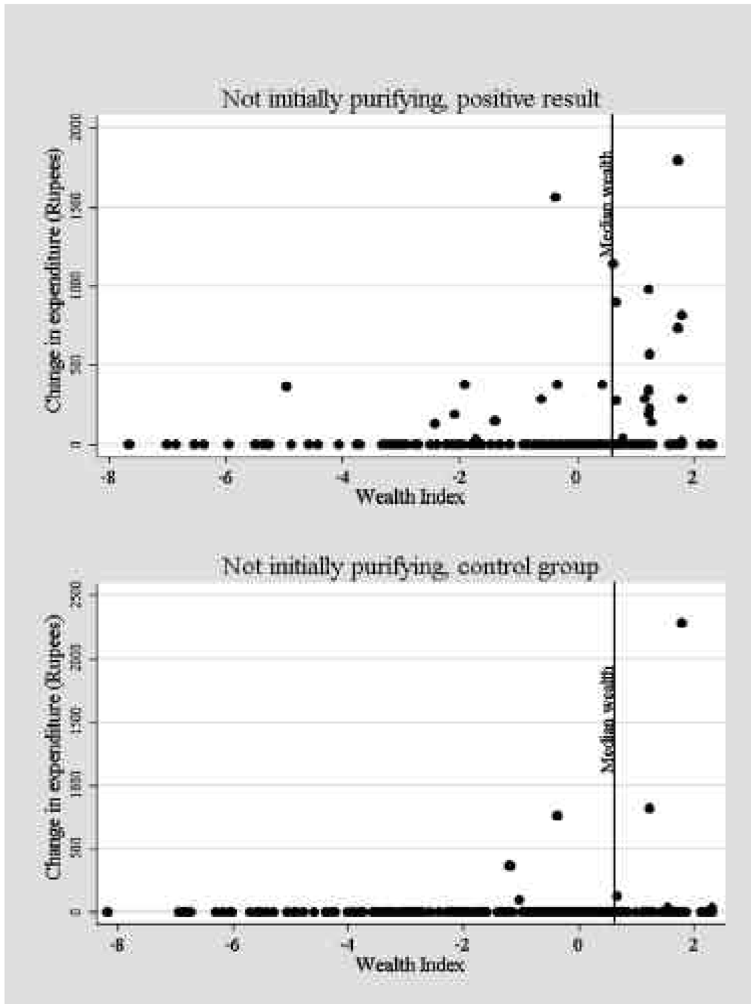
	$\triangle y = \alpha + \beta_1(+ve) + \beta_2(-ve) + \beta_3(+ve)*w_u + \beta_4(+ve)*a_u + u$	
	Dependent variable	
	Change in purification	Change in expenditure
"Dirty" water result $(\beta_1 + \beta_3 * \overline{w}_u + \beta_4 * \overline{a}_u)$	.1081* (.024)	47.99* (16.94)
"Clean" water result (β_2)	.0274 (.026)	6.68 (14.41)
High wealth conditional on "dirty" water result (β_3)	.1556* (.065)	87.16* (40.09)
High awareness conditional on "dirty" water result (β_4)	.0170 (.057)	22.61 (33.53)
Number of observations	569	

Notes:

- $\triangle y = y_{after} - y_{before}$ where y is the purification dummy (column 2) or purification expenditure (column 3)
- Numbers in parentheses are the cluster-corrected standard errors
- * indicates significance at 5 percent or lower
- ** indicates significance levels between 5 and 10 percent

However, the difference b_4 in the response to a "dirty" water result of households who are more and less aware is not statistically significant. So even though the model predicts p^+ to be increasing in awareness, we do not find that in our sample. We also estimated an alternative model where instead of using the awareness index categories as defined above, we used the maximum years of education among adult females as an awareness indicator (Appendix Table 4). The results are similar to those reported in Table 3.

Figure 2: Change in Annual Purification Expenditure against Wealth



The third column of Table 3 examines the impact of a "dirty" water result, and its interactions with wealth and awareness, on changes in household expenditures. The qualitative results are similar to that for changes in purification behavior. The expected increase in annual purification expenditure of a non-purifying household receiving a "dirty" water result is Rs. 48 more than that of non-purifying control households (Rupee 1 » US 2 cents). By way of comparison, the mean initial purification expenditure of all households in the sample was Rs 253.

The mean impact of a "dirty" water result on expenditures incurred by households belonging to the upper wealth category (relative to the lower wealth group) is as much as Rs. 87. As in the case of changes in purification behavior, we find no impact of differences in awareness levels among households getting a "dirty" water result on changes in expenditure.

Another outcome of interest is whether the survey and the treatment given to the households induced them to hold discussions about water quality with family, friends, neighbors or others after the first round. While households may be wealth-constrained in responding to information by adopting some purification, this is not the case for such discussions. Table 4 reports the results for this outcome. Here we estimate the model using the entire sample because there seems no reason to suppose that the outcome would be conditional on whether or not the household purifies its water. The model that we estimate is the same as that reported in Table 3 except that now the outcome variable is discuss.

The interesting result that we get here is that irrespective of whether the household's water tested "dirty" or "clean", on average, the treatment generated enough interest among household members for them to discuss the issue considerably more often than control households. Not surprisingly, the magnitude of the impact was larger (16 as compared to 9 percentage points more than the control) for the group receiving the "dirty" water result. The control group also discussed water quality with a frequency of close to 9 percent. Whether this is a "survey" effect or reflects a pre-existing concern with water quality, is hard to say. The other interesting point emerging from this table, is that the household's initial awareness has a large (16 percentage points) impact on the probability of discussions conditional on a contaminated water result, although the significance level is 7 percent. As expected, wealth does not matter.[20]

Table 4: Effects of Treatment on Discussion Controlling for Wealth and Awareness Effects

	$Discuss = \alpha + \beta_1(+ve) + \beta_2(-ve) + \beta_3(+ve)*w_N + \beta_4(+ve)*a_N + u$
	Discuss dummy
"Dirty" water result ($\beta_1 + \beta_3 * \overline{w}_u + \beta_4 * \overline{a}_u$)	.1637* (.043)
"Clean" water result (β_2)	.0939* (.034)
High wealth conditional on "dirty" water result (β_3)	-.0631 (.088)
High awareness conditional on "dirty" water result (β_4)	.1615** (.089)
Number of observations	965

Notes:
- Discuss is a dummy for whether the household had any discussion on water quality since the first round of the survey.
- Numbers in parentheses are cluster-corrected standard errors
- * indicates significance at 5 percent or lower
- ** indicates significance levels between 5 - 10 percent

We wanted to check whether there was any effect of the handout (independent of the test result) that we gave to the treatment households in the second round on either their purification behavior or on their expenditures. In the information sheet given to the households, it was clearly mentioned that straining and non-electric filters were

[20] The proportion of people in the sample who said that they had discussions on water quality since the first round of the survey was nearly 16 percent. We also estimated this model using test results for unpurified water instead of drinking water. The signs and the magnitudes of the effects were similar to those reported in Table 4.

inferior purification methods that removed some but not all germs. So we looked at the sub-sample of households who were using a non-electric filter in the first round. We defined our outcome indicator as households who not only made a change in their purification behavior but also used a superior method of purification compared to what they were using earlier. We do not find a "handout effect" on households told that their water was "dirty", but this could be because the sample is smaller than before (See Appendix Table 3 for further details).

Finally, we checked whether on average, households who were initially purifying their water and received a "clean" water result were likely to stop purifying their water as the result that $p^{-} < p^{0}$ from the model in Subsection 4.1 might predict. We find no "downgrade impact" of the experiment. (See Appendix Table 3 for further details.)

5. CONCLUSION

In this paper, we asked how much information affects the demand for environmental quality. We found that Gurgaon households who were told that their drinking water was "dirty" and was, therefore, likely to contain germs, were 11 percentage points (*p–value* < 0.01) more likely to begin some form of home purification in the next 7 weeks than households that received no information. Among the households that received a positive result (i.e. "dirty" water), households above the median value of wealth were 16 percentage points more likely to start purifying their water than less wealthy households. Households that received a negative test result (i.e., "clean" water) did not behave significantly differently with regard to purification from households that received no information.

The water test kit that we used cost Rs 20 (less than 50 US cents) per sample, is available off the shelf from an NGO in Delhi, and is simple enough for households to use themselves. It is notable that it has an effect on the probability of purification equivalent to about two and a half times that of an additional year of schooling for the most educated member of the household and more than two-thirds that of a move from one wealth quartile to the next. Public education campaigns that include useful information can evidently make a significant impact on people's behavior in terms of avoiding health risks.

Despite Gurgaon being one of the wealthier towns in India, the drinking water sources of 60 percent of households showed evidence of fecal contamination. Gurgaon, like virtually all other Indian cities and many in the developing world, has an intermittent, not a continuous, supply of piped water. This implies that water is more likely to get contaminated outside the home, (since the pipes are not always pressurized), and that it is more likely to get contaminated within the home because it has to be stored before drinking. While the inconvenience of an intermittent water supply is all too obvious, its adverse consequences for health are not widely known. Indeed, as discussed in Section 3 above, the level of awareness in Gurgaon about the role of water in the spread of diarrheal disease is surprisingly low, given its economic condition.

The experimental results suggest that to the extent that the failure of public authorities to provide safe water is due to lack of demand (whether by way of political expression or lack of willingness to pay for improvements), regular water testing and public information campaigns can help mitigate this problem at a relatively low cost. More generally, the issue of under-provision of information should be taken into account whenever estimates of the demand for environmental quality are used for welfare or policy analysis.

6. ACKNOWLEDGEMENT

Financial support from the South Asian Network for Development and Environmental Economics (SANDEE) is gratefully acknowledged. We are grateful to the office of the Registrar-General of the Census of India for providing enumeration-block level data and copies of census maps, Shahid Jameel for incubator space, and S.N. Prasad at TARA for information about water testing. We thank Tushi Baul, Saraswata Chaudhuri, Kamaal un Nabi Khan, Sreemoyee Moitra and Arindam Nandi for excellent research assistance and Khan and Moitra and the survey team for excellent implementation of the surveys. We thank Abhijit Banerjee, Shreekant Gupta, M.N. Murty, Arindam Nandi, Arijit Sen, Priya Shyamsundar, Rohini Somanathan and Jeff Vincent for useful comments.

REFERENCES

Antle, John M., and Prabhu L. Pingali, "Pesticides, Productivity, and Farmer Health: A Philippine Case Study," *American Journal of Agricultural Economics*, 76 (1994), 418-430.

Borghesi, Simone, "The Environmental Kuznets Curve: A Survey of the Literature," FEEM Working Paper No. 85-99, 1999.

Dasgupta, Purnamita, "Valuing Health Damages from Water Pollution in Urban Delhi, India: A Health Production Function Approach," *Environment and Development Economics*, 9 (2004), 83 106.

Jalan, J., E. Somanathan and S. Chaudhuri, "Awareness and the Demand for Environmental Quality: Drinking Water in Urban India," SANDEE Working Paper No. 4-03, 2003.

Government of India, "Household Consumer Expenditures and Employment Unemployment Situation in India," NSS Report No 484, 2003.

McConnell, K.E., and M.A. Rosado, "Valuing Discrete Improvements in Drinking Water Quality through Revealed Preferences," *Water Resources Research*, 36 (2000), 1575-82.

McKenzie, D and Isha Ray, "Household Water Delivery Options in Urban and Rural India," *mimeo* Stanford University, 2004.

Nester, E.W., C.E. Roberts, N.N. Pearsall, D.G. Anderson and M.T. Nester, *Microbiology: A Human Perspective*, (New York: McGraw-Hill, 1998).

Quick R., E. Mintz, J. Sobel, P. Mead, F. Reiff, and R. Tauxe, "A new strategy for waterborne disease prevention," 23rd WEDC Conference Durban, South Africa: 340-2, 1997.

Smith, V. Kerry, William H. Desvouges, and John W. Payne, "Do Risk Information Programs Promote Mitigating Behavior?" *Journal of Risk and Uncertainty*, 10 (1995), 203-221.

Roy, Joyashree, Subhorup Chattopadhyay, Sabyasachi Mukherjee, Manikarnika Kanjilal, Sreejata Samajpati, Sanghamitra Roy, "An economic analysis of demand for water quality:Case of Kolkata," *Economic and Political Weekly*, 39 (2004), 186-193.

Sobsey, Mark D., and Frederic K. Pfaender, "Evaluation of the H2S Method for Fecal Contamination of Drinking Water," (Geneva: World Health Organization, 2002).

Van Derslice, James, and John Briscoe, "All coliforms are not created equal: A comparison of the effects of water source and in-house contamination on infantile diarrheal disease," *Water Resources Research*, 29 (1993), 1983-1995.

World Health Organization, *The World Health Report 2002*, (Geneva: WHO, 2002).

World Health Organization, *Guidelines for Drinking Water Quality*, (Geneva: WHO, 1997).

Wright, J., S. Gundry, and R. Conroy, "Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use.*Tropical Medicine and International Health*, 9 (2004), 106-117.

Appendix 1

INDIAN STATISTICAL INSTITUTE

Dear Madam/Sir,

We took drinking water samples to test the water quality in your home during the survey conducted in Nov/Dec 2003. Thank you for your cooperation. We are returning the samples.

The color of the water samples will be yellow or black. If the color is yellow it is most likely that your water does not contain germs. If the color is black, then it is likely that the water is contaminated with germs that may make you sick. **<u>But this simple test cannot confirm that the water is contaminated.</u>** You may wish to take the following preventive measures:

1. Get your water tested again to confirm whether the water is contaminated or not.

2. Water can get contaminated quite easily within the home, so keep your drinking water storage containers clean and covered at all times. If your water storage container does not have a tap to take out the water, use a clean utensil with a long handle to take out the water. **<u>Never dip your hands into the water storage container.</u>**

3. Consider using a home water purification method that fits your household's budget. The different methods available and their average prices in Gurgaon are:

Method	Equipment Cost	Operating cost	Features
Straining with clean cotton cloth folded 8 or more times	0	0	Limited protection against germs
Disinfecting tablets/drops		Re. 1 for 10 litres of water	Kills nearly all germs
Non-electric filters	Rs. 225- 3100	Rs 50-300 per year	Removes some germs depending on the fineness of the filter
Electric filters	Rs. 4500-7500	Rs. 250-500 per year	Kills all germs with UV rays if properly maintained
Boiling		Rs 22 for 10 litres of water	Kills all germs
Drink bottled water		Rs. 20-27 for 10 litres of water	Manufacturer's responsibility to ensure germ-free water.
Reverse Osmosis	Rs. 12000-15000	Rs 750 per year	Removes all germs if properly maintained.

4. If using purification methods like tablets, non-electric or electric filters, follow the manufacturer's operating and maintenance instructions carefully as well as the water-handling precautions mentioned above.

Appendix 2

Questionnaire used for the third round of our survey

Date of third round:
Name of surveyors:

1. In our first visit, during the household survey, you had mentioned that you were using _______ purification method/ not using any purification method. Since that visit did you make any changes in the water purification methods you use?
   - Yes • No

2. If question to (1) is "no" go to question 4. If yes, when and what kind of changes did you make?
   Approximate date of change:
   - Adopted new purification method
   - Do not use any purification method any more
   - Others (specify)

3. If answer to question (2) is "adopted new purification method" specify:
   Method: Brand name: Fixed cost of the equipment:
   Whether any AMC has also been purchased and cost:

4. (Ask only of those households who were previously using either an non-electronic filter or an electronic filter and have not changed their water purification method)
   (a) Since our first visit, have you gotten the candles changed (for non-electronic filters) and/or the carbon changed (for electronic filters)? • Yes • No

   (b) If answer to (a) is "Yes" how much did it cost you?
   When did you make the change?

   (c) Did you make other expenditures on repairs and/or maintenance of the equipment?
   • Yes • No.
   If "yes" approximate date and amount spent.

5. In our earlier visit you had mentioned that you store your water in ________.
   Do you still use the same storage facilities? • Yes • No.
   (If answer to above is "No" specify the change)
   Do you cover your storage container? • Yes • No
   In our earlier visit you had mentioned that you take the water out from the storage container by using ________.
   Do you still use the same method?
   (If answer to above is "No" specify the change)

6. Since our first visit, have you discussed the issue of drinking water quality with anyone such as your neighbors, family members, Resident Welfare Associations, doctors, or government organization?
   • Yes • No
   Brief description of your discussion

7. Finally we would like to ask you whether you are planning to make some changes in the future to improve the quality of your drinking water? • Yes • No

8. If answer is "yes" to the above question, what kind of changes do you anticipate making?
When do you think you will make this change?
How much do you think you will be able to spend on such changes?

Appendix 3

Calculating costs of different purification methods in Gurgaon

Straining with a cloth: Zero.

Aquapura tablet: Each tablet costs a rupee and can be used to purify 10 litres of water, and the households using them reported using one per day.

Ordinary filter: Based on household responses supplemented by a market survey in Gurgaon, we obtained prices of the various brands. The fixed cost was annualized using an assumed life of 10 years and a discount rate of 10 percent.

Boiling: Households reported the time per day that they boiled water, and the fuel used, which was always liquefied petroleum gas. Data from a stove manufacturer was used to calculate gas usage per hour (177 gm/hr). We used the price of gas in Gurgaon to compute the expenditure for each household.

Electric filter: Based on household responses supplemented by a market survey in Gurgaon, we obtained prices of the various brands. The fixed cost was annualized using an assumed life of 10 years and a discount rate of 10 percent.

Bottled water: We simply used reported household expenditures, checked for consistency using prices and quantities.

INDIAN STATISTICAL INSTITUTE, DELHI
INDIAN STATISTICAL INSTITUTE, DELHI AND SOCIETY FOR ECONOMIC RESEARCH AND FINANCIAL ANALYSIS

APPENDIX TABLE 1

Purification behavior of households in Gurgaon

	All group	Treatment group (T=1)	Control group (T=0)	Difference in means test between T=1 & T=0	Average annual cost per household in Indian rupees 1 rupee = US 2 cents
Use some purification method	41.04 (1.58)	40.04 (2.20)	42.09 (2.28)	-.0205 (.032)	625
Strain	2.38 (0.49)	2.01 (.63)	2.78 (.76)	-.0077 (.010)	0
Tablets	0.004 (0.002)	-	-	-	365
Use non-electric water filter	11.09 (1.01)	10.66 (1.39)	11.54 (1.48)	-.0087 (.020)	117
Use electric water filter	23.32 (1.36)	23.94 (1.92)	22.65 (1.94)	.0129 (.027)	928
Boil	5.60 (0.74)	4.22 (.90)	7.05 (1.18)	-.0283** (.015)	363
Use bottled water for drinking purposes	.41 (0.21)	.20 (.20)	.64 (.37)	-.44 (.41)	3010
Number of observations	965	497	468	-	965

Notes:
Numbers in parentheses are the associated standard errors
* indicates significance level of 5 percent or lower** indicates significance level between 5-10 percent

APPENDIX TABLE 2

Probability of purification behavior among different wealth categories

Explanatory variables	Upper wealth category	Lower wealth category
Wealth index	.19106*	.06847*
	(.0527)	(.0182)
Awareness index	.03353**	-.00516
	(.0198)	(.0143)
Maximum years of education among household members	.08413*	.01879**
	(.0205)	(.0102)
Proportion of children in the age-group 0 – 3 years	.16609	.25960**
	(.4121)	(.1496)
Number of members in household	-.02399*	-.03432*
	(.0099)	(.0095)
Household head is male	-.00484	.02255
	(.0659)	(.0533)
Age of household head	.00117	.00053
	(.0063)	(.0051)
Age^2 of household head	.00001	-1.88e-07
	(.0001)	(.00004)
Household head works in public sector	.04557	-.10939
	(.0675)	(.0614)
Household head works in private sector	.12356	-.07300
	(.0777)	(.0525)
Household head has his/her own business	-.04618	-.14180*
	(.0718)	(.0554)
Household head works in other services	.05960	-.11686**
	(.0721)	(.0517)
Log-likelihood	-297.53607	-225.16
Number of observations	479	475

Notes:

- Dependent variable:
  y = 1 if household adopts some purification method
  = 0 otherwise
- Standard errors are reported in parentheses
- Upper and lower wealth categories are defined if the household's wealth index is above or below median wealth index.
- * indicates significance at 5 percent or lower
- ** indicates significance levels between 5 - 10 percent

APPENDIX TABLE 3

Average effect of treatment on households

	$y = \alpha + \beta_1(+ve) + \beta_2(-ve) + u$	
	Dependent variable	
	"Handout" effect	"Downgrade" effect
"Dirty" water result (β_1)	.0141 (.041)	.0310 (.033)
"Clean" water result (β_2)	-.0204 (.021)	.0043 (.041)
Number of observations	102	396

Notes:

- In column 2: y is a dummy for whether the household switched to a more expensive purification method. Sub-sample used for this "hand-out" effect model are those who were using a non-electric filter in the first round
- In column 3: y is a dummy for whether the household stopped purifying its drinking water. Sub-sample used for this "downgrade" model were those that were initially purifying.
- Numbers in parentheses are the cluster-corrected standard errors
- * indicates significance at 5 percent or lower
- ** indicates significance levels between 5 - 10 percent

APPENDIX TABLE 4

Average effect of treatment on households not initially purifying their drinking water controlling for wealth and education effects

	$\triangle y = \alpha + \beta_1(+ve) + \beta_2(-ve) + \beta_3(+ve) \cdot w_u + \beta_4(+ve) \cdot maxfedu + u$	
	Dependent variable	
	Change in purification	Change in expenditure (Indian rupees)
"Dirty" water result ($\beta_1 + \beta_3 * \overline{w}_u + \beta_4 * \overline{a}_u$)	.1081* (.024)	47.99* (17.17)
"Clean" water result (β_2)	.0274 (.026)	6.68 (14.41)
High wealth conditional on "dirty" water result (β_3)	.1672* (.071)	88.32* (41.28)
Maximum years of education among adult females conditional on "dirty" water result (β_4)	-.0031 (.006)	-.02 (1.722)
Number of observations	569	

Notes:

- $\triangle y = y_{after} - y_{before}$ where y is the purification dummy (column 2) or purification expenditure (column 3)
- Numbers in parentheses are the cluster-corrected standard errors
- * indicates significance at 5 percent or lower
- ** indicates significance levels between 5 - 10 percent