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Development Journal of the South

Volume 1 | Issue 1 Article 1

1-1-2015

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Recommended Citation
Katuwal, Hari; Mona K. Qassim; José A. Pagán; Jennifer A. Thacher; and Alok K. Bohara. "Knowledge, Information, and Water Treatment Behavior of Residents in the Kathmandu Valley, Nepal." *Development Journal of the South* 1, 1 (2015).
https://digitalrepository.unm.edu/djs/vol1/iss1/1

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Knowledge, Information, and Water Treatment Behavior of Residents in the Kathmandu Valley, Nepal

Hari Katuwal, Mona K Qassim, José A. Pagán, Jennifer A Thacher, Alok K. Bohara

ABSTRACT

Access to safe drinking water plays a crucial role in the overall social and economic development of a community. Unsafe water delivered to household taps increases the risks of waterborne diseases and threatens population health. Consumers can adopt a number of averting behaviors such as filtering or boiling their water. While these approaches are effective in reducing the likelihood of contracting a waterborne disease, not all households treat their water. Given this, it is important to develop a better understanding of factors that influence water treatment behavior. In this paper, we examine determinants of water treatment behavior using survey data (N=1200) from Kathmandu, Nepal. In particular, this paper focuses on the impacts of knowledge, exposure to information, and community participation on drinking water treatment behavior. Previous research has found that income, education level, awareness, and exposure to media are major factors that impact the individual-level decision to treat water before using it. We contribute to this literature by explicitly examining how knowledge about waterborne diseases, exposure to water quality information campaigns, and participation in community organizations impact drinking water treatment behavior. The results from probit regression analyses suggest that either a one percentage increase in the knowledge index or community participation index both increase the likelihood of utilizing drinking water treatment methods by about 0.17 percentage points. Households connected to the distribution system are 31 percentage points more likely to treat water compared to those that are not connected to the system. Multinomial results indicate that wealthier households use more than one treatment method.

Keywords: Drinking water, Averting behavior, South Asia, survey

I. INTRODUCTION

Access to safe drinking water plays a crucial role in the overall social and economic development of a community. Since unsafe drinking water is a major cause of diseases and deaths globally, access to safe drinking water is one of the most important factors related to good health (Sobsey, 2006). More than a billion people lack safe drinking water, 2.6 billion people lack adequate sanitation, and 1.8 million die every year as a result of diarrheal disease. More than 1.5 million deaths of children per year, mostly in developing countries, are attributed to unsafe water and poor sanitation (WHO, 2005). Poor and unsafe water quality is one of the main causes of diarrheal diseases, accounting for 4.3% of the global disease burden, and continues to be a major health threat (Jalan et al., 2009; Wright and Gundry, 2009). The situation is worse in cities in developing countries, where most urban water supply systems are unreliable and do not deliver safe drinking water (Hunter et al., 2009). Unsafe water delivered to household taps increases the risks of water borne diseases and threatens population health.

A variety of methods exist for the treatment of drinking water at the household level, including filtering, boiling, and using chemicals. These averting behaviors are effective and affordable ways of preventing water borne diseases (Colwell et al., 2003; Brick et al., 2004; Fewtrell et al., 2005; Sobsey et al., 2008; Clasen, 2010; Rosa and Clasen, 2010). However, not all households utilize these treatment methods and consequently are exposed to health risks. Since household water treatment can significantly reduce the likelihood of contracting a waterborne disease, it is critical to develop a better understanding of factors that influence household treatment behavior. Poverty could be one obvious explanation for why some households do not treat their drinking water. However, studies have shown that simple household treatment methods such as boiling, filtering, solar disinfection systems, and chlorination are affordable and effective (Brick et al., 2004; Sobsey, 2006). Another possible reason why some households do not treat their water could be lack of knowledge about waterborne diseases. For example, Jalan et al. (2009) in their randomized trial experimental study in India show that provision of information on water quality significantly increases treatment behavior.

Averting behavior and its determinants in response to poor water quality have been examined by several authors (Abdalla et al., 1992; Larson and Gnedenko, 1999; Pattanayak et al., 2005; Katuwal and Bohara, 2011). Water treatment behavior depends on socio-cultural beliefs, practices, and perceptions along with water quality, quantity, affordability, and accessibility (Sobsey, 2006; Wright and Gundry, 2009; Katuwal and Bohara, 2011). A systematic review of these studies suggests that water treatment behaviors are significantly and strongly influenced by knowledge, information, and other psychological factors.

While there exists an extensive body of literature that explores the risks of poor water quality and the types of averting behavior in which households engage to make water safe, there are only a limited number of studies that quantify the impact of knowledge, information, and community participation on averting behavior. Our study contributes to this literature by quantifying the main determinants of drinking water treatment behavior for an urban area in South Asia. Specifically, this paper uses an averting behavior approach to quantify the determinants of water treatment behavior using survey data from Kathmandu, Nepal. We focus on the impact of knowledge, exposure to information, and community participation on drinking water treatment behavior. The paper also examines how water treatment behavior is affected by water source.

Probit regression results suggest that households with greater knowledge about water borne diseases, households with more frequent exposure to information about water quality, and households that participate in community environmental or sanitation programs are more likely to treat their water. Thus, household level water treatment behavior can be influenced through education, social marketing, and the diffusion of information through community programs. Conducting such activities will be important to prevent diseases caused by unsafe drinking water and to reduce burden of diseases attributable to unsafe drinking water.

II. TREATMENT BEHAVIOR: AN APPROACH TO SAFE DRINKING WATER

Averting behavior has been recognized as an important response to avoid the health risks associated with poor environmental quality (Smith and Desvousges, 1986; Abrahams et al., 2000). Several studies have examined determinants of averting behavior (Smith and Desvousges, 1986; Bartik, 1988; Abrahams et al., 2000; Zerah, 2000; Whittington et al., 2002; Pattanayak et al., 2005)[1]. Studies in the US have found that averting behavior in the context of water and hazardous waste depends primarily on perceived health risk, socioeconomic characteristics, and knowledge of contamination (Smith and Desvousges, 1986; Abdalla et al., 1992; Abrahams et al., 2000).

Quality is one of the important dimensions of the water supply system. However, water supply authorities in the developing world have not been able to provide safe water quality to consumers. Several past studies (Larson and Gnedenko, 1999; Madajewicz et al., 2005; Jalan et al., 2009; Wright and Gundry, 2009; Katuwal and Bohara, 2011) have identified key factors that impact the water treatment behavior of households in developing countries: income, education level, awareness, and exposure to media. Using survey data from Brazil, Larson and Gnedenko (1999) found that water treatment behavior was significantly and positively influenced by income, perceptions of water quality, and education level. Using survey data from Bangladesh, Madajewicz et al. (2005) found that information alone can significantly influence behavioral change to avoid risks; the authors further noted that information spread through the community can have a strong influence. In a similar study, Jalan et al. (2009) used national survey data from urban India to examine the impact of awareness on treatment behavior. Wealth, education, and awareness were found to impact the decision of whether to treat water before consumption.

In a more closely related study conducted on this issue for residents of the Kathmandu Valley, Katuwal and Bohara (2011), using survey data from the Central Bureau of Statistics, examined the adoption of different water treatment behaviors and concluded that income, education, and perceptions of water quality are important factors that influence household water treatment behavior. Because the dataset did not include information about respondents' knowledge about waterborne diseases or their participation in the community, the study was not able to examine the impact of these factors on treatment behavior.

These studies show that households in developing countries use several coping strategies to make water safe if they believe that water delivered to their tap is unsafe. These studies also show that the treatment behavior is affected by several factors such as awareness, quality of water, and household characteristics such as income and education level. Our study contributes to this literature by explicitly examining how knowledge about waterborne diseases, exposure to water quality information campaigns, and connections to community organizations with knowledge about water quality impact drinking water treatment behavior.

III. THEORETICAL BACKGROUND AND HYPOTHESES

The Conceptual Model

A simple model of water treatment behavior is constructed to examine the impact of knowledge, information, and community involvement on water treatment behavior using an averting behavior approach. If water delivered to the household is not safe, households can use other inputs such as boiling, filtering etc. to make it safe and potable. The theoretical model is based on microeconomic theory that the household maximizes utility by adopting averting behavior. Households maximize utility by consuming treated water, and utility from water quality is obtained through a health production function. Following Bartik (1988), Larson and Gnedenko (1999), and Katuwal and Bohara (2011), the household production function for intended water quality is given by,

$$S_1 = S(Y, S_0) \tag{1}$$

where S_1 is intended quality of water, S_0 is initial water quality, and *Y* is averting behavior. Given initial water quality (S_0), a household chooses a level of averting behavior that minimizes expenditures, subject to achieving an intended water quality S_1.

$$\underset{\{Y\}}{MinE = PY} \quad \text{subject to } S_1 = S(Y, S_0) \tag{2}$$

Let $E^* = E(p, S_1, S_0)$ be the minimum expenditure on averting measures required to obtain the intended quality S_1, given the initial quality S_0. With the consumption of intended optimal quality (S_1^*) of water and other composite goods, the household maximizes utility given a budget constraint:

$$\underset{\{S_1, Z\}}{MaxU}(S_1, Z; X) \quad \text{subject to } pY + Z \leq I \tag{3}$$

where Z is a composite good, I is income available to the household, and X is a vector of household characteristics. The two-stage problem of minimizing expenditure and maximizing utility can be combined as,

$$\underset{\{S_1, Z\}}{MaxU}(S_1*, Z; X) \quad \text{subject to } \mathrm{E}(p, S_1*, S_0) + Z \leq I \tag{4}$$

The above utility maximization problem can be solved to obtain an indirect utility function V^*,

$$V* = V(p, I, S_1; X) \tag{5}$$

Optimal averting behavior can be obtained from the above indirect utility using Roy's identity,

$$Y^* = -\frac{\partial V / \partial p}{\partial V / \partial I} = \frac{\partial E}{\partial p} = Y(p, S_0, S_1^*(p, I, S_0; X)) \tag{6}$$

where Y^* is the optimal avoidance behavior that maximizes utility and minimizes the averting expenditure. The equation shows that the optimal averting behavior depends on the price of avoidance (*P*), income (*I*), initial drinking water quality (S_0), improved water quality (S_1), and other household characteristics (X). According to Um et al. (2002), household averting behavior is better explained by the perception of quality than by an objective measurement of the water quality (Um et al., 2002). The authors further emphasize that the perception of initial water quality depends on the age and the education level of respondents. Given this, we revise the original model of optimal behavior to integrate household knowledge, information, and community participation in water treatment behavior. Household's decision to treat or not to treat water is assumed to be affected by their knowledge of water quality and risks associated with unsafe drinking water, exposure to public information that deals with drinking water and sanitation, and community involvement towards environmental activities, in addition to treatment costs and other household and individual characteristics. Under these assumptions, optimal treatment behavior can be expressed as,

$$Y_i = f(Z_{ik}; X_{ij}) \tag{7}$$

$$Y_i = \alpha + \sum \delta'_k Z_{ik} + \sum \gamma' X_{ij} + \varepsilon_i \tag{8}$$

where Y_i is the optimal treatment behavior that maximizes utility given the optimal expenditure for health production function, X_i is a vector of household characteristics, and Z_i is a vector capturing knowledge, exposure to information, and community involvement variables. δ_k is the vector of parameters for knowledge, exposure to information and community involvement, and γ_j the other socioeconomic and demographic variables. The above model, for estimation purposes, can be written in more general form as;

$$Y_i = \beta' x_i + \varepsilon_i \tag{9}$$

Hypotheses

In addition to examining the factors that influences the treatment behavior, the following hypotheses are proposed and tested. First, it is expected that knowledge about water quality as well as knowledge about the risk and causes of waterborne diseases influence treatment behavior. Thus, the null hypothesis is,

$H1_0$: Household treatment behavior is not affected by knowledge i.e.,

$$\frac{\partial Y_i}{\partial Z_{i1}} = 0$$

where Z_{i1} is a knowledge index.

Provision of public information through different media such as radio, television etc. influences the behavior of the household. The statement is tested using the null hypothesis,

$H2_0$: Exposure to information does not affect the treatment behavior i.e.,

$$\frac{\partial Y_i}{\partial Z_{i2}} = 0$$

where Z_{i2} is an information index.

It has been well documented that involvement and participation of individuals in environmental and sanitation programs increases awareness about the risk of unsafe water consumption. Increased awareness could influence treatment behavior. The statement is tested using following null hypothesis;

$H3_0$: Community involvement has no influence on treatment behavior i.e.,

$$\frac{\partial Y_i}{\partial Z_{i3}} = 0$$

where Z_{i3} captures the level of community involvement.

Provision of public water supplies increases access to drinking water. However, access to drinking water does not necessarily guarantee access to safe drinking water. The last hypothesis examines whether access to public water supplies affects treatment behavior.

$H4_0$: Provision of access to public water supplies does not affect treatment behavior

$$\frac{\partial Y_i}{\partial X_{ij}} = 0$$

where $X_{ij} = 1$ if a private tap, connected to the public distribution system, is the primary source of drinking water in the household, and zero otherwise.

IV. THE SURVEY AND DATA

The Survey

The data for this study comes from a survey that was conducted in the summer of 2009 in Kathmandu, Nepal. The survey was conducted to collect information on residents' knowledge, exposure to information, and treatment behavior with regards to drinking water quality. As part of survey development, three focus group discussions were conducted followed by a pre-test of 40 households. The survey was conducted in Nepali after back translation from the original English language survey instrument.

A total of 337,298 households from the Kathmandu Valley were divided into eight strata and 206 clusters. Forty clusters, based on the proportion of number of households, were selected from a total of 206 clusters. Thirty households, for a total of 1,200 households, were randomly chosen from each of the 40 clusters. The survey was administered in person to a household representative that was 18 years of age and older. A structured questionnaire was used as the survey instrument for the face-to-face interview. The response rate for the survey was 75.29%.

Survey Sample Profile

Descriptive statistics are presented in Table 1. A typical household in the sample has six family members. Of the total respondents, 36 percent are female. The average education level of the respondent is 12 years, whereas the average education level of most educated person in the household is 14 years. About one third of the households own their house. A little less than half (46%) of the families are Newars, the indigenous people of the Kathmandu Valley. The average monthly reported income of a household is NRS 19,800.

Thirty nine percent of households have at least one child below five years. On average, households have lived in their community for nine years. The knowledge index, discussed in more detail below, ranges from 0 to 1 with a mean value of 0.67, where a higher level indicates greater knowledge about waterborne diseases. Similarly, the community involvement index ranges from 0 to 1 with a mean value of 0.12, where a higher value indicates that a household has greater involvement with community environmental and sanitation organizations and thus may be more exposed to information from these organizations.

Table 1: Definition of Variable and Corresponding Descriptive Statistics

Variables	Definition	Mean	Sd	Min	Max
TREATMENT	Household treats drinking water (1=Yes, 0=No)	0.74	0.44	0.0	1
TREAT_MODE	0 if a household does not treat	0.26	0.44	0.0	1
	1 if a household filters	0.37	0.48	0.0	1
	2 if a household boils	0.07	0.26	0.0	1
	3 if a household boils and filters	0.20	0.40	0.0	1
	4 if a household uses chemicals	0.09	0.29	0.0	1
INCOME	Monthly income in thousands (Based on midpoint of pre-coded income intervals reported by households)	19.80	14.94	3.0	100
EDU_MAX	Education level of household member with highest level of education	13.81	2.56	1.0	18
KNOWLEDGE	Constructed index of knowledge based on knowledge about water pollution, diseases caused by unsafe drinking water, e-coli and how to prevent diarrhea (normalized such that values range from 0 to 1 and higher value represents higher level of knowledge)	0.67	0.19	0.0	1
INVOLVEMENT	Constructed index of community involvement based on household's involvement in environmental institutions and participation in environmental and sanitation programs (normalized such that values range from 0 to 1 and higher value represents higher level of involvement)	0.12	0.25	0.0	1

Table 1: Definition of Variable and Corresponding Descriptive Statistics (Cont'd)

Variables	Definition	Mean	Sd	Min	Max
INFO_EXPOSURE	How often respondents were exposed to advertisements on TV or radio that emphasized the importance of filtering or boiling water (0= Never, 1=Sometimes, 2=Frequently)	0.97	0.64	0.0	2
PUBLIC_CONNECTION	Primary source of water is a household tap that is connected to the municipal water supply (1=Yes, 0=No)	0.63	0.48	0.0	1
RESIDENCY	Number of years household has lived in the community	8.95	1.71	0.5	10
HHSIZE	Number of members in the household	5.71	2.23	1.0	19
YOUNG_CHILDREN	Household has a child under the age of 5 (1=Yes, 0=No)	0.39	0.49	0.0	1
NEWAR	Belongs to Newar Caste (1 = Yes, 0= No)	0.46	0.50	0.0	1
OWN	Owns home (1=Yes, 0=No)	0.72	0.45	0.0	1
Observations		1200			

Boiling, filtering, use of chemical tablets, and some combination thereof are treatment methods frequently used by households in Kathmandu Valley. About three out of every four households in the Kathmandu Valley use at least one treatment method before consuming water. Slightly more than three out of every five households receive water through a private tap connected to the public water supply.

V. EMPIRICAL ESTIMATION

The survey does not provide information on exact quantities (e.g. how much water is boiled) of treatment behaviors. Instead, the survey provides information on which particular water treatment method was adopted in a binary form (yes/no). Moreover, the theoretical model suggests that each household chooses whether or not to treat and then selects from several treatment methods based on the number of explanatory variables. The probability of using at least one treatment method is estimated using a probit model. Under the assumption that the error term in equation (8) is normally distributed, the probability of adopting at least one treatment method is given by,

$$\Pr\left(Y_i = 1\right) = \Phi\left(\beta' X\right) \tag{10}$$

where $Y_i = 1$ if the household chooses to use at least one treatment method and zero otherwise. $\Phi(.)$ is the cumulative distribution function of the standard normal distribution. The parameters of the model (β) are estimated using the maximum likelihood method.

$$\ln L = \sum_{i=1}^{N} \left[d_i \ln \Phi\left(\beta' X\right) + \left(1 - d_i\right) \ln\left(1 - \Phi\left(\beta' X\right)\right) \right] \tag{11}$$

where $d_i = 1$ for $Y_i = 1$; 0 otherwise. The hypotheses mentioned above are tested using a binomial probit model.

Dependent Variables

A binary choice model (*TREATMENT*=1 if at least one treatment method was adopted, and 0 otherwise) is used to estimate the association between explanatory variables and water treatment behavior. A multinomial probit model is used to examine the impact of explanatory variables on specific treatment methods. Each household decides whether or not to treat water and which method to use to make it safe. A treatment method variable (*TREAT_MODE*) is created such that *TREAT_MODE* is 0 for not treating water at all (base category), 1 for filtering, 2 for boiling, 3 for both boiling and filtering, and 4 for the use of chemicals.

Explanatory Variables

The objective of this study is to examine the impact of knowledge, information, and community involvement on the treatment of drinking water. The knowledge index (*KNOWLEDGE)* is created from questions in the survey dealing with respondent's knowledge about water pollution, diseases caused by unsafe drinking water, e-coli, and how to prevent diarrhea. All the components except knowledge about water pollution are binary (1/0). Knowledge about water pollution is rescaled and summed with all the variables to create the knowledge index. The knowledge scale is further normalized such that the values range from 0 to 1 for the estimation purpose.

Public service announcements via radio, TV, posters, and brochures, and social marketing are some of the tools available to organizations to provide information. Radio and TV are two of the primary mediums through which the risks of drinking untreated water are communicated. *INFO_EXPOSURE* describes how often ("Frequently", "Sometimes", and "Never") respondents were exposed to advertisements on TV or radio that emphasized the importance of filtering or boiling water[2].

Community knowledge sharing can help improve water and sanitation conditions. Thus, the adoption of water treatment technology can also be influenced by the extent that a household is connected to a community knowledge base. To examine this impact, community participation is included as one of the explanatory variables in the regression analysis. The community involvement index (*INVOLVEMENT*) is created using information on family members' involvement in environmental institutions and level of participation in environmental and sanitation programs. Since the first component is binary (1/0), the second component is rescaled such that the value ranges from zero to one and summed with the first component to create the community involvement variable. Finally, the involvement scale is normalized such that the values range from 0 to 1.

A dummy variable *(PUBLIC_CONNECTION=1* if a household's primary source of water is a household tap that is connected to the municipal water supply; 0 otherwise*)* is used to capture the effect on treatment of a household being connected to the distribution system.

Evidence suggests that the treatment behavior is significantly influenced by household and respondent characteristics (Larson and Gnedenko, 1999; Jalan et al., 2009; Katuwal and Bohara, 2011). Several household and respondent characteristics are included to control for heterogeneity. Included variables are monthly income of the household (*INCOME*), education level of the most educated person in the household (*EDU_MAX*), and household size (*HHSIZE*). Previous studies have found that the averting behavior also depends on the number of children in the household (Abdalla et al., 1992). Moreover, families with children under the age of five, who are most vulnerable to waterborne diseases, might be more likely to treat drinking water. Accordingly, *YOUNG_CHILDREN* (=1 if household has at least one child below 5 year, 0 otherwise) is used to control for this effect. Home ownership (*OWN*), number of years living in the community (*RESIDENCY*), and belonging to the Newar caste (*NEWAR*), the indigenous people of the Kathmandu Valley, are also expected to influence treatment behavior.

VI. RESULTS

Binomial Regression Results

Three different probit models are estimated. The full specification model is used for the estimation of marginal effects. The specification of the probit model selected is based on the minimum value of the Akaike's Information Criteria (AIC) and Bayesian Information Criteria (BIC) criterion. The signs of most coefficients are as expected, *a priori*.

Results of the three probit models are presented in Table 2. The result from the extended probit regression model (Model 3) shows that income is only marginally important for the determination of the decision to treat or not to treat water[3]. In Model 1, income is highly significant. However, the impact of income wanes out and is significant only at 14% after controlling for whether a household's water supply is connected to the municipal system. This likely reflects the fact that higher income individuals are more likely to be able to afford to connect to the system. As expected *a priori*, the highest level of education in the household positively affects the treatment decision and is highly significant ($p<0.01$).

Personal knowledge about waterborne diseases and community involvement positively affect the treatment behavior and are highly significant. The null hypothesis that treatment behavior is not influenced by knowledge about the causes and consequences of poor water quality is strongly rejected. The probit analysis result also strongly rejects the null hypothesis that community participation has no effect on treatment behavior; the greater the involvement of family members in sanitation and environmental programs, where they are more likely to be exposed to information about water quality issues, the greater the probability of adopting treatment behavior. Information exposure, in terms of self-stated frequency of awareness of water quality information on TV and radio, is statistically significant at the 10 percent level. These results confirm findings from previous studies (Jalan et al., 2009; Katuwal and Bohara, 2011).

The hypothesis that access to public water supplies does not affect the treatment behavior (H4) is also rejected. Contrary to the general assumption, being connected to the public distribution system influences treatment behavior positively and the effect is strong ($p<0.01$). The highly significant and positive coefficient of connection to the public distribution system suggests that the households that are connected to the public distribution system and have a private tap tend to treat their water more than the households that are not connected to the distribution system (and rely either on the traditional public spout or a private tube well). It is possible that having private tap connected to the public distribution system is picking up the income effect of the households that are connected to the distribution system. However, the finding that connection to the public distribution system through a private pipe increases water treatment is consistent with Katuwal and Bohara (2011). Because of the deteriorated and poorly maintained infrastructure, water delivered from public distribution system is not safe. In addition, negative pressure generated from intermittent supply and leakages draws contaminated materials from the surface (Whittington et al. 2004, Katuwal and Bohara 2011). It seems realistic that people believe water coming from traditional and public spout is better than the water coming from the municipal distribution system because of the old and deteriorated infrastructure and adopt treatment action accordingly.

The coefficient of household size is negative, as expected *a priori*: households with more family members are less likely to treat water before drinking. This reflects the fact that the cost of treating more water is higher for a larger family and higher cost reduces the treatment behavior. Years of residency and home ownership decrease the likelihood of treating water. Being Newar increases the likelihood of treating water.

Table 2: Binomial probit regression results (y_i =1 if household adopts at least one treatment method; = 0 otherwise)

	Model 1	Model 2	Model 3
INCOME	0.0079**	0.0039	0.0053
	(0.0033)	(0.0035)	(0.0036)
EDU_MAX	0.0793***	0.0866***	0.0955***
	(0.0180)	(0.0193)	(0.0201)
KNOWLEDGE	0.7127***	0.6407**	0.6063**
	(0.2362)	(0.2540)	(0.2587)
INVOLVEMENT	0.4854**	0.5632***	0.6127***
	(0.1960)	(0.2106)	(0.2154)
INFO_EXPOSURE	0.1361*	0.1689**	0.1451*
	(0.0717)	(0.0776)	(0.0791)
PUBLIC_CONNECTION		1.0215***	1.0170***
		(0.0925)	(0.0936)
RESIDENCY		-0.1175***	-0.0924**
		(0.0310)	(0.0373)
HHSIZE			-0.0576***
			(0.0219)
YOUNG_CHILDREN			-0.0166
			(0.0975)
NEWAR			0.2424**
			(0.1002)
OWN			-0.2268
			(0.1388)
Constant	-1.2144***	-0.7201*	-0.6446
	(0.2598)	(0.3957)	(0.4064)
Observations	1068.00	1065.00	1064.00
Log lik.	-563.48	-486.10	-477.96
Chi-squared	80.74***	231.59***	247.28***
AIC	1138.96	988.19	979.91
BIC	1168.80	1027.96	1039.55

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Multinomial Probit Regression Results

	Model 1				Model 2				Model 3			
	FILTER	BOIL	FILTER_ BOIL	CHEMIC AL	FILTER	BOIL	FILTER_ BOIL	CHEMIC AL	FILTER	BOIL	FILTER_ BOIL	CHEMICAL
INCOME	-0.0016	0.0104*	0.0181***	0.0129**	-0.0055	0.0062	0.0133***	0.0088	-0.0043	0.0068	0.0166***	0.0104*
	(0.0047)	(0.0056)	(0.0047)	(0.0053)	(0.0050)	(0.0060)	(0.0051)	(0.0056)	(0.0051)	(0.0062)	(0.0052)	(0.0057)
EDU_MAX	0.0681***	0.1233***	0.1607***	0.0649**	0.0795***	0.1355***	0.1813***	0.0738**	0.0834***	0.1342***	0.1938***	0.0798**
	(0.0253)	(0.0353)	(0.0289)	(0.0324)	(0.0267)	(0.0369)	(0.0312)	(0.0342)	(0.0276)	(0.0387)	(0.0323)	(0.0352)
KNOWLEDGE	0.6481*	0.8887*	1.4754***	1.0612**	0.6280*	0.8555*	1.4104***	0.9854**	0.6056*	0.8253*	1.2544***	0.8957*
	(0.3353)	(0.4559)	(0.3828)	(0.4392)	(0.3537)	(0.4780)	(0.4129)	(0.4615)	(0.3591)	(0.4907)	(0.4228)	(0.4677)
INVOLVEMENT	0.1307	0.5749*	0.2802	0.8785***	0.1851	0.6331*	0.3627	0.9543***	0.2230	0.6932**	0.4316	1.0131***
	(0.2654)	(0.3233)	(0.2832)	(0.2951)	(0.2786)	(0.3407)	(0.3051)	(0.3123)	(0.2831)	(0.3477)	(0.3120)	(0.3177)
INFO_ EXPOSURE	0.1175	0.1361	0.2104*	0.1920	0.1527	0.1905	0.2834**	0.2403*	0.1403	0.2211	0.2651**	0.2246
	(0.1009)	(0.1364)	(0.1128)	(0.1293)	(0.1074)	(0.1426)	(0.1220)	(0.1360)	(0.1091)	(0.1473)	(0.1240)	(0.1375)
PUBLIC_ CONNECTION					1.0951***	1.3903***	1.7954***	1.3269***	1.0791***	1.4370***	1.7785***	1.3099***
					(0.1302)	(0.1857)	(0.1647)	(0.1730)	(0.1315)	(0.1904)	(0.1677)	(0.1746)
RESIDENCY					-0.1255***	-0.1799***	-0.2135***	-0.1623***	-0.1037**	-0.1286**	-0.1289**	-0.1093*
					(0.0426)	(0.0517)	(0.0463)	(0.0501)	(0.0506)	(0.0626)	(0.0563)	(0.0598)
HHSIZE									-0.0514*	0.0142	-0.1065***	-0.0584
									(0.0310)	(0.0382)	(0.0363)	(0.0388)
YOUNG_ CHILDREN									-0.1100	0.1402	0.0387	-0.0650
									(0.1356)	(0.1788)	(0.1574)	(0.1714)

Table 3: Multinomial Probit Regression Results (Cont'd)

	Model 1				Model 2				Model 3			
	FILTER	BOIL	FILTER_ BOIL	CHEMIC AL	FILTER	BOIL	FILTER_ BOIL	CHEMIC AL	FILTER	BOIL	FILTER_ BOIL	CHEMICAL
NEWAR									0.3294**	-0.3581*	0.3782**	0.2567
									(0.1389)	(0.1970)	(0.1646)	(0.1774)
OWN									-0.2607	-0.1049	-0.6646***	-0.4234*
									(0.1914)	(0.2424)	(0.2122)	(0.2290)
Constant	-1.1398***	-3.5003***	-4.0194***	-2.8091***	-0.6668	-2.7822***	-3.4373***	-2.1282***	-0.5066	-3.2304***	-3.3976***	-2.0672***
	(0.3660)	(0.5284)	(0.4429)	(0.4892)	(0.5447)	(0.7192)	(0.6328)	(0.6791)	(0.5573)	(0.7536)	(0.6566)	(0.6971)
Observations	1068.00				1065.00				1064.00			
Log lik.	-1477.35				-1375.43				-1351.78			
Chi-squared	137.04***				273.88***				307.49***			
AIC	3002.70				2814.87				2799.56			
BIC	3122.06				2973.93				3038.11			

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Multinomial Regression Results

Table 3 summarizes the multinomial probit regression results. Multinomial results indicate that wealthier households use more than one treatment method. Educated and knowledgeable households are more likely to adopt almost all the treatment methods. Exposure to information does not show any effect on the use of specific treatment methods. Households connected to the public distribution system adopt almost all the treatment methods. Number of years in the community has negative effect towards the adoption of all treatment methods. Homeowners are less likely to adopt multiple treatment methods. The probability of the use of these treatment methods decreases with increased household size.

Marginal Effects

Marginal effects are calculated to assess the impact of the explanatory variables on treatment behavior. The marginal effect of explanatory variable (X_k) on the probability of adopting treatment method (P_i) is given by product of marginal effect on P_i of $\beta'\overline{X}$ and effect of X_k on $\beta'\overline{X}$. Furthermore, the marginal effect varies with different values of explanatory variable, so it is evaluated for the mean value of rest of the explanatory variables (Greene, 2006).

$$\frac{\partial P_i}{\partial X_k} = \frac{\partial P}{\partial(\beta'\overline{X})}\frac{\partial(\beta'\overline{X})}{\partial X_k} = f(\beta'\overline{X})\beta_k$$

The most extended versions of the models are used for the estimation of the marginal effects and results are presented in Table 4 and Table 5.

The signs of the marginal effects for all the coefficients in the probit regression model are as expected and consistent throughout all three models. Education level is one of the strongest factors influencing the treatment behavior: a one year increase in education level of the most educated member in the household increases the probability of treating drinking water by about 2.7 percent. Similar marginal effects were also observed in Kathmandu, Nepal (2.6 percent), and in India (1.6 percent if respondent is male, and 1.9 percent if respondent is female) by Katuwal and Bohara (2011) and Jalan et al. (2009) respectively. For one percent increase in index of knowledge of water pollution and diarrheal disease, the probability of treatment increases by about 0.17 percent. The marginal effect of community involvement suggests that the greater the engagement in community environment and sanitation programs, the more likely a household is to treat water: for a one percent increase in the involvement index, the probability of treatment increases by about 0.17 percent. The marginal effects suggest that knowledge and community participation have similar effects on treatment behavior. Results are consistent with the result from previous studies such as Jalan et al. (2009) in that the positive association of treatment behavior was observed with a similar variable created from knowledge about diarrhea, water, treatment and sanitation. Exposure to information in the form of frequency of advertising of environmental sanitation and treatment methods such as filtration also seems to play a significant role in increasing the adoption of treatment behavior. For example, going from no exposure to advertisements about treating water to some exposure increases the likelihood of treating water by about four percent.

Table 4: Marginal effects for binomial probit regression model

	TREATMENT
INCOME	0.0015
	(0.0010)
EDU_MAX	0.0269***
	(0.0056)
KNOWLEDGE	0.1709**
	(0.0729)
INVOLVEMENT	0.1727***
	(0.0603)
INFO_EXPOSURE	0.0409*
	(0.0223)
PUBLIC_CONNECTION (d)	0.3120***
	(0.0291)
RESIDENCY	-0.0260**
	(0.0105)
HHSIZE	-0.0162***
	(0.0062)
YOUNG_CHILDREN (d)	-0.0047
	(0.0276)
NEWAR (d)	0.0675**
	(0.0275)
OWN (d)	-0.0610*
	(0.0355)

Marginal effects; Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Households connected to the distribution system are 31 percent more likely to use at least one treatment method to avoid the risk of publicly distributed drinking water as compared to the households that are not connected to the municipal distribution system. Another interesting result of the probit model is that time of residency influences the treatment behavior in a negative direction. It indicates that the longer people have been living in their community, the less likely it is that they adopt water treatment. An increase in year of residency decreases the probability of treatment by about 3 percentage points. This is consistent with the previous work in the Kathmandu Valley (Katuwal and Bohara, 2011). The marginal effect of household size is negative. An increase of one member in the household decreases the likelihood of treatment adoption by about two percent. This is consistent with the theory that increases in cost leads to reductions in adoption of treatment behavior. Being a Newar family increases the probability of utilizing treatment behavior by about six percent.

Marginal effects of the explanatory variables on the adoption of specific treatment methods are presented in Table 5. The most extended version of the model is used for the calculation of marginal effects. The marginal effect of income is positive and significant for both boiling and filtering. The probability of using both methods increases by 3.4 percent for each thousand rupee increase in monthly income.

Table 5: Marginal Effects of the Multinomial Probit Regression Model

	FILTER	BOIL	BOIL_FILTER	CHEMICAL
INCOME	-0.0039***	0.0004	0.0034***	0.0012*
	(0.0012)	(0.0006)	(0.0008)	(0.0007)
EDU_MAX	-0.0030	0.0056	0.0270***	-0.0017
	(0.0068)	(0.0038)	(0.0053)	(0.0043)
KNOWLEDGE	-0.0195	0.0222	0.1575**	0.0415
	(0.0897)	(0.0481)	(0.0710)	(0.0579)
INVOLVEMENT	-0.0641	0.0424	0.0207	0.1104***
	(0.0660)	(0.0318)	(0.0490)	(0.0355)
INFO_EXPOSURE	-0.0045	0.0089	0.0299	0.0125
	(0.0265)	(0.0142)	(0.0201)	(0.0166)
PUBLIC_CONNECTION (d)	0.0582*	0.0502***	0.1775***	0.0501***
	(0.0326)	(0.0153)	(0.0224)	(0.0186)
RESIDENCY	-0.0082	-0.0051	-0.0106	-0.0035
	(0.0116)	(0.0056)	(0.0087)	(0.0068)
HHSIZE	-0.0033	0.0074**	-0.0159**	-0.0023
	(0.0079)	(0.0037)	(0.0062)	(0.0048)
YOUNG_CHILDREN (d)	-0.0415	0.0216	0.0174	-0.0063
	(0.0336)	(0.0181)	(0.0267)	(0.0208)
NEWAR (d)	0.0683*	-0.0668***	0.0477*	0.0106
	(0.0351)	(0.0180)	(0.0283)	(0.0219)
OWN (d)	0.0187	0.0226	-0.1050***	-0.0218
	(0.0444)	(0.0198)	(0.0385)	(0.0284)

Standard errors in parentheses
(d) for discrete change of dummy variable from 0 to 1
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

One additional year of education of the most educated member increases the probability of boiling and filtering by 2.7 percent. Similar is the effect of knowledge on the adoption of boiling and filtering together. Exposure to information does not show any effect for the selection of specific treatment methods. Households connected to the public distribution system are more likely to adopt almost all methods. In general, a household connected to the distribution system is more likely to adopt treatment method. More interestingly, the household connected to the distribution system is 18 percent more likely to adopt boiling and filtering as compared to the households that are not connected to the distribution system. Household size does not matter as far as boiling and filtering only are concerned. However, size of the household decreases the probability of using both treatment methods by about 1.6 percent. For a Newar family, the probability of boiling is 7 percent lower than for a non-Newar family. Households who own their homes are 10.5 percent less likely to adopt boiling and filtering simultaneously.

The results from binomial and multinomial are consistent with theory. Most of the explanatory variables are statistically significant for the selection of treatment and for the selection of a particular treatment method. Income, education, and exposure to information influence the choice of treatment. More specifically, wealthier households tend to use more than one method. Another interesting result is that the household connected to the distribution system tends to use more treatment methods. The households with connection to the distribution system are supposed to have access to safe water. But our results show that this is not the case, at least for Kathmandu. In fact, households connected to the distribution system are more likely to use one or more than one treatment method.

VII. DISCUSSION AND POLICY IMPLICATIONS

Poor water quality poses health risks from water borne disease and imposes high costs to society. Water supply services in developing countries are not efficient enough to provide safe drinking water to the community. Health risks from water borne disease caused by poor quality of water can be significantly reduced through point-of-use water treatment such as filtering, boiling and the use of chemicals.

The objective of this paper was to investigate the impact of knowledge, exposure to information, and community participation on the water treatment behavior of households in Kathmandu Valley. The determinants of water treatment behavior were examined using an averting behavior approach. The results from the binary probit model show that knowledge, information and community participation significantly influence household behavior towards water treatment by helping people understand the importance of treating drinking water. In addition to household characteristics, knowledge about water borne diseases and community participation seem to play an important role in influencing treatment behavior. The results indicate the potential for knowledge, information, and community participation to increase adoption of treatment behavior. Thus, this study provides several pragmatic policy relevancies towards the reduction of health risk because of the poor water quality in a developing country.

It is generally assumed that income is one of the most important factors behind the demand for environmental quality. However, the result shows that knowledge and exposure to information are also important determinants for the treatment behavior. Thus, in order to increase the treatment behavior and reduce the health risks of poor water quality, improving knowledge about quality of water and related health risks through formal and informal education needs to be emphasized. This can be done by integrating more information on water related health risks in school and college education curricula. Similarly, treatment behavior can be influenced through media intervention by increasing the frequency of information about consequences of poor quality of water and effectiveness of treatment method.

The result also demonstrates that the community involvement and social networks have a strong influence in water treatment behavior. Policy makers can use the community participation through local clubs and NGOs as tools of social marketing to enhance the treatment behavior. Another interesting finding is that households treat more if water is delivered from the distribution system. One of the measures to avoid the health risks of poor water quality is provision of piped water. However, it has not been the case in most of the developing world. Most of the water distribution authorities in developing cities have not been able to provide good quality of water that is free of health risks. Kathmandu is no exception to this. The results that the treatment behavior is more frequent for the household that are connected to the distribution system highlights another important supply side issue in the drinking water supplies in developing countries. Although these households are connected to the distribution system and have access to improved water supply, safe water is not guaranteed. This calls for improvement in the operation and maintenance of the distribution system. This includes rejuvenating and repairing the distribution system continuously. Policy makers and water managers should aim at improving water quality before delivering it to the consumers.

Once knowledge of the importance of clean water is widespread, there will be numerous benefits and reductions in the cost of water borne diseases to society. The effects of diseases such as diarrhea will wane causing overall improvement in health of the residents in the region. Fewer numbers of days that are taken off from work because a worker or a child is sick. This would result in improved productivity. Thus, the benefits of treating household water will make an extremely large impact on the health and wellbeing of society.

This study is based on a survey that was carried out in the capital city of Nepal. Most of the households have access to drinking water from public water supply system in Kathmandu. Unfortunately, the vast majority of rural households are not yet connected to the public distribution system in Nepal. Thus the result might not hold true for other rural parts of Nepal and cannot be generalized. It should also be noted that this study focuses in the household level analysis. The survey does not include water distribution to institutions such as business, schools, hospitals etc. Moreover, several other averting behaviors such as hauling and storing drinking water are not discussed.

These caveats acknowledged, the result provides strong evidence that education, knowledge, information, and community involvement are crucial in determining adoption of water treatment behavior. Thus, these factors are critical in avoiding health risk caused by poor water quality and reducing large health burden of unsafe drinking water. The water treatment behavior can be enhanced to ensure the safe water consumption through policy intervention. As targeted by the Millennium Development Goals (MDGs), one of the goals is to reduce number of people without access to safe water and sanitation to half by 2015 (MDG, 2006). The results, as well as previous studies, show that water supply services in the Kathmandu Valley have not been able to provide good quality water to the community. In other words, people have access to drinking water, but it does not guarantee access to safe drinking water. This is very important for planners and policy makers who design policies to achieve the MDGs. Thus, the water treatment behavior of the household must be influenced through education, social marketing and community participation until the water supply services can provide high quality, safe water that does not compromise health.

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Notes

1 The averting behavior literature has focused in estimating averting expenditures (Abdalla et al., 1992; Abrahams et al., 2000), choices between different behaviors (Abrahams et al., 2000) and determinants of averting behavior.

2 Jalan et al. (2009) also included a variable to capture exposure to information: the frequency of any female household member listening to the radio or reading the newspaper. The information exposure variable included in our study is specific to water quality, as it captures the frequency with which household members watching TV or listening to radio were exposed to discussions of water quality and treatment methods.

3 Most of the past studies on treatment behavior (Jalan et al., 2009; Katuwal & Bohara, 2011; Larson & Gnedenko, 1999) have found income to be one of the most important factors behind the decision of adopting treatment behavior for drinking water. Most of these studies, including one from the Kathmandu Valley (Katuwal & Bohara, 2011) used income in terms of different categories (i.e. quartiles). Income is used as a continuous variable in this study.

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