Households' willingness to pay for quality of drinking water in Jaffna area of Sri Lanka

Sooriyakumar Krishnapillai, Sumangkalai Perinpanathan and Sivashankar Sivakumar

ABSTRACT

Jaffna Peninsula of Sri Lanka depends on groundwater for drinking water. Supply of clean drinking water has become limited due to overuse of agrochemicals, widespread use of pit latrines, and seawater intrusion. The aim of this study is to estimate the willingness to pay for the attributes of water quality and supply. One hundred and twenty households were randomly selected in the study area. A choice modeling approach was employed. The result indicates that, on average, households' willingness to pay for the improvement of water quality is three times higher than their monthly payment. Households are willing to pay more for reduction in calcium than for reduction in nitrate and improvement of other attributes. The education level of households influences willingness to pay for the improvement of water quality more than the income level of households. There is high potential to finance for the improvement of the water quality from the households. Water supply and drainage board can afford to supply the drinking water at the WHO standard and charge price on a volumetric basis. The findings of this study would be useful for policymakers to set the appropriate price and policy to develop a sustainable project.

Key words | choice modeling, conditional logit model, water quality, willingness to pay

Sooriyakumar Krishnapillai (corresponding author)
Sumangkalai Perinpanathan
Sivashankar Sivakumar
Department of Agricultural Economics,
University of Jaffna,
Kilinochchi,
Northern Sri Lanka
E-mail: *kzs0008@tigermail.auburn.edu*

HIGHLIGHTS

- The aim of this study is to estimate the willingness to pay for reduction in nitrate level and calcium level in piped water and the welfare effect of improved water supply.
- There is high potential to improve the water supply as households' willingness to pay for the improvement is much higher than their monthly payment.
- Households are willing to pay more for reduction in calcium than for reduction in nitrate and the improvement of other attributes.
- The education level of households influences willingness to pay for the improvement of water quality and supply more than the income level of households.
- The findings of this study would be useful to the policy makers to set the appropriate price and policy to develop a sustainable project and improve the welfare of the households.

doi: 10.2166/aqua.2020.031

INTRODUCTION

Access to safe drinking water has been one of the main concerns in developing countries over the past four decades (World Bank 2005). World leaders at the United Nations Millennium Summit in 2000 and at the Johannesburg Earth Summit in 2002 agreed to set a Millennium Development Goal to reduce the proportion of people without access to safe drinking water by half. In December 2003, the UN General Assembly recognized this and declared the period 2005–2015 to achieve this Millennium Development Goal. Consumption of clean water keeps us free of diseases and makes us live longer. Sri Lanka spends around LKR 20,000 million per year for provision of safe drinking water. Groundwater is an important source of potable water in Sri Lanka but groundwater is being polluted from modern intensive agriculture and the disposal of industrial and domestic wastes. Some aquifers in Sri Lanka are already contaminated by agrochemicals leached from intensive agriculture and by domestic wastes discharged via pit-latrines (Maheswaran & Mahalingam 1983; Nagarajah *et al.* 1988). Pollution of groundwater is receiving attention in Sri Lanka as nitrates from inorganic nitrogen fertilizers and human waste matter from septic tanks enter the groundwater. A research study has shown that nitrates in the groundwater tend to accumulate in the densely populated region of Sri Lanka. Nitrates that could be transformed as carcinogenic substances within the body cause esophageal cancer in Sri Lanka (Dissanayake 1988).

Nitrate contamination of groundwater in Jaffna Peninsula has been receiving attention from the early 1980s (Maheswaran & Mahalingam 1983). The high nitrate levels in the groundwater in the peninsula are most likely associated with the intensive cultivation in that region. In addition to the heavy application of inorganic fertilizers, farmers apply large amounts of animal waste, green manure, and crop residue. Nitrate-N concentrations in the groundwater in the intensively cultivated area ranged from 10 to 15 mg/L (Mikunthan & De Silva 2008). Nitrate is potentially hazardous when present at sufficiently high levels in drinking water. The WHO reported that high nitrate level was linked to methemoglobinemia (blue baby syndrome), especially in infants. However, there is a high risk of nitrate toxicity related to blue babies in the peninsula. Nitrate, which can be converted into carcinogenic substances such as nitrosamines within the body, cause the carcinogenesis of esophageal and stomach cancers (Dissanayake 1988). A study on the pathology of malignant tumors in Sri Lanka from 1973 to 1977 has confirmed that the occurrence of cancer is relatively higher in the Jaffna District than other districts in Sri Lanka. One of the reasons for esophagus cancer could be the higher levels of nitrate-N in groundwater (Panabokke 1984). Sivarajah (2003) reported that the high nitrate content in water could be associated with the high incidence of cancer of the gastrointestinal tract in the people of Jaffna. Gunalan *et al.* (2011) in their study in the Chunnakam aquifer area concluded that there is a high risk of cancer due to the consumption of well water with nitrate-N concentrations higher than the recommended level by the WHO. Therefore, an awareness program should be conducted on the effects of the overuse of inorganic fertilizers on the quality of groundwater. Calcium in the groundwater is derived from limestone and dolomite. The higher levels of calcium are observed near the coastal regions. Sivarajah (2003) reported that high amounts of calcium and phosphate in drinking water are linked to stone formation in the bladder. In addition to this, calcium precipitates within plumbing and clogs pipes.

Jaffna Peninsula in Sri Lanka depends on groundwater for domestic consumption and irrigation purposes. Jaffna Peninsula has limited surface water sources because of its nature and flat terrain (Meisler 1977; Dissanayake & Senaratne 1981; Senaratne & Dissanayake 1982; Wijesekera *et al.* 2012; Hidayathulla & Karunaratna 2013). All the shallow groundwater found in the cavities originated from infiltration of rainfall. The shallow groundwater forms lenses floating over saline water (Panabokke & Perera 2005). The monsoon rain is the only recharge component of the groundwater. The major factor that has contributed to increased salinity in the well water has been the over-extraction of water from the underground aquifers. The large amount of withdrawals from wells lowered the fresh water heads in the underground aquifers and led to salt water intrusions in several areas in the peninsula

(Nanadakumar 1983). Around 80% of this groundwater is used for agriculture purposes and the remaining 20% is used for domestic use in Jaffna Peninsula. Several studies in water quality have shown higher levels of nitrates in domestic wells situated in municipal areas of the peninsula (Nagarajah *et al.* 1988). The supply of clean drinking water in Jaffna peninsula has become limited due to overuse of agrochemicals, widespread use of pit latrines, and seawater intrusion. The groundwater is easily contaminated with pollutants as the sandy soil layer is very thin in some parts of Jaffna Peninsula. The persistence of these pollutants in aquifers is many times greater than in soils (Lawrence & Foster 1987). Therefore, there is an urgent need to supply drinking water for all the households in Jaffna Peninsula.

Shahzad *et al.* (2019), in their study, concluded that for a sustainable and satisfactory level of water supply, the water industry needs to develop values and a system wherein key performance indicators are used to define targets, develop action plans, and track improvements. Mohammed & Abdulrazzaq (2018) developed a Water Quality Index (WQI) tool to assess the water quality of the Euphrates River as a drinking water source and to classify the quality of the river's water considering eight water quality parameters, such as ion hydrogen concentration (pH), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^{+1}), chloride (Cl^{-1}), sulfate (SO_4^{2-}), nitrate (NO_3^-), and total dissolved solids (TDS). For a sustainable policy, the opinion of all stakeholders should be considered. Consumers are encouraged to participate in determining a water tariff as they are the major stakeholders. Different factors, such as household's water demand, income, education, preference, satisfaction, and available resources should be considered while designing a reasonable water tariff. Volumetric pricing is an appropriate approach for sustainable management of water resources. Due to non-volumetric pricing, a great deal of water is being wasted in the distribution system. It is observed that the price of water charged to consumers for piped water is somewhat less than that of water supplied by tankers (Imad *et al.* 2019). Economic analysis and econometrics application studies have been employed to find out an appropriate water tariff (Chicoine & Ramamurthy 1986).

Many researchers state that for a water supply project to be sustainable consumers should be willing to pay user charges that are sufficient enough to cover all operating costs and capital consumption. Willingness to pay (WTP) is interpreted as an indication of the demand for improved services and their potential sustainability (Kaliba *et al.* 2003). Our primary aim is to estimate the willingness to pay for reduction in nitrate level and calcium level and improvement of water supply and taste and the welfare effect of good quality water supply in Jaffna Divisional Secretariat area. Figure 1 shows the map of Jaffna Divisional Secretariat area of Jaffna District.

METHODOLOGY

Non-market valuation method can be used to assess the value of goods and services that are not bought or sold in a market. Valuation of water quality improvements can use either market or non-market valuation techniques. Contingent valuation method (CVM) is used to estimate the values people place on changes in a natural resource (Koteen *et al.* 2002). The CVM creates a hypothetical market to elicit value people place on environmental or public goods in terms of WTP. It directly asks people how much they would be willing to pay for a benefit. The CVM is mostly used to estimate the nonuse value of the environment including existence, bequest, and option value through directly asking respondents on WTP for environmental attributes in a hypothetical market (Mitchell & Carson 1989; Haab & McConnell 2003).

Contingent valuation is a simple direct survey approach to estimate a consumer's willingness to pay for a good or services which can be traded in a hypothetical market. An appropriately designed survey questionnaire describes the contingent market which defines the good itself and the way it would be financed. Respondents are asked to express their maximum WTP for a hypothetical change in the level of provision of good. An increasing number of empirical studies started to reveal that this contingent valuation approach is not ideally suited for multidimensional changes in the level of attributes of a good. Valuation practitioners have developed alternative stated preference formats such as choice modeling (CM). CM is a survey-based methodology to estimate a consumer's WTP for a good which is described in terms of levels of its attributes. CM approach has some advantages relative to the contingent valuation

Figure 1 | Map of Jaffna Divisional Secretariat Area of Jaffna District.

(CV) method. CM is the most appropriate approach to estimate consumer's WTP when changes in the attributes of a good are multidimensional. As the CM approach has the ability to separately value the individual attributes of a good, the trade-offs between attributes can be easily estimated. CM approach can measure marginal value of changes in various attributes of a good more precisely than the CV approach. As CM provides multiple choices to express respondents' preference for a valued good over a range of payment amounts, it is more informative than CV studies. As CM includes cost as one of the attributes of the good, WTP can be indirectly recovered from people's choices.

Choice modeling assumes that individuals act rationally and select a choice that yields the highest utility from a choice set. Therefore, the probability of selecting a given choice is higher if the choice yields the highest utility among the different choices. Instead of asking about one proposed situation as in a CVM questionnaire, CM respondents are asked many times to select a choice from different proposed situations (choice sets). The CM method is a variant of conjoint analysis, which was initially developed by Louviere & Hensher (1982) and Louviere & Woodworth (1983). This CM approach has its roots in Lancaster's characteristics theory of value, in random utility theory, and in experimental design (Hanley *et al.* 1998). Lancaster's theory (Lancaster 1966) states that consumer decisions are determined by the utility derived from the attributes of a good or service.

CM method is a stated preference method used to estimate the non-market values of a good or service (Adamowicz *et al.* 1998; Hanley *et al.* 2001). The main advantage of CM is that it considers the environmental good or service as a set of attributes with different levels. It can estimate not only the value of a particular good but also the relative value of attributes of a good or service (Hanley *et al.* 1998). This method induces people to reveal their WTP for the provision of a non-market good such as environmental quality (Ribaudo & Hellerstein 1992). With information provided by the respondents, a change in welfare can be estimated for a change in water quality. The aggregate WTP can serve as an estimate of benefits to consumers from improvements in drinking water quality (Jordan & Elnagheeb 1993). CM was thus selected to estimate the benefit from improved water supply services because these services can actually be described as a bundle of attributes related to both water quality and water availability characteristics. The CM method is consistent with utility maximization and demand theory (Hanemann 1984). If a cost attribute is included in the choice set, welfare estimates for improvements in the water supply services can be derived.

Our primary aim is to estimate the WTP for reduction in nitrate level and calcium level and improvement of water supply and taste and the welfare effect of good quality water supply. Hence, we employ choice modeling that is one of the stated preference techniques. Choice modeling was formulated in a random utility framework that permits measurement of the values of non-market goods and services. Random utility theory (RUT) underpins the choice models used in a wide array of academic and practical situations to model choice processes (McFadden 1974; Ben-Akiva & Lerman 1985; McFadden 2001).

The utility function (U) is a function of an observable component (indirect utility function) and an unobservable error component:

$$U = V + \varepsilon \tag{1}$$

where V is the indirect utility function and ε is the stochastic error term. We assume that the indirect utility is a linear form:

$$\begin{aligned} V_i &= \beta_i X_{ki} + \alpha m \\ &= \beta_1 + \beta_2 x_{2i} + \beta_3 x_{3i} + \ldots . + \beta_k x_{ki} + \alpha_i m_i \end{aligned} \tag{2}$$

where ($X_{ki} = \{x_{1,2}, \ldots, x_k\}$) is a vector of k attributes associated with alternative i, β is a coefficient vector, m_i is income for a respondent choosing the alternative i bundle, and α is the coefficient vector of income. If the stochastic error term is logistically Gumbel distributed (Type I extreme value distributed), the choice probability for alternative i is given by:

$$\Pr(i) = \frac{\exp(\rho V_i)}{\sum_{j \in C}^{J} \exp(\rho V_i)} \tag{3}$$

where ρ is a positive scale parameter and C is is the choice set for an individual. For convenience we generally make the assumption $\rho = 1$. To estimate willingness to pay for a change from the status quo state to the chosen state, the following formula is used:

$$V_i(X_i, y) + \varepsilon_i = V_j(X_j, m - CV) + \varepsilon_j \tag{4}$$

where V_i and V_j represent utility before and after the change and CV is compensating variation, the amount of money that makes the respondent indifferent between the status quo and the proposed scenario. Conditional logit model can be applied to estimate the welfare measure in Equation (4). Equation (4) can be restated as:

$$\beta_i X_{ki} + \alpha_i m + \varepsilon_i = \beta_j X_{kj} + \alpha_j (m - CV) + \varepsilon_j \tag{5}$$

α_i and α_j are assumed to be equal if marginal utility of income for a respondent is constant. The welfare change is estimated by:

$$CV = -\frac{1}{\alpha}[(\beta_i(X_{ki} - X_{kj}) + (\varepsilon_i - \varepsilon_j)] \tag{6}$$

In conditional logit model, coefficient of k attributes across all alternatives are the same, and $\beta_i = \beta_j$; only the attribute levels differ across the alternatives, Under this condition, welfare change is estimated by the following:

$$CV = -\frac{1}{\alpha}[(\beta(X_{ki} - X_{kj}) + (\varepsilon_i - \varepsilon_j)] \tag{7}$$

Equation (7) is used to estimate welfare changes, assuming the impact of the attributes of drinking water quality.

The attributes of water quality and water supply services in this study were nitrate level, calcium level, taste and water supply services. Each attribute has several discrete levels of delivery. For nitrate level, there were two levels presented to respondents: reduction in nitrate level (*NL*) and no change in current *NL*. The attribute of calcium level is limited to two levels: reduction in calcium level (*CL*) and no change in *CL*. The third attribute, taste, is limited to two levels: improving taste and no change. The fourth attribute, water supply service, has two levels: increasing the frequency of water supply (*FWS*) and no change. Definitions of selected attributes are presented in Table 1. The choice modeling

Table 1 | Description of attributes and levels

Attributes	Levels	Definitions
Nitrate level (*NL*)	Reduction of nitrate level	Decrease the nitrate amount to minimum consumption level
	No change	Maintain current nitrate amount in water
Calcium level (*CL*)	Reduction of calcium amount	Decrease the calcium amount to minimum consumption level
	No change	Maintain current calcium amount
Water supply (*FWS*)	Increase the frequency of water supply	Providing enough water for the maximum utilization
	No change	Maintain water supply at current level
Taste (*TS*)	Increase the taste	Increase the water taste for human consumption
	No change	Maintain current taste of water
Cost	60:90:120:140	Monthly cost for water

surveys contain multiple choice sets about water quality and supply services. In the surveys, before the choice set questions, respondents were briefed about the four attributes and associated cost to the household. The cost to the household is the monthly payment to the water supply and drainage board. The discrete range of cost alternatives given to respondents was LKR 60, LKR 90, LKR 120, and LKR 140. As there are two levels in the attribute of *NL*, two levels in the attribute of *CL*, two levels in taste, two levels in frequency of water supply and four levels in the cost to household, there are $2^4 \times 4$ factorial designs. Thus, 64 orthogonal choice combinations are possible but it is impossible to include all the choices into the questionnaire and impossible to ask the respondents to select the choice among the choice sets, hence we reduced the number of choices to half. For statistically efficient choice designs, a D-efficient design excluding unrealistic cases was adapted to each of the choice questions. Here, we assume, interaction effects between attributes are insignificant. Among 32 choices, 21 choices were selected after 11 unrealistic options were excluded.

In the choice questions, respondents were asked to select an option (choice) they favoured the most out of the three alternatives provided. Each option contains the four attributes and the cost to the household with various levels of attribute combinations. The cost to the household in option A was designed higher than in option B, and option C was set as the status quo across (no change) all choice sets. Therefore, 10 choice sets were formulated from 21 choices including option C. A pilot study with randomly selected households was conducted to prepare the final draft of the questionnaire for this survey. A sample of choice sets is shown in the Appendix. For this study, 120 households from a total of 1,688 families in all the G.S Division of Jaffna Divisional Secretariate were randomly selected. Data were gathered from personal interviews with randomly selected households using a structured questionnaire. The questionnaire include household's demographic and social characteristics such as age, education, income, number of people in household, number of children, water quality, water supply services, and health status of the household. The attributes, levels, payment of cost, the benefits of quality drinking water are briefly introduced to the respondents during the survey. After being given brief information, the respondents were asked to select the most preferred alternative among the choice sets. Conditional logit model was estimated for the selection of choices. Definitions of the effect codes for attributes and variable description are presented in Tables 2 and 3,

Table 2 | Effect codes: choice modeling

Attributes	Variables
Nitrate level	1 if reduction in nitrate amount, −1 if no change
Calcium level	1 if reduction in calcium amount, −1 if no change
Water supply	1 if increase frequency of water supply, −1 if no change
Taste	1 if increase the taste, −1 if no change

Table 3 | Variable description

Variables	Description	Unit
EDU 1	Education 1	1, if household head education ≤11th grade, otherwise 0
INCO 1	Income 1	1, if household income ≤30,000 LKR, otherwise 0

respectively. Household education and income was categorized into two groups.

RESULTS AND DISCUSSION

The descriptive statistics of Jaffna Divisional Secretary Area are given in Table 4. The result indicates that the average age of respondent, education level, and monthly income was 50 years, 10 years, and 25,000 LKR, respectively. Three conditional logit models were developed using effective codes for four water attributes. Results of three conditional logit models are presented in Table 5. As a simple model, model 1 includes no social characteristics and is estimated as a simple pooled model. All variables except reduction in *NL* are significant at 1% level. The negative coefficient of cost indicates that households are likely to accept the option with lower cost to them. Dummy values for educational groups were included in model 2 as interaction terms with each water attribute. The interaction terms of water attributes with educational and income groups were included in model 3.

The coefficients of reduction in *NL* and *CL* and increase in the frequency of water supply (WS) are positive and significant at 1% level in model 2 and model 3. Taste is positive and significant at 1% level in model 2 and 10% level in model 3, respectively. This indicates that households with above 11th grade education and monthly income above 30,000 LKR are averagely willing to pay more for reduction in calcium level, reduction in *NL*, and increase in the frequency of water supply than households with lower education and income level. The interaction terms of reduction of *CL* and *NL* with lower level of education are negative and significant at 5% level. This result indicates that households with lower education level are willing to pay less for reduction in calcium and nitrate level than households with higher education level. The interaction term of reduction in *NL* with lower income is negative and significant at 5% level.

Table 5 | Conditional logit models

Variable	Model 1	Model 2	Model 3
NL	0.0362	0.1990***	0.3641***
CL	0.4210***	0.5834***	0.5454***
WS	0.1930***	0.2059***	0.2663***
TS	0.2048***	0.2105***	0.1613*
Cost	−0.0079***	−0.0079***	−0.0080***
*NL*EDU1*		−0.2383***	−0.2597***
*CL*EDU1*		−0.2363***	−0.2316***
*WS*EDU1*		−0.0135	−0.0205
*TS*EDU1*		−0.0065	−0.0004
*NL*INCO1*			−0.2093**
*CL*INCO1*			0.0505
*WS*INCO1*			−0.0767
*TS*INCO1*			0.0639

***, **, *, significant at 1, 5, and 10% respectively.

This implies that households with lower income level are averagely willing to pay less for nitrate reduction than households with higher income level.

The interaction of reduction in *CL* with income level is not significant at 5% level. This shows that, on average, there is no difference in WTP to reduce *CL* in the drinking water among households with different income level while other things are equal. As all households in this study area know there is a higher level of calcium in the tap water and also they observe calcium deposits in kitchen utensils while boiling water, all households would like to pay to reduce *CL* in the drinking water. The higher magnitude of coefficient of reduction in *CL* among the attributes of the tap water shows that households give higher priority to reduce *CL* than the improvement of other attributes of tap water.

Even if higher *NL* in the drinking water causes serious health effects to humans than calcium in drinking water, households give less priority to the reduction in *NL* than reduction in *CL*. This might be due to their lower education

Table 4 | Descriptive statistics of socioeconomic and demographic variables

Variable	Observation	Mean	Standard	Minimum	Maximum
Age (years)	2,520	50.24	12.27	29	83
Education (years)	2,520	10.58	1.48	5	12
Income (LKR)	2,520	24,909	15,744	2,500	80,000

level and also they could not observe the effect of nitrogen immediately. The interaction terms of frequency of water supply and taste with education and income are not significant at 5% level. Since most of the households collect enough drinking water for the needs of a day from a tap installed in a common place near to their home at one time, the interaction terms of frequency of water supply with income and education level are not significant at 5% level.

Mean welfare values from the improvement of each attribute of water quality except taste attribute and supply for different household groups were estimated by using Equation (7) and the estimated mean WTP for each attribute is presented in Table 6. Since taste attribute is not significant at 5% level in model 3, WTP for it is not estimated. It shows that households with above 11th grade education and income above 30,000 LKR are willing to pay more (296 LKR) for reduction in *NL*, reduction in *CL*, and increase the frequency of water supply than other household groups with either lower income or lower education level. All households are, on average, willing to pay more for reduction in *CL* than for the improvement of other attributes. Households with education below 11th grade and income below 30,000 LKR are willing to pay the lowest amount (120 LKR) for the improvement of water quality and supply among all the household groups and also they are not willing to pay for reduction in *NL* as indicated by negative WTP. As shown in Table 6, among the randomly selected households, percentage of households with income more than 30,000 LKR and higher than 11th education level, with income more than 30,000 LKR and lower than 11th grade education, with less than 30,000 LKR and higher than 11th grade education, and with less than 30,000 LKR and lower than 11th grade education is 6%, 20, 27, and 47%, respectively. Therefore, it can be expected that average WTP from households in this study area for the improvement of water quality and supply is around 174 LKR (USD 1) per month as user charge. As there are a total of 1,688 families in Jaffna Divisional Secretariat area, the total WTP from households per month for the improvement of water supply is around 293,712 LKR (USD 170). As shown in Table 6, education level of households influences WTP for the improvement of water quality and supply more than the income level of households. Even if *NL* in drinking water causes serious effects to humans, they are willing to pay less for reduction in *NL* than reduction in *CL*. The result of this study shows that there is high potential to improve the water quality and supply as all households' WTP for the improvement is much higher than their monthly payment of 60 LKR (USD 0.33) for water from a common tap. Since most of the places in the study area are coastal areas, groundwater from households' own well is saline. As the study is densely populated and there is no common sewage system, groundwater is polluted with *Escherichia coli* bacteria and nitrate. Therefore, they use this well water for washing and bathing but not for drinking. Household's WTP for the improvement of water supply in this study area is three times higher than the current monthly payment. Therefore, there is high potential to finance the improvement of the water quality and supply from the residents of this area. The water supply and drainage board can find good quality water sources with less nitrate and calcium concentration in Jaffna Peninsula and purify the water to the WHO standard. This good quality drinking water could be efficiently utilized if the authority provides a supply to homes and charges the price for the water on a volumetric basis.

Table 6 | Mean willingness to pay for improved water quality and supply

	Willingness to pay (LKR)			
Attributes	Edu $\geq$ 11th grade Inc $\geq$ 30,000 LKR	Edu $\leq$ 11th grade Inc $\geq$ 30,000 LKR	Edu $\geq$ 11th grade Inc $\leq$ 30,000 LKR	Edu $\leq$ 11th grade Inc $\leq$ 30,000 LKR
NL	92	26	39	−26
CL	137	79	137	79
FWS	67	67	67	67
Total willingness to pay (LKR)	296	172	243	120
Percentage of households	6	20	27	47

Average WTP = 174 LKR.

CONCLUSION

This study concludes that there is high potential to improve the water quality and supply as all households' WTP for the improvement is much higher than their monthly payment

(60 LKR) for water from the common tap. All households are, on average, willing to pay more for reduction in *CL* than for the improvement of other attributes. The education level of households influences WTP for the improvement of water quality and supply more than the income level of households. Even if *NL* in drinking water causes serious effects to humans, they are willing to pay less for reduction in *NL* than reduction in *CL*. The groundwater from households' own well is saline and polluted with *E. coli* bacteria. Households willing to pay for the improvement of water supply is three times higher than the current monthly payment. Therefore, there is high potential to finance the improvement of the water quality and supply from the residents of this area. The water supply and drainage board can afford to supply the drinking water at the WHO standard to households and charge price on a volumetric basis. The government health department should conduct an awareness program for the households in this study area regarding the serious health effects of nitrate in drinking water. The findings of this study would be useful for policymakers to set the appropriate price and develop a sustainable project to improve the water quality and supply from the common tap in this study area.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

REFERENCES

Adamowicz, W., Boxall, P., Williams, M. & Louviere, J. 1998 Stated preference approaches for measuring passive use values: choice experiment and contingent valuation. *American Journal of Agricultural Economics* **80**, 64–75.

Ben-Akiva, M. & Lerman, S. 1985 *Discrete Choice Analysis*. MIT, Cambridge, MA, USA.

Chicoine, D. L. & Ramamurthy, G. 1986 Evidence on the specification of price in the study of domestic water demand. *Land Economics* **62**, 26–32.

Dissanayake, C. B. 1988 Nitrates in the groundwater in Sri Lanka – implications for community health. *Journal of Geological Society of Sri Lanka* **1**, 80–84.

Dissanayake, C. B. & Senaratne, A. 1981 Paleogeographic reconstruction of Jaffna peninsula. *Journal of the Geologic Society of India* **23**, 369–377.

Gunalan, K., Asanthi, H. B., Gamage, T. P. D., Thushyanthy, M., Saravanan, S. & Jayakumaran, N. 2011 In: *Incidence of Oesophageal and Stomach Cancer Related to Nitrate-N Concentration in Groundwater in Jaffna Peninsula. The Water Resources Research in Sri Lanka* (N. D. K. Dayawansa & R. P. De Silva eds). Symposium Proceeding of the Water Professionals' Day, Peradeniya, Sri Lanka, pp. 91–103.

Haab, T. C. & McConnell, K. E. 2003 *Valuing Environmental and Natural Resources. The Econometrics of Non-Market Valuation*. Edward Elgar, Cheltenham, UK.

Hanemann, W. M. 1984 Welfare evaluations in contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics* **66** (3), 332–341.

Hanley, N., Wright, R. E. & Adamowicz, W. 1998 Using choice experiments to value the environment. Design issues, current experience and future prospects. *Environmental and Resource Economics* **11** (3–4), 413–428.

Hanley, N., Mourato, A. & Wright, R. 2001 Choice modeling approaches: a superior alternative for environmental evaluation? *Journal of Economic Surveys* **15** (3), 435–462.

Hidayathulla, M. S. M. & Karunaratna, G. R. R. 2013 Assessment of groundwater quality in shallow aquifers in Jaffna Peninsula. In: *Proceedings of the 29th Technical Sessions of Geological Society of Sri Lanka*, pp. 109–113.

Imad, H. U., Akhund, M., Ali, M., Pathan, A. A. & Ahmed, A. 2019 Non-volumetric pricing is a threat to water reserves. *Civil Engineering Journal* **5** (2), 422–428.

Jordan, J. L. & Elnagheeb, A. H. 1993 Willingness to pay for improvements in drinking water quality. *Water Resources Research* **29** (2), 237–245.

Kaliba, A., Norman, D. & Chang, Y. 2003 Willingness to pay to improve domestic water supply in rural areas of central Tanzania: implications for policy. *International Journal of Sustainable Development and World Ecology* **10** (2), 119–132.

Koteen, J., Alexander, S. J. & Loomis, J. B. 2002 *Evaluating benefits and costs of changes in water quality*. Gen. Tech. Rep. PNW-GTR-548. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR, USA, 32.

Lancaster, K. J. 1966 A new approach to consumer theory. *Journal of Political Economy* **74**, 132–157.

Lawrence, A. R. & Foster, S. S. D. 1987 *The Pollution Threat From Agricultural Pesticides and Industrial Solvents*. Hydrogeological Report 87/2, British Geological Survey, Keyworth, UK, p. 30.

Louviere, J. & Hensher, D. A. 1982 On the design and analysis of simulated choice or allocation experiments in travel choice modelling. *Transportation Research Record* **890**, 11–17.

Louviere, J. & Woodworth, G. 1983 Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data. *Journal of Marketing Research* **20**, 350–367.

Maheswaran, R. & Mahalingam, S. 1983 Nitrate – nitrogen content of well water and soil from selected areas in the Jaffna Peninsula. *Journal of National Science Council, Sri Lanka* **2** (1), 269–275.

McFadden, D. 1974 Conditional logit analysis of qualitative choice behavior. In: *Frontiers in Econometrics* (P. Zarembka ed.). Academic Press, New York, USA.

McFadden, D. 2001 Economic choices. *American Economic Review* **91** (3), 351–378.

Meisler, H. 1977 *Summary of Ground-Water Conditions in the Jaffna Peninsula, Republic of Sri Lanka, with A Plan for Investigating Feasibility of Ground-Water Development USGS Open-File Report: 77–558, 47*. US Geological Survey, Reston, VA, USA.

Mikunthan, T. & De Silva, C. S. 2008 In: *Nitrate Pollution in Groundwater: A Case Study in Thirunelvely and Kondavil in Jaffna District. The Water Resources Research in Sri Lanka* (N. D. K. Dayawansa & R. J. De Silva eds). Symposium Proceedings of the Water Professionals' Day, Peradeniya, Sri Lanka, pp. 27–37.

Mitchell, R. C. & Carson, R. T. 1989 Using surveys to value public goods: the contingent valuation method. *Natural Resources Journal* **29**, 900–902.

Mohammed, S. I. & Abdulrazzaq, K. A. 2018 Developing water quality index to assess the quality of the drinking water. *Civil Engineering Journal* **4** (10), 2345–2355.

Nanadakumar, V. 1983 Natural environment and ground water in the Jaffna Peninsula, Sri Lanka. *Climatological Notes* **33**, 155–164.

Nagarajah, S., Emerson, B. N., Abeykoon, V. & Yogalingam, S. 1988 Water supplies of some wells in Jaffna and Kilinochchi with special reference to nitrate pollution. *Tropical Agriculture* **144**, 61–78.

Panabokke, R. G. 1984 The geographical pathology of malignant tumours in Sri Lanka–a 5 year study. *Ceylon Medical Journal* **29** (4), 209–224.

Panabokke, C. R. & Perera, A. P. G. R. L. 2005 *Groundwater Conditions in the Coastal Regions of the dry Zone of Sri Lanka*. Administrative Report Water Resources Board, p. 28.

Ribaudo, M. O. & Hellerstein, D. 1992 *Estimating Water Quality Benefits: Theoretical and Methodological Issues*. Technical Bulletin 1808. U.S. Department of Agriculture, Economic Research Service, Resources and Technology Division, Washington, DC, USA, p. 36.

Senaratne, A. & Dissanayake, C. B. 1982 Palaeogeographic reconstruction of Jaffna Peninsula, Sri Lanka. *Journal of the Geological Society of India* **23**, 545–550.

Shahzad, G., Rehan, R. & Fahim, M. 2019 Rapid performance evaluation of water supply services for strategic planning. *Civil Engineering Journal* **5** (5), 1197–1204.

Sivarajah, N. 2003 Health related problems of water pollution in Jaffna. Faculty of Medicine, University of Jaffna, Sri Lanka. Available from: http://repo.jfn.ac.lk/med/handle/701/882 (accessed 22 March 2020).

Wijesekera, J., Senaratne, A. & Gunatilake, A. A. J. K. 2012 Land gain in northern Sri Lanka. In *Proceedings of AutoCarto 2012*, September 16–18, Columbus, OH, USA.

World Bank. 2005 *Capacity Building in Africa*. World Bank Operations Evaluation Department, Washington, DC, USA.

First received 29 March 2020; accepted in revised form 9 July 2020. Available online 27 August 2020