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Impact of Different Tariff Structures on Residential Water Demand: A Case Study from Kandy, Sri Lanka

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ABSTRACT. *In this study, first the differences of two tariff structures imposed by National Water Supply and Drainage Board (NWSSDB) and Kandy Municipal Council (KMC) were compared, and the factors affecting residential water demand in Kandy city was investigated using primary data collected from a field survey. Then the impact of alternative tariff structures on water demand of consumers in different income categories was simulated using existing demand elasticities. It was found that the tariff structure imposed on NWSDB consumers was more aggressive than that of KMC. Therefore, as water was more subsidized, water consumption was skewed towards higher blocks for KMC consumers. The relatively low expenditure on water by KMC consumers encouraged them to use piped-water for washing vehicles, washing machines, flushing toilets, and home gardening. The impact of income was found to be more prominent in households using NWSDB water than those consuming KMC water. The simulation results revealed that no substantial changes in residential water demand can be expected due to any of the policy shocks used by the two institutions. This was due to the fact that the household water bill is only a small fraction of income and the water demand is income inelastic. Also, there is a heavy subsidy given to low income groups, who constitute the vast majority of users. Although the degree of subsidy reduces with increased income, consumers in high-income groups also enjoy these benefits, especially with the KMC water. The findings of the study indicate that there is great potential to increase the price of higher blocks which target high income groups. This will have the twin effect of saving water and increasing the revenue of the water supply authorities.*

INTRODUCTION

With the commitment to target 7C of the Millennium Development Goals, by 2015, the government of Sri Lanka is planning to provide clean drinking water and safe sanitation to 86% and 93% of the population respectively. The National Water Supply and Drainage Board (NWSDB), the main service provider of water supply and sanitation, has also set its own target to provide safe drinking water to 85% of the whole population by 2010 and to

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100% by 2020. Though the country has achieved 79% coverage of improved water supply according to the UNDP (UNDP, 2004), there are persisting inequalities between rural and urban areas, and a majority of the people without access to improved water supply continue to live in rural areas.

Kandy, a world heritage city in Sri Lanka, suffers from a serious problem of wastewater disposal which eventually contributes to the pollution of Mahaweli river. The city has a population of around 160,000 people with a water consumption of about 25,000 cubic meters per day. Since there is no proper system of wastewater disposal, about 80% of used water is released as wastewater, polluting Kandy Lake, *Meda Ela* and eventually the Mahaweli river. Due to the inefficiencies in the sewage disposal systems within the city, sewage also contributes significantly to the pollution of the Mahaweli river (NRMS, 2005). To remedy this problem, the NWSDB has proposed a Sewage Treatment Plant (STP) for the Kandy municipality. The aim of the project is to collect sewage in the city and surrounding areas through a system of lateral pipes connected to a main pump and treat them before disposal (EIA Report, 2005). The project expects to reduce the pollution of Mahaweli river and to maintain a sustainable drinking water service to the city. The NWSDB and Kandy Municipal Council (KMC) are planning to charge for the sewage service through increased water tariffs.

According to the secondary data available on costs of production, the operation and maintenance (O&M) cost of water vary from Rs. 0.50 to 100.00 per m^3 depending on the amount of chemical treatment needed to bring the quality of water to FAO standards. At present, full treatment is needed for the bulk of the drinking water supply and the O&M cost per cubic meter of water ranges between Rs. 35.00 and 40.00 (revised price after tariff hike in electricity)[3] in the Kandy municipal area. However, for any consumer, the average price for the first 15 m^3 is Rs. 1.85 (see appendix Table 1) and on average, people consume around 30-40 m^3 per month indicating that the domestic water sector in Sri Lanka is highly subsidized. Thus, even without the proposed STP, the NWSDB will have to increase its revenue to be financially viable and to maintain a sustainable service. However, increasing water tariffs may cause the reduction of water consumption so that the expected revenue generation may not be achieved. On the other hand, since water has been declared by the World Water Forum in 2004 as a human right, the price should be affordable to the poor as well. Thus, formulating an appropriate tariff system is very crucial.

An appropriate tariff system should ensure sufficient revenue to deliver a sustainable service, support society's interest in improving the quality of service, deliver the funds to extend service coverage, particularly to serve low-income consumers (subsidy) and ensure better use of scarce resources by signaling to consumers the cost of the resource used. Choice of suitable design parameters for a tariff scheme needs to be supported by appropriate empirical analysis to simulate the impact of alternative types of tariff schemes on the target population. This is important in order to guarantee that the tariff system meets the intended objectives. How households respond to increasing tariffs depend on the individuals' demand functions or demand for residential water by households. Therefore, it is essential to simulate different tariff scenarios with an appropriate demand function in order to select the appropriate tariff structure.

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Though there is much literature on demand estimation of water where different variables, functional forms and econometric techniques have been tested (Arbues *et al*., 2003), there are no studies that have looked into the impact of alternative tariff structures on revenue generation and equity issues. Therefore, this study aims to determine an appropriate tariff system which generates the revenue to recover O&M cost to the service provider and also addresses the equity issues by simulating different tariff schemes using an appropriate demand function for the Kandy municipality in Sri Lanka. However, as stated earlier, there are two water suppliers in the Kandy municipality with two different tariff structures.

Against this background, it is expected to accomplish two objectives from this study. One is to compare the differences of tariff structures imposed by these water supplying agencies and to identify the factors affecting the residential water demand. The other is to examine the impacts of alternative tariff scheme on water demand of consumers of different income categories. .

Water tariff systems

A tariff structure is a set of behavioral rules used to determine the conditions of service and monthly bills for water users in various categories or classes (Singh *et al*., 2005). OECD (1999) shows that designing tariffs is always complex and pricing is aimed at pursuing not only greater allocative efficiency but also objectives of equity, pubic health, environmental efficiency, financial sustainability, simplicity and transparency. Mehrotra and Kumar (1996) showed that water tariffs should be designed after taking all the policy scenarios—whether only O&M costs are to be recovered or debt and interest also have to be recovered—into account. According to them, there are five major objectives in a municipal water tariff system: cost recovery, economic efficiency, equity, affordability and simplicity. Revenue through tariffs ensures that cost recovery equals financial cost of supply. It requires that prices signal to the consumers the financial, environmental and other costs that their decisions to use water impose on the rest of the system and on the economy. Equity, on the other hand, means that water tariff discriminates between consumers relative to their economic capability. Thus, the prices for the poor should be affordable. Finally, a tariff design should be very simple and easy to understand (Singh *et al*. (2005).

In Sri Lanka, domestic water supply is charged according to a two-part tariff system where there is a fixed rate of Rs.50 per month and increasing block rate for the variable part. There are two suppliers of water in Kandy municipal area, the NWSDB and KMC. Even though both suppliers follow the two-part tariff system with the same fixed rate and an increasing block rates, the block prices are different in the two suppliers (see Appendix Table 1 for the details of tariff structures). The NWSDB's tariff system is such that it starts with a very minimal block rate and increases very rapidly in the higher blocks. On the other hand, though KMC charges a higher rate for the initial blocks, the block rates do not increase steeply. The NWSDB consumers pay much higher rates than KMC consumers at higher blocks and therefore, the tariff structure of NWSDB can be understood as more aggressive than KMC.

The O&M costs increase with the increasing treatment cost associated with the level of water pollution (Appendix Table 2). At the highest treatment level where the NWSDB mostly operates, the O&M cost of supplying drinking water is Rs. 75-100/ m^3. The tariff structure shows that the water supply system is highly subsidized. Thus, there is a question of institutional sustainability.

Demand estimations, tariff settings and water revenue

Economists have been trying to understand the effects of different types of tariffs on the quantity of water demanded. They have established relationships through econometric modeling, which relates water consumption to some measure of price and other factors such as income, household type, and household composition. Even though, there is no general consensus on the methodology of analyzing water demand with regard to price variables and other explanatory variables, water demand in most cases is price inelastic since water has no substitute for basic uses and the water bill represents only a small portion of income (Chicoine and Ramamurthy, 1986; Arbués *et al*., 2000)

Arbués *et al*. (2003) provide a very comprehensive review of studies on the estimation of residential water demand. In their study, they reviewed more than 100 articles on demand estimations. Studies by Hansen (1996), Kulshreshtha (1996), Hoglund (1999) and Pint (1999) used marginal price (MP[4]) in domestic water demand estimations. Kulshreshtha (1996), Hoglund (1999) and Nauges and Thomas (2000) used average price instead. Taylor (1975) showed that studies that used marginal price did not capture the effect of changes in intra-marginal rates (in a block rate system) which do not correspond to the current level of consumption. Later, Nordin (1976) introduced the *difference variable*[5] *(DV*) which is supposed to represent the income effect imposed by the tariff structure. After this introduction, there were several studies using MP along with DV (Agthe and Billings, 1997; Dandy *et al*., 1997; Corral *et al*., 1998; Renwick and Archibald, 1998; Renwick and Green, 2000).

Theoretically, the DV should be equal in magnitude and opposite in sign to the income effect variable in linear models. This theoretical expectation has been tested, but with little success. According to Arbués *et al*. (2003) this can be due to various reasons i.e. lack of information about the tariff structure, and the water bill being just a small fraction of the household income (Nieswiadomy and Molina, 1989) and biased estimations in aggregate data due to incorrect estimation of effects of the intra-marginal changes on price (Schefter and David, 1985). Other explanatory variables that were used in demand estimation of water are income, household size, housing characteristics such as number of bathrooms, size of the garden etc., and indoor and outdoor uses (Arbues, 2003).

METHODOLOGY

Empirical model and data

Since there are two sources of residential water supply with different tariff systems for the Kandy city, it is essential to look at the behavioral differences of the consumers connected to the two tariff systems. A multiple regression was fitted using the quantity of water

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4 Marginal price is the last block price of an individual consumes at

5 Difference variable is the difference between the total bill and what the user would have paid if all units were charged at the marginal price.

consumed as the dependent variable and a set of explanatory variables as independent variables. The independent variables used were household income, household size, use of piped-water for luxury items (namely flushing toilets, washing machine and vehicles), availability of water sources other than piped-water, use of piped water in home gardening, awareness of the block pricing system and a dummy variable for the source of water (NWSDB = 1 and KMC = 0). A set of interaction terms with dummy variable was also incorporated into the model. The multiple linear regression model was specified as:

$$Y_i = \alpha + \beta D_i + \gamma_i X_i + \theta_j DX_i + \epsilon \quad (1)$$

Where,

Y_i	=	Household demand for water (i.e. amont of water consumption)
D_i	=	Dummy variable for water source (NWSDB = 1 and KMC = 0)
X_i	=	Vector of other explanatory variables i.e. income, household size, land area, use of piped-water for luxury items[6] (washing vehicles, flushing toilets, washing machines), awareness on tariff structure, availability of other sources of water and use of water for home gardening.
D_iX_i	=	Interaction of the vector of explanatory variables with water source dummy
ε_i	=	Random error term

The above function was estimated using Ordinary Least Square (OLS) method using TSP (Time Series Package).

The study population includes the households in the municipality area of the Kandy district who will benefit from the proposed improvements. Fourteen *Grama Niladhari* (GN) divisions were randomly selected for data collection to represent all income categories. Within each GN division, samples of households were randomly chosen, probability proportional to the size, thus making a total sample of 250 households which is 2% of the study population. The study used a structured questionnaire to gather demographic and socio-economic data related to water consumption. For quantity of water and amount paid, households were asked to produce the latest water bill and amount consumed, and the cost for that month was recorded to avoid the confusion of arrears payments.

The study used the income, difference price and marginal price elasticities of residential water demand in the Kandy Municipality estimated by Gunathilake *et al* (2001) to examine the impact of different tariff structures. In the simulation exercise, the water demands of the three income groups were studied under five scenarios. The scenarios considered were: base-case, 50% increase of the fixed price, 50% increase of the third block price, 50% increase of all the blocks from the fourth and 50% increase of all the blocks from the fifth.

RESULTS AND DISCUSSION

[6] If a household uses piped water for washing vehicles, washing machines and flushing toilets it was taken as 1 otherwise 0.

Descriptive statistics

The descriptive statistics of the water consumption related variables for the three income groups[7] for both NWSDB and KMC consumers are given in Table 1. As expected, average landholding size increased with increasing income of households connected to both water suppliers. The same directional relationship was found in the quantity of water consumed as well. This is justified by the fact that with increasing income, the percentage of households with flushing toilets, washing machines and households using piped-water for gardening increases. It seems that with increasing income, households tended to solely depend on piped water. This was more prominent in households which are connected to NWSDB. Since NWSDB tariffs are higher than that of KMC, at higher blocks income really matters in consuming more water. It is interesting to note that middle-income groups who are connected to KMC were more aware of the water charging system than the lower income groups or high-income groups. The low-income people were not aware of the tariff structure because they consume at lowest block rates while the people in highest income category (earning more than Rs. 50,000/month) were not much concerned about cost of water since it is just a very small fraction of their income. On the other hand, higher income consumers will be more dependent on piped-water. Further, it is also interesting to note that the percentage of households with leakages in their water systems increases with income and is more prominent in households connected to KMC. This may be again attributed to the fact that for higher income households, water is under-priced. Since KMC prices are lower at higher blocks, this is more prominent in the households connected to KMC.

Table 2 depicts the distribution of consumers among tariff blocks. A majority of the consumers were concentrated within the third to fourth blocks i.e. they consumed 16 to 30 cubic meters of water per month. However, consumers of NWSDB were skewed towards the lower blocks, whereas the consumers of the KMC were skewed towards higher blocks. This is due to the more aggressive nature of the block rates of NWSDB than that of KMC. This also implies a certain degree of responsiveness of consumers to the price.

Table 3 presents the percentage of households that are subsidized (the households that pay less than the quantity consumed multiplied by Rs 30.00) at three income categories due to the block tariff structure. The breakeven quantity (with O&M cost) of water was determined by matching the actual bill with the quantity, multiplied by Rs. 30.00. At the lowest income category, 93% and 100% percent of the households were subsidized or paid less than the actual O&M cost connected to NWSDB and KMC respectively. This table also shows that even though the degree of subsidy reduced with increased income, people with high income were also highly subsidized. This fact is more prominent with the households connected to KMC. This implies that there is a great potential to increase the price of higher blocks which target high income groups. This in turn could save water and increase the revenue of the water supply authorities. Serious attention should be paid in this regard when formulating policies on water tariffs.

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[7] The lowest income category was determined as Rs. 15,000 since the minimum per capita expenditure of Kandy is Rs. 3000 per month (Census and Statistics, 2008) and assuming five members per family. The other two income categories are Rs. 15,000 to 50,000 and over Rs 50,000 respectively

Table 1. Descriptive statistics of the explanatory variables by water source and income group

Explanatory variable	Units	NWSDB Income Group 1	NWSDB Income Group 2	NWSDB Income Group 3	KMC Income Group 1	KMC Income Group 2	KMC Income Group 3
Total area of land including the house	Perches	11.99 (9.70)	17.74 (15.97)	22.39 (17.40)	8.81 (4.73)	13.98 (24.64)	13.88 (6.15)
Quantity of water consumed	(m^3)	17.89 (6.95)	21.08 (7.23)	28.33 (7.05)	17.18 (7.70)	25.23 (8.70)	36.10 (12.87)
Household size	Number	5.10 (1.54)	4.73 (2.30)	5.33 (1.50)	4.48 (1.60)	4.76 (1.29)	5.61 (1.76)
Households using piped-water for washing vehicles	%	27.59	22.50	44.44	4.76	48.42	27.78
Households using washing machine	%	3.45	32.50	100.00	23.81	55.79	80.56
Households with at least one flushing toilet	%	44.83	62.50	100.00	33.33	58.95	86.11
Households using piped-water for home gardening	%	37.93	35.00	66.67	57.14	65.26	61.11
Households with any other source of water	%	20.69	32.50	0.00	9.52	4.21	16.67
Knowledge on how water consumption is charged (increasing block tariff structure)	%	37.93	30.00	44.44	28.57	45.26	30.56
Households having any wasteful use of water	%	10.34	12.50	22.22	9.52	17.89	52.78
Number of observations	Number	29	40	9	21	95	36

Values in parenthesis are the Standard Deviations

Table 2. Distribution of consumers among blocks by water sources

Tariff Blocks	NWSDB		KMC	
	Percentage	Cumulative Percentage	Percentage	Cumulative Percentage
1-10	7.69	7.69	5.26	5.26
11-15	12.82	20.51	11.18	16.45
16-20	34.62	55.13	13.82	30.26
21-25	24.36	79.49	19.08	49.34
26-30	11.54	91.03	19.08	68.42
30-40	8.97	100.00	17.76	86.18
40-50	0.00		11.84	98.03
>50	0.00		1.97	100

Table 3. Subsidy levels at alternative income levels

Source of Water	Break even Quantity	Income Groups		
		Group 1	Group 2	Group 3
NWSDB	27	93.10	90.00	55.56
KMC	47	100	98.95	75.00

Results of the econometric estimations

The factors affecting the consumption of water under the two tariff structures were identified using the multiple regression models specified above. Of the various functional forms attempted, the following linear functional form was selected (Table 4).

Table 4. Parameter estimates of the regression model

Variable	Estimated Coefficient	Standard Error
Constant	14.71***	2.14
Household monthly income	0.00005**	0.00
Use of luxury items (flushing toilets, washing machine and vehicles)	8.53***	1.66
Number of persons living in the house	1.31***	0.37
Availability of other source of water	-2.73^{NS}	1.80
Awareness on tariff structure	-1.76^{NS}	1.24
Use of piped-water for home gardening	2.77**	1.23
Dummy variable for source of water (D=1 for NWSDB)	-5.04**	2.17
Interaction terms		
Income x source of water	0.0001*	0.00
Use of luxury items x source of water	-7.54**	3.73
R^2	0.33	

* Significant at 10%, ** significant at 5% and *** significant at 1%

Results show that household monthly income, use of piped-water for luxury items like washing vehicles, washing machines and flushing toilets and the number of persons living in a household had a significant positive influence on household water consumption. However, the coefficient for income is very small indicating that income impact of water consumption is minimal. As expected, availability of other sources of water and awareness of tariff structure reduces water consumption, but were not statistically significant.

Water consumption of households connected to NWSDB was significantly less than the households connected to KMC. This indicates that consumers obtaining water from KMC consume significantly more water than NWSDB consumers if all the other variables are held constant. This is attributed to the more aggressive tariff structure of NWSDB compared to KMC. The NWSDB water tariff is designed in such a way that it discourages water consumption at higher blocks. For example, if a household consumes 40 m^3 of water, the water bill of a household connected to NWSDB will nearly double (Rs. 1811) as compared to the households connected to KMC (Rs. 959) (see appendix Table 1).

Though the coefficient of the interaction between the water source dummy and income variable was very small in magnitude, it is positive and significant. This is consistent with the above results that the impact of income is more prominent in households connected to NWSDB than that of KMC. As expected, interaction between use of piped-water for use of luxury items and the water source dummy was negatively significant at P=0.05. This indicates that KMC consumers use water more freely for luxury purposes compared to NWSDB consumers.

Results of the Simulation

As described in the methodology section, the water demand of the three income categories under four potential changes in the tariff structures (policy shocks) were examined using the elasticity estimates of Gunathilake (2001)[8] (see table 5). The results of the simulation are given in Table 6. Overall, no substantial differences were observed due to any of the policy shocks used. As expected, increasing fixed price as well as third block price had reduced the water consumption of the highest income group of the consumers connected to the KMC. This result is consistent with the block-wise distribution of KMC consumers where it was skewed towards the higher blocks. In contrast, hardly any difference can be seen in consumers connected to NWSDB. In fact, they have slightly increased the consumption when the third block price is increased by 50%. However, there were some inconsistencies within the results. For example, though small in magnitude, a rise in block prices increases the consumption except in the highest income category of KMC. This is attributed to a slightly bigger coefficient for difference price than the marginal price. Mathematically, in order to have a downward sloping demand function, the elasticity of marginal price should be greater than that of difference price.

Table 5. Estimated elasticities used for the simulation

Variable	Estimated Elasticity
Marginal price	-0.3365
Difference price	0.3454
Income	0.0800
Household size	0.3825

Source: Gunathilake *et al*. (2001)

Table 6. Results of the simulation by water sources and income groups

[8] They have estimated a log-log demand function for Kandy municipal area using panel data. Monthly data for 40 randomly selected households for a six-year period were used for the estimation.

Scenarios	NWSDB			KMC		
	Income Group			Income Group		
	1	2	3	1	2	3
Base case scenario	17.89 (6.95)	21.08 (7.23)	28.33 (7.05)	17.18 (7.70)	25.22 (8.70)	36.10 (12.83)
Fixed price increased by 50%	14.54 (7.22)	18.01 (8.73)	27.10 (8.36)	18.82 (8.33)	25.25 (9.31)	32.36 (13.81)
Third block price increased by 50%	19.58 (7.64)	22.59 (6.91)	28.74 (6.39)	18.91 (11.07)	24.57 (10.41)	28.82 (14.87)
50% increase of all the blocks from the fourth	18.09 (7.18)	21.42 (7.51)	28.93 (7.21)	19.87 (7.23)	27.07 (9.89)	33.98 (14.16)
50% increase of all the blocks from the fifth	17.94 (7.06)	21.20 (7.42)	28.76 (7.34)	19.57 (9.39)	26.99 (10.55)	34.25 (14.86)

Values in the parenthesis are standard deviations

CONCLUSIONS AND IMPLICATIONS

In this study, the differences between two tariff structures imposed by NWSSDB and KMC were compared. This was supplemented by identifying the factors influencing the water demand in the two water supply bodies. Using the existing elasticity estimates, the impacts on water consumption of different income categories, under different tariff policies were simulated.

It was found that the tariff structure imposed on consumers connected to NWSDB was more aggressive than that of KMC. Therefore, water consumption was skewed toward higher blocks and water was more subsidized for KMC consumers. Therefore, KMC water users had the tendency to use piped-water for washing vehicles, washing machines, flushing toilets, and home gardening. The impact of income was found to be more prominent in households connected to NWSDB than KMC.

The simulation results showed the impact of different tariff structures on consumption and revenue. The results revealed that no substantial changes in residential water demand can be expected due to any of the policy shocks used by the two institutions. This is due to two reasons, one is that the household water bill is fairly low and the water demand is income inelastic. The other is that the heavy subsidy given to low income categories, which constitute a vast majority of users, does not act as an incentive for conservation. Although the degree of subsidy reduces with increasing income, people with high incomes also enjoy the subsidy benefits, especially in households receiving KMC water. This study reveals that the tariff structures are highly subsidized and that there is room for increasing tariff levels at higher blocks which is pro-poor and equitable policy decision. Further increasing prices at higher blocks would discourage the wasteful use of purified treated water for non-essential/luxury uses.

The findings of the study implies that there is a great potential to increase the price of higher blocks which target high income groups, and saves water and increases the revenue of the water supply authorities. Policymakers should pay serious attention to these factors in designing future tariff structures for water.

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APPENDICES

Table 1. Tariff structures for residential water use

Consumption Units Per Month	NWSDB		KMC	
	Number of Units	Rate Per Unit (Rs.)	Number of Units	Rate Per Unit (Rs.)
01 to 15	01 - 10	1.25	01 to 10	3.00
	11 - 15	2.50	11 to 15	8.00
16 to 20	01 - 10	1.25	16 to 20	10.00
	11 - 15	2.50	21 to 25	25.00
	16 - 20	8.50	26 to 30	30.00
21 to 25	01 - 10	1.25	31 to 40	40.00
	11 - 15	2.50	41 to 50	50.00
	16 - 25	30.00	More than 50	60.00
26 to 30	01 - 10	1.25		
	11 - 15	2.50		
	16 - 30	50.00		
31 to 40	01 - 10	1.25		
	11 - 15	2.50		
	16 - 40	60.00		
41 to 50	01 - 10	1.25		
	11 - 15	2.50		
	16 - 50	70.00		
More than 50	01 - 10	1.25		
	11 - 15	2.50		
	> 15	75.00		

Source: NWSDB and KMC unpublished

Table 2. Water treatment and O&M costs

Treatment	Unit Involvement	Cost of treatment per connection (Rs.)	O&M cost per m^3 (Rs.)
Only disinfection	Screening & disinfection	1,500	0.5-1.5
Minimum treatment	Screening, filtration & disinfection	8,000	1-3
Partial treatment	Screening, roughing filtration, filtration & disinfection	16,000	3-10
Full treatment	Screening, coagulation, flocculation, sedimentation, filtration & disinfection	60,000	10-25
Advanced treatment	Screening, coagulation, flocculation, sedimentation, filtration & adaptation, and disinfection	150,000	75-100

Source: Attanayake and Athukorala (2007)