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Valuing Water Service Improvements through Revealed Preference: Averting Behaviour Method

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Abstract

Access to quality and adequate water supply is a basic need to sustain human life. Health risk of unsafe drinking water is a serious issue in many poor and underserved communities in developing countries. Therefore, the improvements of the health status of the people are considered as one of the main justifications of promoting investment in water infrastructure. People take a number of coping strategies for water service improvement and the expenditures on such measures implicitly reflect their preferences for water service improvements. This paper leads to estimation of the benefits of water service improvements using the Averting Expenditure Method. This study examines the determinants of averting actions and the prevailing health impacts using the Probit models aiming to examine why some households practice averting measures and have experienced with health impacts while others not. Study found that the respondent's socio-economic attributes significantly determine the choice of averting behaviours. Then this study calculates the monitory values of number of averting measures and it was found that the mean averting expenditures of the household are Rs. 577 and Rs,. 740 per month respectively the households connected to the system and un-connected to the system. piped households spending an average about Rs. 500 per month as a damage cost of water related health impacts which is unseen but part of the real cost of lack of access to good quality water supply. Study conclude that the WTP estimates are much higher than the payments for existing piped schemes hence cost of clean and consistent water supply could be finance through a user payment scheme.

Key words: *Water quality, health impacts, averting behaviours, averting expenditures, willingness to pay.*

Introduction

Understanding household's demand for water service improvements is important for public policy making in water service improvements. However, this does not straightforward owe to the facts that clean, adequate and consistent water supply is considered a non-market commodity in general (Pattanayak *et al.*, 2005)**.** Economic analysis plays an important role in designing and implementing effective water resource management. It is well documented that such analysis can help to measure the benefits of water service improvements (Altaf, 1994; Nam and Son, 2005a; Birol *et al.*, 2006b). Several attempts have been made to value water resources management under different contexts using an array of valuation techniques. Valuing environmental amenities has become one of the rapidly developed areas in the discipline of environmental economic in last few decades (Louviere *et al.*, 2000) Environmental and resource economics attempts to value the individual preferences of an environmental policy and program rather than the commodity or environmental services itself unlike many non-economists believe . The value of environmental quality changes are measured in monetary terms using the concept of willingness to pay (WTP) or willingness to accept (WTA) compensation for changers in environmental conditions. Currently many countries examine the potentials for public water supply based on the WTP for water service improvements in which imply how much people willing to forgo some benefits in exchange for better access to good quality water supply (Wang *et al.*, 2010). This WTP pricing for water service improvements can assist policy makers in understanding the demand for water service improvements (Pattanayak *et al.*, 2006a). Valuing the benefits of water access and quality improvements provides the required inputs for the cost-benefit performance on water management policies/programs and for the policy relevance information water management.

Public policies should reflect an understanding of the public values in relation to the environment amenities and such values are not correctly reflected by the market system (Champ *et al.*, 2003). Integration of non-market valuation of environmental resources into the decision making process have been extensively developed over the past two decades (Bateman *et al.*, 2002; Champ *et al.*, 2003; Bennett and Birol, 2010). Quantification of the cost and benefits of public projects are an important aspect of public policy making and non-market valuation play an important role in this context (Alpizar *et al.*, 2003). Non market valuation is employed to infer monetary values of individual preferences for outcomes of policy proposals or events (Freeman, 2003; Young, 2005). In this study, the outcome concerned is the provision of improved water service among rural communities. Water quality improvements cannot be measured through the existing market system, various non-market valuation techniques have been developed to measure the benefits of water quality improvements. As a Revealed Preference (RP) approach, Averting Behaviour Method (ABM- this is also called as averting or defensive expenditure method) assumes that in the absence of explicit market, it is possible to value the change of water quality and service explicitly through observing the individuals behaviours on water quality improvements. ABM is a technique for valuing environmental quality changers based on the few key important assumptions. Bartik (1988) discusses these assumptions and explained how they can be violated in real world applications.

Households in the study area perform a number of coping strategies in order to reduce the health risk and the expenditures they incur for such actions implicitly reflects their preferences for water service improvements. It is generally accepted that expenditures on averting measures provide a conceptually rationale conservative estimate of actual costs or benefits of drinking water quality changers (Abdalla *et al.*, 1992). Household could refrain from the averting measures if they are provided the improved, reliable and affordable water supply. Therefore, averting measures give the rational starting point for examining the demand for water service improvements (Pattanayak *et al.*, 2005). Expenditures on averting behaviours of water consumers are considered as a one of the indicators which reflect the individuals demand hence willingness to pay for ensuring water access and quality improvement. However, averting expenditures do not reflect the full social cost of lack of access to quality water supply or on the other hand the true benefits of water quality improvements. Averting measures are not perfect substitute for quality water supply hence it only reflects a part of the overall benefits from providing improve quality water supply. Theoretically averting expenditures reflects the lower bound of the WTP for environmental improvements under certain assumptions (Courant and Porter, 1981; Bartik, 1988; Abdalla *et al*., 1992; Laughland *et al.*, 1996)

Averting behavior method is grounded in household health production approach of consumer choices. This model is developed using an individual utility maximizing framework and captures the individual’s behavior in order to prevent the reduction in environmental quality (Markandya and

Richardson, 1992). The notion of a household health production function model formally developed by Grossman (1972) with the application to measuring health impacts of air pollution. Since then the method has been widely applied in health and environmental economics as techniques of valuing the welfare effects of environmental quality changes by observing consumer behaviors. Important contributions to the literature includes (Markandya and Richardson, 1992). (Freeman, 2003), Bateman (2003), (Bockstael and McConnell, 2007) on its theoretical basis and the empirical studies in relation to water quality and service improvements in different context include (Abdalla, 1990; Abdalla *et al.*, 1992; Collins and Steinback, 1993; Laughland *et al.*, 1993; Alberini *et al.*, 1996; Laughland *et al.*, 1996; Whitehead *et al.*, 1998; Larson and Gnedenko, 1999; Abrahams *et al.*, 2000; McConnell and Rosado, 2000; Zérah, 2000; Wu and Huang, 2001; Um *et al.*, 2002; Roy *et al.*, 2004; Pattanayak *et al.*, 2005; Haq *et al.*, 2007; Yoshida and Kanai, 2007; Jalan and Somanathan, 2008; Jalan *et al.*, 2009b; Nauges and Van Den Berg, 2009b; Wright and Gundry, 2009; Katuwal and Bohara, 2011; Jessoe, 2013; Lanz and Provins, 2014; Othman *et al.*, 2014)

Katuwal and Bohara examined (2010) the household demand for water treatment behaviours using the ABM in the same area Kathmandu Nepal. This study specifically examined the demand for treatment behaviours like boiling, filtering etc with respect to the change of the socio economic variables like wealth, education, gender, information, etc. Study found that the majority of the households practice at least one treatment behaviour and people tend to take more than one treatment behaviour if they are wealthier. Study also highlighted that wealth, education, perception about the water quality and information are important determinants of treatment behaviours. However, this study only examined the demand for treatment behaviours with the range of econometric methods, but did not focus on measuring the welfare effects (WTP) for quality improvements. Pattanayak (2005) employed ABM and CVM to measure the demand for water quality improvements surveying 1500 randomly selected households in Kathmandu, Nepal. This study found that the coping cost of households is about USD 3 per month while WTP under the CVM is USD 17.36. However, it is really surprise to see such a significant difference between the estimations provided by the two approaches when it compared to the available literatures.

The study was done by McConnell and Rosado, (2000) to show the non-marginal benefits from higher drinking water quality using discrete choice model. A discrete choice modeling has used to get parameters of a preference function for four averting behaviors undertaken by the water consumers in order to improve the water quality. The estimated parameters indicated that households in Espirito Santo, Brazil were WTP, an average, USD 3/month if they have access to safe drinking water. Wu and Huang, (2001) have done a study in Ping-tung shian, Thaiwan to compare the averting expenditure and stated WTP measures to examine whether averting expenditure is a lower bound of the willingness to pay measured from CVM. The empirical results of the study confirmed the theoretical expectation that averting expenditure is a lower bound of WTP generated from the SP approach. In Sri Lankan context, Nauges and Van Den Berg (2009b) examined households perception of risk in relation to the water consumption and how this affect to the averting behaviours of the water consumers in Southwest, Sri Lanka. This study mainly found that the households assessed safety risk of water quality mainly based on the characteristics such as taste, colour and also confirmed that the impacts of socio-economic attributes on households averting behaviours specially education and access to information significantly determine the household decisions on averting actions .

Despite the extensive literature on examining the determinants of averting behaviours, handful of studies attempted to find out the household expenditures on averting behaviours. No previous study found in Sri Lankan in this context. Therefore this study attempted to fill this research gaps by estimating the cost of range of averting behaviours under two different water supply scenarios namely piped and non-piped water supply while exploring the determinants of averting behaviours, expenditures and water related health impacts using different econometric models.

Materials and Method

Study Area

Sri Lanka is an island with an area of 65610 km^2 and 2.1 million inhabitants. This study is conducted in the North Central Province (NCP) (Figure 3-1), where the majority of poor households depend on non-piped sources of water. Water sources in the area are polluted by both natural and man-made contaminants. Ground water contains high concentration of fluoride (F) and has high electrical conductivity (EC) and hardness (H) (Dissanayake, 1991,1996; Padmasiri and Dissanayake, 1995; Padmasiri, 2004; Tennakoon, 2004; Padmasiri and Jayawardana, 2010). The high fluoride content causes dental fluorosis, particularly common in children, and skeletal fluorosis cases have also been recorded (Dissanayake, 1996; Padmasiri, 2004). Surface and ground water are also polluted with heavy metals due to excessive use of agro-chemicals, and they cause a variety of health problems. Chronic kidney disease (CKD) is one of the ilnesses particularly prominent in the province. It has been suggested that arsenic, cadmium and other agrochemical residues in water are the main factors responsible for CKD, and hardness and electrical conductivity are associated with an increased risk of renal failure (WHO/Sri Lanka study report, 2012). Households are boiling and filtering water, buying water from vendors, using bottled water, and collecting water from more distant but better sources to avoid the adverse health effects of contaminated water. Data was collected surveying 713 households in which 307 households connected to the piped water systems while remaining 406 depending on non-piped sources to meet their drinking water requirements.

Model Specification

Following Bartik (1988), Um *et al.* (2002) and Katuwal and Bohara (2011), the household production function for expected better water quality can be modelled as,

$$E = E(A, E_0) \qquad (1)$$

Where E is the expected water quality and the E_0 is the perception and the actual quality levels of the existing water supply (Previous studies have only considered perception, but this research tested the actual water quality of the drinking water sources). A represents any averting behaviours of the households.

Then the households minimize the expenditures (C) based on both perception of the current water quality and the minimum required level E_1.

Minimize $C = p A$ (2)

Subject to $E_1 = E(A, E_0)$ (3)

Where pA is the price of the averting behaviour.

Then above minimization problem can be solved for minimum expenditures on averting behaviours.

If $C^* = C(p, E_1, E_0)$ is the minimum expenditures on averting actions needed to derive the expected water quality E_1 with the given initial quality E_0. (4)

Then the utility maximization subject to given budget constrain can be written as,

Max $U(E_1^*, X; Z)$ (5)

Subject to $pA + X \leq I$

X is the other composite goods other than quality water and Z is the vector of the socio-economic characteristics of the households. I is the households income,

Then the minimizing expenditures and maximizing utility problem is combined,

Max $U(E_1^*, X; Z)$ (6)

Subject the $C(p, E_1, E_0) + X \leq I$

Then the indirect utility function can be derived through solving above utility maximization problem,

$V = V(P, I, E_1^*; Z)$ (7)

Based on the above indirect utility function, the optimal averting behaviour can be derived as follows,

$$A^* = \frac{dV/dp}{dV/dI} = \frac{dC}{dp} = A\,[p, E_0, E_1^*(p, I, E_0; Z)] \qquad (8)$$

A^* is denoted as the optimal averting behaviour maximizes the utility and minimizes the averting expenditures.

Above equation state that the optimal averting measure depends on the variables such as; the price of the averting measure (*p*), household disposable income (*I*), individual perception and the measured quality level denoted by E_0 and other socio-economic characteristics of the households which determine the averting behaviours represented by the Z (Katuwal and Bohara, 2011).

Estimating averting expenditures

Estimate the monitory values of averting activities is complicated by the facts that majority of households taking multiple measures and data on actual expenditures are not readily available for some of the coping activities. It was attempted to derive the monitory values of the averting actions as much as possible with the application of array of techniques. The Table 1 provide the cost components associated with series of averting actions and the valuation techniques employed to estimate monetary value of the coping activities.

Table 1 Cost components different averting measures

Averting Actions	Cost Components	Valuation Method
Boiling	Capital cost-instruments Energy cost- electricity, gas, fuelwoo	Purchased price Market price Opportunity cost of time
Filtering	Capital cost-instruments	Purchased price
Buying bottled water	Payments for sellers	Market price
Fletching from dista sources	Time devoted for collecting water Transportation cost if available	Opportunity cost if time Market price
Buying from vendors	Payment for vendors	Market price
Rain water harvesting	Capital cost- RWH tank	Construction cost
Pumping ground water	Capital cost Energy Cost	Purchased price Market price

Results and Discussion

Averting behaviours of the households

It was found that people practice a number of averting measures and devoted considerable amount of money and time to improve the quality and well as availability of the water for drinking and other domestic requirements

- Boiling
- Filtering
- Buying bottled water and water from private vendors
- Water pumping from ground water sources
- Water collecting from distance sources
- Rain water harvesting (RWH)

Table 2 Averting actions practice by households

Averting Measures	Pool (713)	Piped (307)	NP (406)
Boiling	219	112	107
Filtering	242	105	137
Boiling and Filtering	75	38	37
Bottle Water (Regular)	11	08	3
Fetching from distance sources	416	58	358
Pumping	96	18	78
Rain water harvesting	221	60	161
RWH Tank	51	4	47

According to the Table 2, boiling and filtering are the most commonly use in-house coping strategies while some households practice both boiling and filtering. is the commonly use in house treatment method followed by the water boiling. This study also found that the majority of households collecting water from distance but more reliable interms of quality and quantity.

Foloowing briefy discuess the followed approaches to estimate the averting expenditures for the range of measures and the calculations used.

Averting expenditures: Water boiling

It was found that 219 households practicing water boiling regularly as a measure of water quality improvements. In order to estimate the averting cost of water boiling, this study taken into account both onetime capital cost and variable cost. The capital cost consist of purchasing boiling instrument and two variable cost components: the cost of energy and the cost of time spending for water boiling were considered

Capital expenditures

People in the area use different instruments for water boiling; such as pots, kettles, heaters, Purchased price of such instruments was amortized to get the monthly cost considering the 2 years life time of the instruments. Usually household's use the same instrument for boiling and do not use for other cooking purposes hence we assume that the capital expenditures incurred on the instruments are only pertaining to water boiling. Households purchased Instruments cost them ranging from Rs.25-4000 and average household spending about Rs. 16 per month as a capital expenditure pertaining to water boiling.

Recurrent expenditures

Cost of time spending for water boiling and the cost of energy were taken in to account. Household spending in average 33 minutes per day for water boiling and the opportunity cost of time was taken as proxy for time cost.

Energy cost-Fuel wood

According to the survey findings, 90% of households are using fuel wood as a main source of energy for water boiling in the study area and remaining 10% use electricity or gas as an energy source for water boiling. Majority of the households (95%) in the area collecting firewood from their/relatives home gardens and other public forest and women's are mainly engage in collecting firewood in the study area. The remaining 5% buying fuel wood from the sellers. This study collected the information pertaining to the households those who buying firewood from the sellers and we refer the opportunity cost of average time spending for collecting fuel wood as a proxy to calculate the monitory value of averting expenditures for those who collecting firewood. Usually households collecting firewood not only for water boiling but mainly for daily cooking purposes as well. Having considering the facts, the study taken into account only 20% of the time taken as a real time spending for collecting fuel wood for the purpose of water boiling.

Energy cost- Electricity charges

According to the Abdalla *et al.* (1992) to boil half of US gallon of water (1 US Gallon=3.785L) it is approximately required 0.35kWh of electricity hence approximately 0.185 kWh to boil 1L of water. However, with the information gathered from the field survey and consulting the experts in this sector, researcher found that this is somewhat over estimation of the electricity requirement to boil 1L of water (this may be the reason people use more energy efficient instruments for water boiling nowadays). In order to validate this, researcher personally tested the electricity requirement with the similar kind of instruments (many of them use water heaters) using by the household in the area and found that it takes approximately 3-4 minutes to boil IL of water depending on the instrument use. Then,

Assuming that the households use the instrument with 1000w (1 kWh) capacity and the time required for boiling 1L of the water is 3.5 minutes in average, required electricity (kWh) to boil 1L of water is app: 1/60*3.5 = 0.058kWh

The average unit price of electricity in Sri Lanka=4.7 kWh

Electricity cost to boil IL of water = app. **Rs.0.27**

Opportunity cost of time for water boiling and fuel wood collection

Women are mainly engaged in water boiling and collecting required fuel wood in the study. This study uses the agricultural sector average market labour wage rate for women's (Rs. 500/day) as a baseline to calculate the opportunity cost of time spending for water boiling and collecting fuel wood. Considering the low opportunity cost of unskilled labour in rural agricultural sector, in this study researcher only taken into account 40% of the women's wage rate as a real opportunity cost of time spending for water boiling and collecting fuel wood (The studies done by Whittington *et al.* (1990b); Pattanayak *et al.* (2005) taken 50% of the daily wage rate as an opportunity cost of time). It was found that piped and non piped households incur Rs 414 and 465 per month for water boiling.

Averting expenditures: Water filtering

Filtering is most widely used in-house averting measure practicing by the households in the area. 242 households regularly practicing filtering and residents using filter costing them are ranging Rs. 1500 to 32000. We only consider the capital cost as an averting cost of water filtering where the purchasing costs were amortized to get the monthly cost considering the 4 years of lifetime for normal filters and 10 years for advanced and expensive filters (like RO filters). Survey data revealed that 8 households have been received filters free of charge from the NGOs where conducting the community level awareness program in the area. Calculated figures found that Piped and non-piped households spending in average Rs.85 and Rs.86 per month as filter cost respectively.

Averting expenditures: Water pumping

Capital expenditures

Totally 96 households pumping water from ground water sources to meet the drinking and other domestic requirements. Both purchasing price of water pumps considering 10 years lifetime and cost of energy (electricity) for pumping are taken into account. Households using pumps costing ranging from Rs 3500 to 58000. In average piped and non-piped households spending Rs 139 and Rs 169 per month as a capital cost for water pumping.

Cost of Electricity for pumping

First we need to find out the amount of electricity required for the pumping of ground water. The electricity cost mainly depends on the size of the water pump (people in the area normally use 0.5hp-1hp water pumps for pumping water for domestic purposes) and the operating time of the pump. With the consultation the officers of the Ceylon Electricity Board (CEB) and from the household survey information, it was found that people in the area operate water pump for about 30 minutes/day to meet the domestic water requirements. Assuming the households using the 0.75hp water pump and the operating time is 30 minutes/day, Then the required amount of electricity can be calculated as follows,

1hp = 0.746 kWh

Electricity required for day [(0.75*746)/2]/1000 = 0.28kw/h

Unit price of electricity= Rs 4.70/kWh

Cost of electricity Unit price of electricity*0.28

Cost of electricity for pumping/month= Rs. 1.26 (0.28*4.5)*30 = Rs. 39/month

Based on the above calculations study found in average piped and non piped households spend Rs. 139 and 169 respectively for water pumping.

Averting expenditures: Cost of water collecting from distance sources

This is one of the important and aspect of the averting expenditures. In developing countries, lack of access to drinking water within the own house or shorter distance affects the livelihood of the households in different ways (Whittington, 1990; Boone *et al.,* 2011*;* United Nations, 2010). Out of the 713 total sample 416 households collecting from the distance but better/reliable sources (this can be either primary or secondary sources). Households spending 10 to 200 minutes per day to collect water from distance but better/reliable sources with spending an average 31minutes[1] . In this study, research found that both men and women spending considerable time for collecting water. The study taken 40% and 60% of wage rate (Rs. 500 and Rs. 800 per day) as a real opportunity cost of time taken into the considering the prevailing opportunity cost of unskilled labour of the agricultural sector agricultural sector to calculate the monitory value of time cost. In addition to time cost the applicable cost of transportation also taken into account.The study found that the opportunity cost of collecting water from distance source are Rs. 514 and Rs. 532 respectively for both piped and non piped water users.

Averting expenditures: Rain water harvesting

In total 221 households engage in RWH regularly in the rainy session, but only 51 households having proper RWH tank. People do engage in RWH, mainly due to the combination of factors such as lack of alternative water sources, drying up of other alternative water sources in the dry session

[1] WHO (2010) found that households spending 30 minutes per day for collecting water from distance sources

and also the poor quality of the existing sources. The capacity of the RWH tank ranging from 8000-12000 Litters. When estimating the averting expenditures we only had taken into account those who are regularly practicing the RWH with a proper RWH tank.

We only consider the initial capital cost of constructing of RWH tank as an averting expenditure. Constructing a proper RWH is a capital incentive work and NGOs working in the area providing financial and technical assistance the household to construct RWH tanks. After discussing with the households and consulting the NGOs working in the area, we found that in average households spending only about 40% of the total capital cost required to construct RWH tank and rest of the 60% received from the organizations. Therefore we only taken into account the 40% of the capital cost and this amortized to calculate the monthly cost considering the 10 years of life time. We found in average household spending Rs.67 per month for rain water harvesting.

Mean averting expenditures on water quality improvements

The following table summarize the averting expenditures for each averting action follows by the respondents.

Table 3 : Summary of the averting expenditures

Averting Measures	Piped	Non-piped
Boiling	414 (66-1595)	465 (63-1533)
Filtering	85 (31-267)	86 (31-281)
Buying bottled water	1352(510-2625)	540 (500-600)
Pumping	139 (68-239)	169(93-522)
Collecting from distance sources	514 (126-3600)	532 (126-2205)
Rain water harvesting	67	67
Mean Averting expenditures	**577 (31-4100)**	**740 (63-4800)**
Lowest and highest values are in brackets		

It was found that the mean averting expenditures of the household are Rs. 577 and 740 per month respectively (Table 3) for the households connected to the system and un-connected to the system. According to the above calculations households are not connected to the system spending higher than the households already connected to the system. The higher However it is important to note those households already connected to the piped system currently paying about Rs. 300 in average as water utility chargers in addition to the averting expenditures for water quality improvements.

Expenditures on water borne diseases (Cost of Illness)

Non communicable diseases prevailing in the area was taken in to account. Related medical and non-medical expenditures were calculated during the household survey. The monthly cost of medical expenditures (treatment cost, doctor visits, and transportation) and the average income loss due to illness were calculated. Quality water is not the only factor responsible for the water related diseases prevailing in the area (specially CKD) . Hence, cannot take the total expenditures as a damage cost due to the low quality level of the drinking water sources in the area. There is not data available over the marginal effects of water quality on water borne diseases prevailing in the area. So, as most conservative estimate study only taken 40% of the expenses incur on water related illness as a real cost of water borne disease prevailing in the area. However even under such conservative estimated this particular study found that the households spending an average about Rs. 500 per month as a damage cost of water related health impacts which is unseen but part of the real cost of lack of access to good quality water supply.

Identifying the factors affecting on averting behaviours and health impacts

It is important to examine the underlying factors determining the averting measures in order to identify why some households practice averting measures while others do not. This is important in a policy context for promoting averting actions among the rural households targeting the households yet to practice such actions and enhance the effectiveness of such actions, etc. This study employs univariate and bivariate probit models to examine the factors affecting averting measures and the water related health impacts.

Model specification

Probit model is used when the dependent variable is a binary response. In this case;

If the households practice at least one averting action=1, otherwise 0. Binary outcome models estimate the probability that Y=1 as a function of the explanatory variables; such as education level, income, gender, water source, etc.

Then the model can be specified as,

Probability (A^*) = A (p, I, E_0; Z)

The same model specification is used to identify the determinants of having experience with water related health impacts

Table 4 Determinants of averting behaviours and water related health impacts

Variables	**Averting Actions**	**Health impacts**
Constant	-2.072(**0.395**)***	-1.513(**0.380**)***
Members	-0.055(**0.043**)	0.136(**0.412**)***
Gender	-0.185(**0.111**)*	0.029(**0.108**)
Age	0.003(**0.004**)	0.003(**0.004**)
Education	0.217(**0.085**)***	-0.162(**0.081**)**
Income	8.610(**2.970**)***	0.052(**2.860**)
Perception (1=Excellent, Very bad)	0.106(**0.060**)*	0.038(**0.058**)
Participation	1.513(**0.110**)***	0.186(**0.107**)*
Fluoride	**-** 0.017(**0.087**)	0.322(**0.085**)***
TDS	0.001(**0.000**)***	0.0006(**0.0003**)*
Source (Piped/NP)	0.183(**0.112**)**	- 0.360(**0.109**)***
Rho (Averting, Health)	**0.242(0.0720)*****	
No of Observations	**713**	
LLR	**-746**	

,**, refers to 10%, 5% and 1% significance level with two-tailed tests**

The table 4 provides the results of the bivariate probit model[2] tested for averting actions and health impacts to identify the underlying factors for practicing averting actions. The analysis also helps to address the relationship between averting actions and health impacts. The positive and highly significant coefficients of the education, income and the participation variables indicate that households with higher educational attainments, higher income and the experience of participating in community level awareness/water testing programs have a positive relationship with practicing averting measures. They may be more aware about the adverse health risks of drinking unsafe water and more likely to take averting actions with the intention of avoiding such health impacts. The study also finds that high TDS level of the drinking water sources is one of the significant determinants of averting actions. Moreover, study also finds that women also are more likely to take averting measures compare to men. Furthermore, those who have the perception that the current water quality is not at an acceptable level have a higher propensity to take averting actions (the study ranked the excellent water quality as 1 and the very bad quality as 5). However, the perception variable is significant only at 10% confidence level. The results also suggest that household households which have been subject to any water related health impacts also tend to practice averting measures.

The study also examines the determinants of the water related health impacts in the area (Table 6.2). Non-communicable health impacts prevailing in the area such as dental fluorosis, skeletal fluorosis and the chronic kidney diseases are the only health issues considered. The results of the bivariate probit model tested suggests that the number of family members in the household, low education level and absence of attending community level programs have higher tendency for getting water related health impacts. A highly significant positive coefficient of the fluoride variable indicates that the effects of fluoride level on health impacts. The negative and significant coefficient of the water source (coded piped-1 and 0 otherwise) variable shows that there is a higher probability of getting health impacts for those who depends on non-piped sources. The coefficient of the "Rho" in the bivariate probit model is highly significant and which confirms that there is a strong relationship between the averting actions and the health impacts prevailing in the area

[2] Here only show the result of the bivariate probit model. Study also estimated the separate univariate probit models to identify the determinants of the averting actions and health impacts. Both estimations show relatively similar coefficients.

Determinants of Averting Expenditures

This study employs the separate Tobit models (also called as censored regression model) for piped and non-piped water users to estimate the relationship between averting expenditure and socioeconomic characteristics. Tobit model allows an examination of the relationship between the non-negative dependent variable (in this case total averting expenditures of each household) and the relevant explanatory variables; socio-economic variables and water quality parameters. As there are zero values for those who are not practicing any coping strategies, the study use the tobit model rather than using an OLS regression model to generate unbiased estimation. This study employs separate Tobit models for both connected and un-connected households to the piped network as the context for their averting actions are very different. (Table 5)

Table 5: Determinant of averting expenditures

Variables	Piped	Non-piped
Constant	**646.88(236.43)*** **	**-926.72(318.47)*** **
Members	-55.37(**26.38**)**	2.17(**33.20**)
Gender	-5.790((**69.66**)	-.30.89(**84.62**)
Age	0.487(**2.76**)	5.215(**3.22**)
Education	111.43(**54.72**)**	152.32(**61.14**)**
Income	0.004(**0.002**)**	0.003(**0.001**)*
Perception	-20.33(**37.41**)	52.754(**43.91**)
Participation	-38.81(**69.37**)	399.17(**84.67**)***
Fluoride	-48.04(**66.92**)	16.32(**69.091**)
TDS	0.374(**0.247**)	0.288(**0.323**)
N of observations	406	307
LLR	-3172	-1768

,**, refers to 10%, 5% and 1% significance level with two-tailed tests**

The model shows that education and income have positive effects on averting expenditures for piped water users while education and participation for community level awareness program also have positive effect on averting expenditure for non-piped users.

Conclusion

Access to quality and adequate water supply is a basic need to sustain human life. Health risk of unsafe drinking water is a serious issue in many developing countries and has become a central public policy issue. People in the study area take a number of coping strategies for water quality improvement and those measures create significant economic and social implications at household level. This study finds that the respondent's socio-economic characteristics significantly determine the choice of averting behaviours. The estimations show that both households connected to the piped water system as well as households depending on non-piped sources expend significant amount on practice averting behaviours hence implicitly reflect they are willing to pay substantial amount for water quality improvements. However, benefits derived from the households connected to the piped network are higher than the un-connected households. WTP estimates are much higher than the payments for existing piped schemes hence cost of clean and consistent water supply could be finance through a user payment scheme.

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