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Coping with poor water supplies: empirical evidence from Kathmandu, Nepal

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ABSTRACT

The authors examined the demand for clean drinking water using treatment behaviors in Kathmandu, Nepal. Water supply is inadequate, unreliable and low quality. Households engage in several strategies to cope with the unreliable and poor quality of water supplies. Some of the major coping strategies are hauling, storing, and point-of-use treatment. Boiling, filtering, and use of Uro-guard are some of the major treatment methods. Using Water Survey of Kathmandu, the authors estimated the effect of wealth, education, information, gender, caste/ethnicity and opinion about water quality on drinking water treatment behaviors. The results show that people tend to increase boiling and then filtering instead of only one method if they are wealthier. In addition, people boil and then filter instead of boiling only and filtering only if they think that water delivered to the tap is dirty. Exposure to information has the strongest effect in general for the selection of all available treatment modes.

Key words | averting behavior, drinking water supply, Kathmandu, treatment

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INTRODUCTION

Access to adequate and good quality drinking water is a basic need. Unsafe drinking water threatens the health of people and is one of the most serious challenges for developing countries. Rapid urbanization and growth have made developing cities unable to meet the increased demand and the situation is worsened by an ever increasing population (McConnell & Rosado 2000; Whittington *et al.* 2004; Pattanayak *et al.* 2005). One of the major problems that most of the developing cities face is to provide enough good quality drinking water. It is also clear from the systematic reviews that poor quality of water, which accounts for 4.3% of the total global disease burden (Wright & Gundry 2009; Jalan *et al.* 2009), is one of the main causes of diarrhea and diarrheal diseases. Thus, poor quality of water is one of the main reasons for the increase in health burden in developing countries. Kathmandu is no exception to this. Water is not supplied consistently, pressure is insufficient to pump it to the tap and the amount of water made available to the public is not directly potable.

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According to Prasai *et al.* (2007), 82.6 and 92.4% of drinking water samples cross the WHO guideline value for total plate and coliform count respectively for drinking water. Provision of poor quality drinking water is one of the major reasons for waterborne diseases in Kathmandu. Admission of 1360 diarrheal patients to the Sukraraj Tropical Infectious Disease Hospital in Kathmandu from 2 to 21 May 2004 shows the seriousness of waterborne diseases in the valley (NGOFUWS 2005). People from Kathmandu face a dire situation with unreliable and unsafe drinking water supplies.

Households in Kathmandu engage in several coping strategies to combat the unreliable and poor quality of water supplied. Some of the major coping strategies are hauling, storing, and treatment. Data from the Water Survey of Kathmandu-2005 shows that boiling, filtering, use of Uroguard and Solar Disinfection System (SODIS) are some of the major treatment methods. Many households still don't treat water and are exposed to health risks.

Goal 7, target 10 of the Millennium Development Goal (MDG) aims at reducing the proportion of people without sustainable access to safe drinking water and basic sanitation to half by 2015 (*Millennium Development Goal Report*; United Nations 2007). Thus, drinking water supply has become an important public policy issue, especially for developing countries. Designing policy requires careful study of the demand for safe drinking water. If water delivered to the tap is not safe, measures undertaken to make it safe need to be examined. The analysis of different types of treatment behavior can be helpful in minimizing the risk of waterborne diseases by influencing behaviors through policy implications (Larson & Gnedenko 1999; Jalan *et al.* 2009). More specifically, the demand side analysis of quality of water is important in the context of restructuring and reformation of water supply services. Thus, households demand for safe drinking water and treatment behavior are important in designing policy for water services. However, these treatment behaviors have rarely been examined for Kathmandu's drinking water supply.

A number of studies have investigated the averting behavior for the improvement of drinking water quality in the developing world (Larson & Gnedenko 1999; Zerah 2000; McConnell & Rosado 2000; Jalan *et al.* 2009). Larson & Gnedenko (1999) and Zerah (2000) examined household demand for averting behavior for drinking water in Brazil and Delhi respectively. Averting behaviors were found to be significantly and positively influenced by income, opinion on quality of water, and education level. In another study, using national survey data from India, Jalan *et al.* (2009) found that awareness influences the home treatment behavior and the effects are significant. Thus, wealth, education, awareness and quality of water are some of the major factors that influence averting behavior and health of the consumers.

Perhaps more relevant, several studies (Tiwari 2000; Whittington *et al.* 2002; and Pattanayak *et al.* 2005) have investigated willingness to pay (WTP) for safe and adequate drinking water in Kathmandu, Nepal. Households' WTP for the improvement of water services is one of the common conclusions reached from these studies. Furthermore, WTP is significantly higher than they are currently paying. Coping strategies and averting expenditure are investigated on households' demand for improved water services by Pattanayak *et al.* (2005). The authors discuss the averting behavior, averting cost and compare that with WTP for the water services. These averting behaviors also include hauling and storing. The authors concluded that households engage in five types of coping strategies: collecting, pumping, treating, storing, and purchasing. Coping costs and WTP were found to be statistically correlated (Pattanayak *et al.* 2005).

These studies (Larson & Gnedenko 1999; Zerah 2000; McConnell & Rosado 2000; Tiwari 2000; Whittington *et al.* 2002; Pattanayak *et al.* 2005; Jalan *et al.* 2009) showed that consumers are spending a significant amount of money in the form of averting expenditure to avoid the health risks of unsafe drinking water in developing countries. Casual observations as well as data from the Water Survey of Kathmandu–2005 show that the majority of households treat water before consuming it. Boiling, filtering, use of chemicals, etc. are some of the common treatment methods adopted by the households to avoid the health risks of unsafe drinking water. Despite their significance and extensive use, there has been little empirical analysis of treatment behaviors for Kathmandu water supplies. This study attempts to fill this gap by investigating the demand for safe potable water in Kathmandu valley using treatment behaviors. The specific purpose of this study is to examine the demand for environmental quality, clean drinking water in particular, using treatment behavior in Kathmandu, Nepal. These treatment behaviors and the factors influencing these behaviors were investigated using a survey of 2000 households in Kathmandu, Nepal. The survey was conducted in 2005. A probit model was used to estimate the marginal effects of the factors that influence these treatment behaviors. Different types of treatment are considered as an indicator of demand for environmental quality and the effect of wealth, education, exposure to information, gender, caste/ethnicity and opinion about water quality on adoption of different treatment methods are estimated.

The results show that the marginal effect of wealth is stronger for the use of boiling and filtering both (27%) as compared to boiling only and filtering only. It implies that people tend to increase both boiling and filtering instead of only one method if they are wealthier. 'Dirty water' is one of the problems reported by the respondents in the survey. Other problems are: low discharge pressure, inappropriate time distribution, poor service and no problem. Households boil and then filter (or vice versa) instead of boiling only and filtering only if they think that water delivered to the tap is dirty. Exposure to information has the strongest effect in general for the selection of all available treatment modes.

The remainder of the paper is organized as follows. The background of the water supply situation is discussed in the second section followed by a theoretical framework for treatment behavior. Binomial, ordered, and multinomial probit regression models are used and the results discussed in the next section. The last section concludes with some policy implications.

BACKGROUND

Kathmandu valley, the only metropolitan and capital city, is the center of the sociological and economic activities of Nepal. The valley is inhabited by more than 1.5 million people with 220,000 households (Disaster Risk Management Profile–2005). It includes five major cities: Kathmandu, Lalitpur, Bhaktapur, Kirtipur and Madhyapur Thimi. In addition to its permanent residents, the valley welcomes thousands of visitors each day. One of the instructions given to the person, who is coming into the valley, is not to drink water unless it has been treated. Basically, everyone is instructed to make sure if water has been treated before consuming it.

Nepal Water Supply Corporation (NWSC) fulfills the increasing demand for water through nine major supply systems, 15 water treatment plants and has 132,803 legal connections including 809 community taps (NGOFUWS 2005). Many households are not connected to the official water supply network. Total demand for water in the valley is more than 200 million litre per day (MLD). Until February 2008, NWSC was supplying about 80 MLD during the dry season and 120 MLD during the wet season. NWSC was responsible for the distribution of water in the Valley when the survey was conducted. But, as a part of institutional restructuring, an autonomous body 'Kathmandu Upatyaka Khanepani Limited (KUKL)' was formed in February 2008 for the distribution of drinking water in the Valley. The KUKL, a public limited company, has undertaken the responsibility for the Kathmandu Valley drinking water management system since February 2008. Because of the old, deteriorated, and poorly maintained infrastructure, the water supply is neither reliable nor safe (Whittington *et al.* 2004). Much of the water, approximately 40%, which is produced is lost before it reaches the consumers (Whittington *et al.* 2002). Water is available only for four days in a week, and even during these four days, water is available for only about 2.4 h. More seriously, whatever water is delivered is not clean and safe to drink.

Due to the intermittent, unreliable, and poor quality of the water supplies, households spend extra money in coping with these problems. On the one hand, consumers spend a large amount of time fetching and storing water, while on the other hand, a significant amount of money is spent on treatment of water. Thus, despite being connected to a piped water supply network, consumers do not have access to safe water because of the quality dimension. Given the current distribution system that the valley has at work, it cannot be assumed that water quality is adequately safe for consumption.

Drinking water supply and its quality

Like many other developing cities, the Kathmandu water supply suffers from several problems. Because of an old and poorly maintained distribution system, the service is not efficient (Whittington *et al.* 2004; Pattanayak *et al.* 2005). Water is not supplied consistently, pressure is insufficient to pump it to the tap and the amount of water made available to the public, is not directly potable. Table 1 summarizes some of the major problems based on the information collected from the household survey.

Low discharge and intermittent supply is one of the most serious problems of Kathmandu water supply services. Distribution is not regular at all. The majority of the households in an urban area (34%) report that the discharge is either low or there is no discharge of water at their tap. Most important, about 17% of households, connected to the distribution system, think that water flowing out of their tap is dirty.

There are several reasons associated with the poor quality of water delivered to the households. Not all water distributions have appropriate treatment facilities. Either, water is improperly disinfected or not disinfected at all. Moreover, because of the intermittent supply and leakages, negative pressure often draws contaminated material from the surface. Even a good quality of water delivered from the source gets polluted due to infiltration of contaminated water through leakage points.

Table 1 | Opinion on water quality of the households connected to the distribution system

	Percentage of households with their views on the current pipeline water distribution system				
Background characteristics	**Low discharge pressure**	**Inappropriate time**	**Dirty water flow**	**Poor service**	**No problem**
Rural	20.42	3.46	7.27	5.54	66.44
Urban	33.52	9.05	14.95	1.81	34.46
Total	38.16	9.83	16.60	3.07	49.57

Note: Some of the households report more than one problem. The percentage is based on multiple responses.

Treatment methods

Because of the severity of the quality of water, several treatment methods are adopted to make the water potable. The survey provides data on different types of treatment methods that are being applied by each household (Table 2).

More than 34% of households in Kathmandu valley boil water to make it safe. Not all the households in the rural area, unlike households in the urban area, are connected to the municipal distribution system. Urban households that are connected to the distribution system are supposed to have access to safe and reliable supplies. On the contrary, it is interesting to note that the percentage of households that boil water is higher in the urban area (44.3%) as compared to the rural households (19%). Filtering is the most common household practice of water treatment used in the valley. The percentage of households that use filters to make water potable is higher than the percentage of households that boil it. Forty percent of households in Kathmandu filter water to make it potable. A considerable number households think that boiling only or filtering only is not enough to make water safe. So they use both methods consecutively to avoid the risk of unsafe water. About 19% of households in Kathmandu (25% in urban and 9% in rural areas) boil as well as filter. Uro-guard is a comparatively expensive electronic filter used by hotels and other institutions serving more people. The survey does not include data for such institutions. But the households that use Uro-guards are included in the survey and the number of households is significantly low (1%). There are some other treatment methods such as SODIS and use of tablets that have been used in Kathmandu. SODIS is a simple technology that uses plastic bottles to disinfect water by exposing the bottles filled with water to sunshine for five to eight hours. Piyush, aquatabs (chlorine tablets) are some of the tablets used for point of use treatment. On average, 8.5% use these methods. There are still significant numbers of households that do not use either of these treatment methods. Thirty five percent of households consume water without any treatment (27% in urban areas and 47% in rural areas). This percentage may not look significant at a glance. However, these behaviors are not temporary (e.g. due to a sudden problem with the water supply) but permanent. Thus, these behaviors have a significant impact on health and overall welfare for the society.

Table 2 | Treatment method based on household characteristics

	Percentage of Households								
Household characteristics	**Boil**	**Filter**	**Tablet**	**Cover vessel**	**Clean sources**	**Uro guard**	**Mineral water**	**SODIS**	**Nothing**
Rural	19.0	29.4	1.0	13.0	9.6	0.0	0.0	0.1	46.9
Urban	44.3	47.8	0.7	3.9	2.0	1.7	1.0	0.2	26.8
Total	34.2	40.4	0.8	7.6	5.1	1.0	0.6	0.2	34.9

Note: Some of the households report more than one problem. The percentage is based on multiple responses.

Theoretical framework of treatment behavior

Households undertake several strategies to avoid health risks associated with poor environmental quality. In the case of drinking water, several avoidance measures are undertaken to improve the quality of the water so that it is safe and potable. If the available water is not safe, households avoid the risks by treating at point of use. The household health production function provides a theoretical basis for the avoidance behavior (Bartik 1988; Abdalla *et al.* 1992; McConnell & Rosado 2000). If available water is not safe, households use other inputs such as boiling, filtering, etc. to make it safe. Consumption goods, safe water in this case, is produced by using either one or a combination of different treatment methods. Following Bartik (1988), Larson *et al.* (1999) and Um *et al.* (2002), the household production function for better (intended) quality of water is given by,

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

where S_1 is intended quality of water, S_0 is opinion on initial water quality, Y is averting behavior. A household minimizes expenditure based on opinion on initial quality of water S_0 to achieve the intended water quality S_1.

$$\underset{\{Y\}}{Min} E = pY$$
$$\text{subject to } S_1 = S(Y, S_0) \tag{2}$$

where p is price of averting behavior.

The above minimization problem can be solved for minimum expenditure. Let $E^* = E(p, S_1, S_0)$ be the minimum expenditure on avoidance 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 composited goods, a household maximizes its utility given the budget constraint.

$$\underset{\{S_1, Z\}}{Max} U(S_1^*, Z; X)$$
$$\text{subject to } pY + Z \leq I \tag{3}$$

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

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

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

$$V^* = V(p, I, S_1^*; X)$$

Optimal averting behavior can be obtained from the above indirect utility using Roy's identity (Varian 1992),

$$Y^* = -\frac{\partial V/\partial p}{\partial V/\partial I} = \frac{\partial E}{\partial p} = Y(p, S_0, S_1^*(p, I, S_0; X)) \tag{5}$$

Y^* is optimal avoidance behavior which maximizes utility and minimizes the averting expenditure. Equation (5) shows that optimal averting behavior depends on four types of variables in general: the price of avoidance represented by p; income represented by I; the household's opinions about tap water represented by S_0; and other households' characteristics X. Thus, we can estimate the optimal avoidance behavior based on explanatory variables; price of avoidance behavior, income, opinion on initial quality of water and the households' characteristics.

Under the assumptions that the avoidance behavior is a normal good, it can be expected that the higher the price of avoidance behavior, the lower the choice of avoidance behavior i.e. $\frac{dY^*}{dp} < 0$. The implication of this hypothesis is that, all else being equal, more and poor households will use cheaper methods given the choice of several avoidance options. For example, filtering can be cheaper as compared to boiling and other avoidances. If that is the case, the maximum number of household will choose a filter. More avoidance behavior gives more utility to the households. Thus, avoidance behavior in general is a normal good. However, a household can treat some particular avoidance measure such as filtering as an inferior good. Wealthier households may start replacing filtering with other expensive avoidance measures. Thus, it can be expected that, wealthier households will use either more expensive avoidance behavior or multiple treatment methods instead of a single one, i.e. $\frac{dY^*}{dI} > 0$. Opinion on initial quality of water is also an important explanatory variable for avoidance behavior. According to Larson & Gnedenko (1999), economic theory does not suggest an unambiguous relationship between initial water quality and the level of avoidance. But if households think that they benefit from avoidance, they will increase avoidance behavior according to the opinion on initial quality of water, i.e. $\frac{dY^*}{dS_0} > 0$ (see Larson & Gnedenko 1999 for a more detailed explanation). This hypothesis indicates that if people believe water delivered to their tap is dirty, they will use either more effective or more than one treatment method.

Econometric methods and estimation

The survey does not provide information on the exact quantities of treatment behaviors (such as how much water is boiled). Instead, it provides information on which particular method is adopted in discrete terms. Moreover, the theoretical model shows that each household chooses whether or not to treat and then selects from several treatment methods based on a number of explanatory variables. Such a binary (1/0) decision can be specified by a probability model,

$$\Pr(Y^*) = Y(p, I, S_0; X) \tag{6}$$

Two approaches are used to estimate such discrete choice behaviors; logit and probit regression models. Optimal averting behavior, given by equation (6) can, thus, be estimated using either a logit or probit regression model. In the following section, these behaviors are analyzed and the above-mentioned hypotheses tested using binomial, ordered, and multinomial probit regression models. The binary probit model was used to analyze the decision of adopting at least one treatment method. To investigate the behavior of households that use more than one treatment method, the ordered probit model was used. The multinomial probit model was also used to investigate the adoption of a specific treatment method out of several methods available. Although both logit and probit regression models can be used to estimate such discrete choice behaviors, one of the restrictive assumptions of the logit model, especially the multinomial logit (MNL) model, is Independence from Irrelevant Alternative (IIA). According to this property, the ratio of probability of two choices (P_i/P_j) is independent of the remaining alternatives. If this assumption is violated, MNL estimation is not valid. The multinomial probit (MNP) model, relaxes the IIA assumption (Greene 2003, p. 727). Moreover, as required for the interpretation of these discrete choice models, marginal effects were estimated and the effect of explanatory variables on the adoption of different types of treatment behaviors were discussed.

The authors used data from 'Water Survey of Kathmandu–2005' conducted by the Central Bureau of Statistics, Government of Nepal in 2005. The survey was conducted to identify the status of water supply, level of water consumption and demand, water tariff, and WTP in Kathmandu valley. Altogether 2000 households were surveyed. A multi-stage sampling design was used to select households.

Explanatory variables

The descriptive statistics of a household in Kathmandu valley are reported in Table 3. A typical household of Kathmandu has 4.7 family members. Almost half (41%) of the households live in rented houses. Of the total, 84% of household heads are male. The majority of the household heads (88%) in the study area are literate. Out of 2000 households surveyed, about half of the households have a private pipe line. Seven percent in the urban and 46% in the rural areas do not have any water source in their household premises. Average education level of the household heads is 7.8 years. Households with radio and TV are 87 and 81%, respectively. Newar (29%) and Brahmin (24%) are major caste/ethnic groups in Kathmandu in terms of population size followed by Chhetri (18%). About 11% of households reported that water delivered to their household is dirty.

The survey did not collect detailed information on household wealth or income. However, questions were asked on possession of durable goods. Several previous studies have used the possession of durables to create a proxy for wealth index (Jalan *et al.* 2009; Wright *et al.* 2009).

Information collected on possession of durable goods was used to create a proxy for wealth. A wealth index was created using first principal component of appropriate variables (PCA). PCA is a technique for extracting linear combinations of the variables that best capture the common information. The first principal component is the linear index of variables with the largest amount of information common to all of the variables. In other words, the components are ordered in such a way that the first component explains the largest possible amount of variation in the original data, subject to the constraint that the sum of the squared weights is unity.

Table 3 | Description of variables

Variable	Description	Mean
Dependent		
TREATMENT	0 if a household does not treat	34.9
	1 if a household treats drinking water	65.1
TREAT_ORDER	0 if a household does not treat	34.9
	1 if uses at least one method and	46.8
	2 if uses more than 1 treatment methods	18.3
TREAT_MODE	0 if a household does not treat	34.9
	1 if a household boils	15.6
	2 if a household filters	21.2
	3 if a household uses other methods	10.1
	4 if a household boils and filter both	18.3
Explanatory		
W_QUARTILE3	Wealth quartile 3	3.6
W_QUARTILE2	Wealth quartile 2	20.5
W_QUARTILE1	Wealth quartile 1	28.6
EDU	Education level of household head	7.83
INFORMATION	Exposure to information	88.9
HSIZE	Household Size	4.7
H_OWNERSHIP	Ownership of household	58.9
WQ_PROBLEM	Perception on quality of water	10.5
PIPED_LINE	Connected to the distribution system	63.8
URBAN	Residence of the household	60
MALE	Gender of the household head	84.8
BRAHMIN	Caste of the household	23.8
CHHETRI	Caste of the household	17.9
NEWAR	Caste of the household	29.3

Note: Mean of all the dependent variables represents the percentage of households that adopt given treatment methods. Most of the explanatory variables except household size and education level are binary; hence the mean represents the percentage when the dummy for the binary variable is 1.

The variables included in the wealth index were: possession of a refrigerator, radio, computer, television, phone, washing-machine, and motorcycle. Moreover, it is difficult to interpret the coefficients and marginal effects of wealth in terms of index, so the wealth quartile from the wealth index for our analysis was created and used. Four quartiles (W_QARTILE4, W_QARTILE3, W_QARTILE2, and W_QARTILE1) were created where W_QARTILE1 is the top quartile. Along with wealth, education level (EDU), information (INFORMATION), size of the household (HSIZE), ownership of the house (H_OWNERSHIP) are expected to influence the treatment behavior. No direct information on household exposure to information is available in the survey. Following Jalan *et al.* (2009), radio and television were used as proxy for exposure to information for our analysis. A household which possesses either of the media is assumed to be exposed to information.

Household averting behavior also depends on the perception of the initial quality of available water. According to Um *et al.* (2002), household averting behavior is better explained by perception of quality than the objectively measured one. Water quality characteristics such as opinion on quality of water (WQ_PROBLEM) and connection to the distribution system (PIPED_LINE) were introduced to estimate the effect of these quality characteristics on the treatment behaviors. Dummy variables for gender (e.g. MALE = 1 if gender is male and MALE = 0 if gender is female) were used to introduce the respondents' heterogeneity. Similarly, dummy variables for other household characteristics such as place of residence (URBAN), and caste/ethnicity (BRAHMIN, CHHETRI, and NEWAR) were used to capture the effect of household characteristics on treatment behaviors.

Dependent variables

Data show that households adopt none, one, or more than one treatment method. Each household's decision and marginal effects of explanatory variables on whether to treat (TREATMENT) water to make it safe was estimated using a binary probit model (Table 4). About 65% of households use at least one treatment method. However, a binary probit model does not allow us to analyze the behaviors when households use more than one treatment method, which is significant (about 18% of households in the valley use more than one method). To capture the effect of explanatory variables on the choice of adopting more than one treatment methods, an ordered probit model was used (Table 5). The treatment behavior was ordered and scaled (TREAT_ORDER) into three categories; 0 if no treatment, 1 if at least one method is adopted and 2 if more than one method is adopted. Based on this assumption, the ordered probit model was used to assess the choice of making none or more than one treatment behavior. Percentages of households that use one and more than one treatment methods are 47 and 18%, respectively. There are several options available in the market for the point of use treatment of water in the valley. Boiling, filtering, use of tablets, SODIS, Uro-guards are some of the frequently used treatment methods. Each treatment method differs in effectiveness as well as cost. Moreover, use of some specific method is also guided by individuals' opinion about quality of water and belief on the effectiveness of the method. Accordingly, each household decides whether or not to treat water and which method (TREAT_MODE) to use to make it safe, where TREAT_MODE is; 0 for not treating water at all (base category), 1 for boiling, 2 for filtering, 3 for other (SODIS, Uro-guard and Tablets), and 4 for both boiling and filtering. There are very few observations for some treatments such as use of tablets, SODIS and Uro-guard. So they were clustered and another treatment mode was created and called 'other'. To investigate the impact of explanatory variables on specific mode of treatment (e.g. boil vs. filter etc.), a multinomial probit model was used. The coefficients from the multinomial probit model, however, do not provide the quantitative change in probability of treatment behaviors. To estimate these changes, marginal effects were estimated (Table 7) and the results are discussed in the following section.

RESULTS AND DISCUSSION

In this section the factors that influence the treatment behavior of households are investigated. Goodness of fit (AIC, BIC) suggests that the most extended version of all three models fits the data well (Greene 2003). Based on goodness of fit measure, the most extended version of each model was used for the estimation of marginal effects. The marginal effects of these three models are summarized in Table 7. Marginal effects, calculated at the mean of the rest of the variables, are significant for almost all variables. In general, the estimation for use of at least one treatment method using binomial probit, for the use of number of treatment methods using the ordered probit and for the choice of specific treatment methods using the multinomial probit model are consistent and exhibit a similar pattern.

Probit regression analysis of treatment behavior

Using the discrete choice binomial probit model, the probability of adopting at least one strategy and marginal effects of

Table 4 | Binomial probit regression results

	Model 1	Model 2	Model 3
W_QUARTILE3	0.388* (0.18)	0.151 (0.19)	0.194 (0.20)
W_QUARTILE2	0.712*** (0.09)	0.540*** (0.09)	0.597*** (0.10)
W_QUARTILE1	1.122*** (0.10)	0.866*** (0.10)	0.947*** (0.11)
EDU	0.077*** (0.01)	0.075*** (0.01)	0.077*** (0.01)
INFORMATION	0.709*** (0.11)	0.570*** (0.11)	0.566*** (0.11)
HSIZE	−0.051** (0.02)	−0.053*** (0.02)	−0.037* (0.02)
H_OWNERSHIP	−0.648*** (0.07)	−0.452*** (0.08)	−0.303*** (0.08)
WQ_PROBLEM		0.515*** (0.14)	0.506*** (0.15)
PIPED_LINE		0.665*** (0.07)	0.742*** (0.08)
URBAN			−0.035 (0.08)
MALE			−0.358*** (0.10)
BRAHMIN			0.137 (0.11)
CHHETRI			0.173 (0.10)
NEWAR			−0.638*** (0.10)
Constant	−0.591*** (0.13)	−0.897*** (0.13)	−0.679*** (0.15)
Observations	2000	2000	2000
Log lik.	−988	−929	−876
Chi-squared	611***	727***	834***
AIC	1991	1879	1783
BIC	2036	1935	1867

Dependent variable; $y_i = 1$ if household adopts at least one treatment method; = 0 otherwise. Standard errors in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

explanatory variables for the adoption of corresponding behavior were estimated.

The results from the binomial probit model, as shown in Table 4, indicate that wealth has a positive influence on the decision to adopt at least one treatment method. Similarly education, exposure to information, opinion on quality of water have significant and positive influence on the decision to treat water. As expected, households are less likely to treat water if the household head is male. Households who own their house are less likely to treat water as compared to the households who rent the house.

As shown in the second column of Table 7, probability of treatment does not increase for the households in the third quartile. But the effect gets significant for households that are in the second and top quartile. The probability of treatment is 18 and 28% higher for the households in the second and top quartile.

Education level of the household head has a positive effect on a household's decision to treat water before drinking. One additional year of schooling results in about a 3% increase in treatment. The results show that households that are exposed to information, increase treatment behavior by 21%. Increase in household size increases the cost of treatment for the household. So, a household with more members will either tend to use cheaper methods or use the treatment method less as compared to smaller household size. Increase in one member decreases the probability of treatment by 1%. Ownership of the household has a negative

Table 5 | Ordered probit regression results

	Model 1	Model 2	Model 3
W_QUARTILE3	0.259 (0.15)	0.064 (0.16)	0.113 (0.16)
W_QUARTILE2	0.776*** (0.07)	0.644*** (0.08)	0.684*** (0.08)
W_QUARTILE1	1.136*** (0.08)	0.938*** (0.08)	0.978*** (0.08)
EDU	0.080*** (0.01)	0.077*** (0.01)	0.079*** (0.01)
INFORMATION	0.683*** (0.10)	0.555*** (0.11)	0.548*** (0.11)
HSIZE	−0.048*** (0.01)	−0.050*** (0.01)	−0.040** (0.01)
H_OWNERSHIP	−0.457*** (0.06)	−0.310*** (0.06)	−0.189** (0.07)
WQ_PROBLEM		0.410*** (0.09)	0.408*** (0.09)
PIPED_LINE		0.609*** (0.06)	0.602*** (0.07)
URBAN			0.078 (0.07)
MALE			−0.282*** (0.08)
BRAHMIN			0.080 (0.08)
CHHETRI			0.044 (0.08)
NEWAR			−0.542*** (0.08)
cut1_Constant	0.723*** (0.12)	0.988*** (0.12)	0.789*** (0.13)
cut2_Constant	2.409*** (0.12)	2.753*** (0.13)	2.616*** (0.14)
Observations	2000	2000	2000
Log lik.	−1671	−1604	−1557
Chi-squared	791***	926***	1019***
AIC	3360	3230	3146
BIC	3410	3291	3236

Dependent variable; $y_i = j$ if household adopts j of treatment methods, $j = 1, 2$; 0 otherwise. Standard errors in parentheses, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

effect on treatment behavior. People who own their house tend to purify 10% less as compared to those who rent their property.

Opinion on quality of water delivered at the tap has a strong and significant impact on treatment behavior. Someone, who thinks that water is dirty (if WQ_PROBLEM = 1), is more likely to treat and probability increases by 15%. It is also interesting to note that households connected to the distribution system adopt treatment behavior by about 26% more as compared to the households that are not connected to the distribution system.

Place of residence (urban vs. rural) does not seem to play any significant role on the treatment behavior for at least one or more than one treatment method. As expected, a household with a male as the household head tends to care less about the treatment. The probability of treatment decreases by 11% if a household head is male. Being Newar decreases the treatment behavior by about 23%.

Ordered probit regression analysis for more than one treatment method

The results of the ordered probit regression model are summarized in Table 5. The results show that most of the variables are significant at 1% for the decision of adopting more than one treatment method.

The results also indicate that adoption of more than one method is significantly and positively influenced by wealth, education and opinion on water quality. A household which is exposed to information tends to use one or more than one treatment method. Poor quality of water also increases the probability of using more than one treatment method. Household size, ownership and household head being male influence negatively.

Results from the marginal effect estimation, for the use of number of treatment methods, indicate that the probability increases as we move from the bottom to the second and the top quartile. For households in the second and top quartile, the probability of using at least one treatment method increases by 5 and 7%. But, for the adoption of two treatments, wealth has a stronger effect, probability increasing by 15 and 22%, respectively.

Education is statistically significant, but does not seem to play a significant role in deciding one or more than one treatment method. The marginal effect is about 1.4% to move from no treatment to one treatment or more than one treatment. It is interesting to note that information increases the probability of adopting at least one treatment by about 13%; the effect is less strong for the adoption of more than one treatment (7.2%). The ordered probit result shows that, household size does not influence the decision of selecting either one or more than one treatment method. Ownership decreases the probability by 3 and 3.4% for the adoption of one and more than one treatment, respectively.

People, who believe that water is dirty, increase adoption of one treatment method by 4%, but the probability for more than one treatment increases by about 8.6%. Probability of adopting at least one method increases by 12%, if the household is connected to the distribution system, whereas the probability increases by 9.5% for the adoption of more than one treatment method.

Multinomial probit regression analysis for the choice of treatment method

Table 6 summarizes the multinomial probit regression results. The results show that wealthier, educated and informed households are more likely to use different treatment methods. However, the probability of the use of these treatment methods decreases with increased household size. A household head, who own his house and male, is found to care less about treatment. More interesting is the quantitative difference in marginal effects of the wealth on the selection of specific treatment method. Marginal effect of wealth is significant for boiling and filtering both, but only for the household in the top quartile. The probability of using both methods increases by 22 and 27% if the households are in the second and top quartile whereas the marginal effect for boiling only and filtering only are not significant. In addition, the probability of using other methods decreases for the households that are in the top quartile. This implies that people tend to use both boiling and filtering instead of one method only, if they are wealthier.

In terms of specific method, one additional year of education is found to increase the probability of boiling by one percent, filtering by a little less than 1%, both boiling and filtering by about 2%, and use of other treatment methods by 0.7%. Exposure to information has the strongest effect in general for the selection of specific treatment methods, as in the case of using at least one treatment method. However, the effect is strongest for filtering only (20%) relative to both boiling and filtering (9.7%), boiling only (7%) and others (10%). Educated households tend to use the filter only instead of two methods, unlike wealthy households. 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% and others by 1%. Interestingly, our multinomial results show that a household that owns the house uses filters the least as compared to other methods. The probability of filtering decreases by 7.4% as compared to boiling (7%).

As compared to other explanatory variables, it is worth commenting on the marginal effect of opinion on quality of water on the selection of specific treatment mode. Marginal effects of opinion on quality of water are higher for both boiling and filtering (9%). Effect of water quality is not significant for the selection of other specific methods. People boil and then filter (or vice versa) instead of boiling only and filtering only if they think that water delivered to the tap is dirty. It is consistent with our theoretical model, i.e. if people think that water delivered to the tap is dirty, they use more than one and stronger methods to ensure the quality of the water. Households connected to the distribution system tend to filter more as compared to other methods. The probability

Table 6 | Multinomial probit regression results
Dependent variable; yi = j if household adopts jth treatment mode, j = 1, 2, 3, 4; 0 otherwise

	Model 1				Model 2				Model 3			
	Boil	Filter	Other	Boil & Filter	Boil	Filter	Other	Boil & Filter	Boil	Filter	Other	Boil & Filter
W_QUARTILE3	0.64*	0.50	0.20	0.58	0.35	0.21	−0.03	0.15	0.40	0.20	0.06	0.26
	(0.29)	(0.28)	(0.32)	(0.36)	(0.30)	(0.29)	(0.33)	(0.37)	(0.31)	(0.30)	(0.35)	(0.39)
W_QUARTILE2	0.83***	0.77***	0.52***	1.63***	0.64***	0.58***	0.35*	1.41***	0.67***	0.64***	0.49**	1.47***
	(0.15)	(0.14)	(0.16)	(0.16)	(0.15)	(0.14)	(0.16)	(0.16)	(0.16)	(0.14)	(0.17)	(0.17)
W_QUARTILE1	1.31***	1.17***	0.91***	2.30***	1.04***	0.88***	0.66***	1.96***	1.08***	0.99***	0.86***	2.03***
	(0.15)	(0.14)	(0.16)	(0.16)	(0.16)	(0.15)	(0.17)	(0.17)	(0.16)	(0.16)	(0.18)	(0.18)
EDU	0.11***	0.09***	0.03	0.17***	0.11***	0.09***	0.03	0.17***	0.11***	0.09***	0.04*	0.17***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)
INFORMATION	0.98***	1.57***	0.27	1.57***	0.85***	1.41***	0.13	1.32***	0.83***	1.40***	0.14	1.28***
	(0.20)	(0.22)	(0.17)	(0.37)	(0.21)	(0.23)	(0.17)	(0.37)	(0.21)	(0.23)	(0.18)	(0.38)
HSIZE	−0.09**	−0.08**	0.00	−0.10***	−0.09***	−0.08**	0.00	−0.10***	−0.07*	−0.06*	0.02	−0.09**
	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
H_OWNERSHIP	−0.98***	−0.84***	−0.57***	−0.92***	−0.76***	−0.61***	−0.36**	−0.66***	−0.54***	−0.52***	−0.17	−0.38**
	(0.12)	(0.11)	(0.12)	(0.13)	(0.13)	(0.12)	(0.13)	(0.13)	(0.13)	(0.13)	(0.14)	(0.14)
WQ_PROBLEM					0.73***	0.60**	0.11	1.01***	0.68**	0.60**	0.16	0.95***
					(0.21)	(0.20)	(0.25)	(0.20)	(0.21)	(0.21)	(0.25)	(0.21)
PIPED_LINE					0.72***	0.84***	0.74***	1.01***	0.68***	1.00***	0.94***	0.91***
					(0.12)	(0.11)	(0.12)	(0.14)	(0.14)	(0.13)	(0.14)	(0.15)
URBAN									0.28*	−0.22	−0.32*	0.39**
									(0.14)	(0.13)	(0.14)	(0.15)
MALE									−0.56***	−0.47**	−0.23	−0.56**
									(0.16)	(0.16)	(0.17)	(0.18)
BRAHMIN									0.37*	0.40*	−0.43*	0.28
									(0.16)	(0.16)	(0.18)	(0.17)
CHHETRI									0.29	0.36*	0.10	0.10
									(0.16)	(0.16)	(0.16)	(0.18)
NEWAR									−0.68***	−0.47**	−1.06***	−0.94***
									(0.16)	(0.15)	(0.16)	(0.17)

Constant	−1.80***	−2.04***	−1.19***	−3.41***	−2.14***	−2.45***	−1.52***	−3.93***	−1.95***	−2.18***	−1.26***	−3.67***
	(0.23)	(0.25)	(0.20)	(0.40)	(0.24)	(0.26)	(0.21)	(0.40)	(0.27)	(0.28)	(0.24)	(0.42)
Observations	2000				2000				2000			
Log lik.	−2580				−2508				−2418			
Chi-squared	642***				709***				804***			
AIC	5223				5095				4957			
BIC	5403				5319				5293			

Standard errors in parentheses, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

of filtering increases by 13% as compared to other (6.1%), and both (5.4%). This result shows that if households are connected to the distribution system, they tend to use more treatments as compared to the household that are not connected to the distribution system.

Multinomial probit regression results show that probability of boiling increases by about 7% whereas probability of filtering decreases by 8% if the household lives in an urban area. The probability of using both methods increases by about 7% if the household lives in an urban area. Probability of using more than one method decreases by 5.6% if the household head is male. As already shown by the previous probit model, the probability of using all methods in general decreases (by 4 to 6%) if the household head is male and less likely to use both methods. For a Newar family, the probability of using both methods decreases by 9.5%.

The results from binomial, multinomial and ordered probit models are robust and consistent with theory. Most of the explanatory variables are statistically significant for the selection of treatment, whether to use one or more than one method and for the selection of a particular treatment method. Thus wealth, education, exposure to information and opinion on quality of water influence the choice of treatment. The marginal effects are stronger for wealth, exposure to information and whether or not the household is connected to the distribution system. More specifically, households in the top quartile 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.

In addition to the results discussed above, there are some interesting results that deserve special attention. For example, wealth is significant and important for the adoption of at least one treatment method. Moreover, it increases the probability of adopting both boiling and filtering by about 27%. Unlike wealth, exposure to information increases the probability of filtering only, by about 20%, whereas its impact on selection of boiling and using both methods are comparatively lower

Table 7 | Marginal effects for binomial, ordered and multinomial probit regression model

	Binomial Probit	**Ordered Probit**		**Multinomial Probit**			
	TREATMENT[a]	***TREAT_1***[b]	***TREAT_2***	***Boil***[c]	***Filter***	***Others***	***Boil and Filter***
W_QUARTILE3	0.063 (0.06)	0.017 (0.02)	0.021 (0.03)	0.067 (0.07)	0.008 (0.06)	−0.021 (0.05)	0.016 (0.06)
W_QUARTILE2	0.182*** (0.03)	0.054*** (0.01)	0.152*** (0.02)	0.014 (0.03)	0.007 (0.03)	−0.023 (0.02)	0.217*** (0.03)
W_QUARTILE1	0.279*** (0.03)	0.069*** (0.01)	0.220*** (0.02)	0.039 (0.03)	0.016 (0.03)	−0.015 (0.02)	0.272*** (0.03)
EDU	0.026*** (0.00)	0.014*** (0.00)	0.014*** (0.00)	0.011*** (0.00)	0.007* (0.00)	−0.007** (0.00)	0.018*** (0.00)
INFORMATION	0.212*** (0.04)	0.133*** (0.03)	0.072*** (0.01)	0.067* (0.03)	0.204*** (0.03)	−0.094** (0.04)	0.092*** (0.03)
HSIZE	−0.013* (0.01)	−0.007** (0.00)	−0.007** (0.00)	−0.009 (0.01)	−0.008 (0.01)	0.010** (0.00)	−0.009* (0.00)
H_OWNERSHIP	−0.102*** (0.03)	−0.031** (0.01)	−0.034** (0.01)	−0.065** (0.02)	−0.074** (0.03)	0.027 (0.02)	−0.014 (0.02)
WQ_PROBLEM	0.152*** (0.04)	0.041*** (0.01)	0.086*** (0.02)	0.060 (0.03)	0.044 (0.04)	−0.051* (0.02)	0.113*** (0.03)
PIPED_LINE	0.263*** (0.03)	0.119*** (0.02)	0.095*** (0.01)	0.021 (0.02)	0.129*** (0.02)	0.061*** (0.02)	0.054** 0.02)
URBAN	−0.012 (0.03)	0.014 (0.01)	0.013 (0.01)	0.073** (0.02)	−0.078** (0.03)	−0.064** (0.02)	0.069*** (0.02)
MALE	−0.113*** (0.03)	−0.036*** (0.01)	−0.056** (0.02)	−0.063* (0.03)	−0.044 (0.03)	0.022 (0.02)	−0.044 (0.03)
BRAHMIN	0.046 (0.03)	0.013 (0.01)	0.014 (0.01)	0.057 (0.03)	0.084* (0.03)	−0.095*** (0.02)	0.022 (0.02)
CHHETRI	0.058 (0.03)	0.007 (0.01)	0.008 (0.01)	0.033 (0.03)	0.068 (0.04)	−0.014 (0.02)	−0.015 (0.02)
NEWAR	−0.230*** (0.04)	−0.113*** (0.02)	−0.082*** (0.01)	−0.050 (0.03)	0.001 (0.03)	−0.094*** (0.02)	−0.074*** (0.02)
Observations	2000	2000	2000	2000	2000	2000	2000
Log lik.	−876	−1557	−1557	−2418	−2418	−2418	−2418
Chi-squared	834***	1019***	1019***	804***	804***	804***	804***
AIC	1783	3146	3146	4957	4957	4957	4957
BIC	1867	3236	3236	5293	5293	5293	5293

Standard errors in parentheses, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$.

[a] *TREATMENT* is a dependent variable of the binomial probit regression model.

[b] *TREAT_1* and *TREAT_2* are two ordered categories of dependent variable (TREAT_ORDER) of the ordered probit regression model.

[c] *Boil*, *Filter*, *Others* and *Boiling and Filtering* are specific treatment methods for the dependent variable *(TREAT_MODE)* of the multinomial regression model.

and almost equal. Similarly, higher probability of filtering, if a household is connected to the distribution system, suggests that a household connected to the distribution system tends to use filtering more as compared to boiling and using both methods.

CONCLUSIONS AND POLICY IMPLICATIONS

Enough and safe quality of water constitutes a satisfactory water supply and is a prerequisite for good health. Poor quality of drinking water increases the health risks. In other words, drinking water has a quantity as well as a quality dimension. But drinking water in Nepal, although confined to the urban areas, does not guarantee the safe and good quality of the water supply. Because of poor quality delivered to the household, drinking water is a major issue not only in rural areas but for the urban setting as well. Households delivered with poor water quality take measures to reduce or eliminate the risks. The treatment behaviors of households in Kathmandu were examined. The results show that the majority of households use either one or more than one treatment method to make the water safe for drinking. Wealth, education level, exposure to information, and opinion on water quality play a significant role in treatment behavior. This can have several policy implications in general. First, the households that are poor, lack education and not exposed to information are exposed to the health risks of unsafe drinking water. Given the poor quality of water, treatment behaviors of these households can be influenced by policy instruments. In addition to income, information and education level are important to reduce the health risks of poor quality of water. For example, increasing education level and providing information through media can significantly reduce the health risks by influencing treatment behaviors. Second, even the households that are connected to the distribution system are exposed to health risks because of poor quality of water delivered to their tap. Consumers connected to the distribution system are exposed to health risks even when officially deemed to have access to improved water supplies. This, if not taken into account, can be misleading to planners and policy makers for the further development of the water supply infrastructure. Third, despite a smaller current payment for water, a significant amount of money is being spent on treatment by a major portion of the population in the Valley. As explained by the economic theory of averting behavior, households are willing to pay more for drinking water if households are ensured about the quality of the water. To conclude, the results show that: a majority of the households, especially the poor, are exposed to the health risks of poor quality of water and households from Kathmandu are paying a significantly higher amount of money to treat water than they are paying as the current tariff. Until the quality of water is ensured, policy should aim at reducing the health risks of poor quality of water by influencing the treatment behaviors of people in the Valley.

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