

RESEARCH ARTICLE

## Interrelations among self-reported water use behavior, awareness, and metered water consumption in domestic use in Southern Sri Lanka

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**Abstract:** Water use behaviors, awareness on the water conservation and purification process have an influence on the water consumption of people. Hence, this study assimilates measured water consumption and the data collected in a questionnaire survey to understand the relationship between self-reported water use behaviors and measured water consumption. The study was conducted in four coastal cities in southern Sri Lanka and about 70% of households had alternative water resources. First, self-reported water use behaviors were used to cluster the sample into two clusters. Households reported with highly positive water use behaviors (HPB) were consuming less water than those who with moderately positive water use behaviors (MPB). Positive water use behaviors of HPB group seems to be supported with their higher awareness on the need for water conservation and water treatment process and associated costs. Therefore, this study suggests that increasing awareness on the need of water conservation, underuse of water, water efficient appliances and increasing the awareness on the water treatment and distribution process and cost will help in shifting consumers towards positive water use behaviors.

**Keywords:** *Water consumption, water use behaviour, water conservation*

### Introduction

Urban water scarcity is a global concern. Many water supply facilities face limitations of water availability due to increased demand as well as drought and unpredictable weather patterns in many parts of the world (Willis et al., 2011). Countries with adequate water sources even face the constraints in providing potable water because of water pollution and increased treatment costs (Millock & Nauges, 2010). Hence, sustainable management of urban water has become a timely requirement. Recent findings reveal that water consumption is not relational to the water price in most parts of the world, because cost of water is relatively low compared to that of other essentials in the life (Barret, 2004; Willis et al., 2011). Therefore, reduction of water wastage and demand are expected

to be achieved through technological improvement and increasing awareness and growing positive attitudes towards the environment (Randolph & Troy, 2008; Straus et al., 2016). Hence, urban water demand management, water conservation and increasing public awareness have become major topics in discussion (Millock & Nauges, 2010; Randolph & Troy, 2008; Willis et al., 2011).

Domestic water consumption is dependent on numerous factors such as number of family members, socio-economic factors such as income, age, education, lot size, efficiency of water use appliances and the attitudes, beliefs and behaviors of consumers (Willis et al., 2011; Yu et al., 2015). Low flow shower heads, dual flush toilets, rain water tanks, low water consuming gardens and imposed regulations in lawn

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watering and vehicle washing are a few examples of technological and regulatory movements towards sustainable water consumption in Australia and USA (Randolph & Troy, 2008; Straus et al., 2016). However, technological improvements and regulations cannot minimize water wastage, since it is controlled by human behavior (Coelho et al., 2016; Randolph & Troy, 2008). Therefore, psychology has a key role in minimizing water wastage (Coelho et al., 2016; Koutiva et al., 2017).

The role of psychological perspective in water conservation behaviors was reported in the literature (Coelho et al., 2016; Grafton et al., 2011; Russell & Fielding, 2010; Straus et al., 2016; Willis et al., 2011). These studies suggest that shifting consumers towards sustainable water consumption practices require instilling of awareness, understanding and appreciation of the water as a resource (Willis et al., 2011). (Straus et al., 2016) reported that, high-profile information campaigns carried out encouraging more mindful water usage in USA is proliferated across communities. Increased awareness and technological improvement resulted in falling water demand in many states despite of the population growth (Straus et al., 2016). (Russell & Fielding, 2010) categorized determinant factors of water conservation behavior into five categories. They are attitudinal factors, beliefs, habits or routines, personal capabilities and contextual factors. There are many studies which focused on exploring the connection between the attitudinal factors, beliefs, and actual water consumption (Hassell & Cary, 2007; Willis et al., 2011). (Willis et al., 2011) have studied the influence of environmental and water conservation attitudes on household end use water consumption in Gold Coast, Australia and found that people with very high concern on environment consume less water compared to the people with moderately high concern. Further, they suggest that to generate effective awareness campaigns, the driving forces on water conservation should be identified and awareness programs should address appropriate aspects to increase the water conservation behaviors in different socio-economic groups (Willis et al., 2011).

### **Sri Lankan context in pipe-borne water supply**

Decades ago, shallow groundwater wells were the major water supply sources for Sri Lankans living in the wet zone of the country, while man made tanks and tube wells were the major source of water for dry zone (Chandrajith et al., 2010). Piped water supply in Sri Lanka was initiated in 1960s. National water supply and drainage board (NWSDB) is the principal authority providing safe drinking water in Sri Lanka (NWSDB, 2017). By 2012, 94% of Sri Lankan population had access to improved water sources (WHO 2015). The coverage of piped water supply was 45.9% in 2015, while the other sources are dug wells, tube wells and hand pumps (NWSDB, 2017).

NWSDB supply piped water to almost all city centers and their suburbs. In most of the situations, surface water is being used as source water while boreholes and deep wells used in some areas. Supplying the demand is a challenge due to the limitations in source water as well as the capacity limitations in the water treatment plants (Ellawala & Priyankara, 2016). Specifically, large scale funding is sought for constructing water treatment and supply infrastructure. At present the annual water supply of the NWSDB is approximately 600 million m<sup>3</sup>. Further, there are several ongoing infrastructure development projects (NWSDB, 2017). Total domestic connections in Sri Lanka were 1,831,549 (Total connections 1,953,721 - 94% of connections being domestic) as of year 2015 (NWSDB, 2017). In year 2005, it was estimated that 63.5% of water produced by NWSDB is accounted for residential water use (Dharmaratna & Harris, 2012). Therefore, domestic water consumption and demand management is a very important aspect in water demand management in Sri Lanka.

### **Research objectives**

NWSDB focus on promoting water conservation awareness campaigns with the aim of reducing water wastage (NWSDB, 2017). However, there is not any attempt made yet to identify areas which need to be focused on these awareness campaigns. Hence, it is very important to evaluate the role of behaviors, attitudes and awareness of consumers on water demand management strategies. Therefore, the objective of this study was to explore the relationship

between the self-reported water consumption behaviors and actual water consumption. Thus, this study was planned to answer the following research questions.

1. Is there any link between the self-reported positive water use behaviors and domestic water consumption?

Hypothesis: Consumers with positive water use behaviors are consuming less water.

2. If there is any connection between the self-reported positive water use behaviors and domestic water consumption, whether the awareness of less water consumers is higher than the others?

Hypothesis: Consumers with positive water use behaviors are more aware on water conservation and water resources management.

### **Methods**

This study was conducted in four coastal cities (Galle, Ambalangoda, Matara and Weligama) located in Galle and Matara administrative districts controlled under Southern Regional Support Center, NWSDB, Sri Lanka.

#### **Situational context**

Galle and Matara districts are in the wet zone of Sri Lanka, hence receive a rainfall of >2500 mm. In general, the area experiences a relatively low rainfall in February to April and the temperature is about 30o C. In the other periods of the year, monsoons are active, and the area receive a plenty of rain. Approximately there are 100,000 service connections in each district. The average daily water availability in Galle and Matara districts are 17 and 14 hours per day respectively. Recent unpredictable weather patterns caused longer dry periods and considerable limitations in source water in the area. Consumers experienced limited water supply (Ellawala & Priyankara, 2016), which cause some consumers to receive water every other day. Further, salinity intrusion and insufficient treatment facilities also interrupt the continuous water supply in the region.

Limitation of water supply is more vulnerable regarding Matara than Galle. Additionally, there is a continuous demand for new water supplies in both cities in parallel to new settlements and developments. Domestic water demand is the major component of water demand in both cities.

#### **Questionnaire development and survey**

In total, survey was conducted in 265 households. Respondents were requested to give their water billing account number and consumption data was obtained from the NWSDB records for the years 2013-2016 (36 months). Consumption data was evaluated to check whether the consumption patterns are reliable. Houses with missing data and non-continuous consumption were removed. Table 2 shows the questions used to evaluate water use habits and attitudes on water conservation. The questionnaire development and categorization of questions based on (Willis et al., 2011). A four point Likert scale was adopted for rating the response on attitudinal items, with 4-very often, 3-mostly, 2-seldom and 1-never (The questionnaire survey was conducted in Sinhala and translated into English to display the questions in this article). Consumer's awareness on the reasons to have intermittent water supply, awareness on the routine activities and processes and associated costs in production of purified water were evaluated in a secondary survey. In the secondary survey, consumers were asked to tick Yes/No according to their opinion for the questions/statements listed in Table 2. They were requested to choose the production cost from the given answers (10, 20, 30 and 40 LKR). Further discussions were made to gather qualitative data on their awareness on water purification process. Table 1 Socio economical characteristics of the respondents (n=231).

#### **Statistical analysis**

Statistical analysis was carried out using R statistical software package.

Table 1: Socio economic and demographic characteristics of the respondents (n=231)

Variable	Categories	Percentage (%)
Gender	Male	40.3
	Female	59.7
Age	18-34 Years	25.9
	35-49 Years	41.1
	50 Years and above	32.9
Education	Up to GCE O/L*	19.4
	Up to GCE A/L*	54.1
	University Education	26.4
Monthly Income (Family)	Less than Rs. 25000/-	11.7
	Rs. 25000-50000/-	26.8
	More than Rs. 50000/-	61.5

### Data analysis and Results

Table 2: Measurement items used for evaluating water use behaviors

Measurement	Question	Code
Habits or routines	I close the taps while brushing the teeth and soaping.	d1
	I usually take shorter showers less than 5 min.	d2
	I fill the washing machine completely before use (full load).	d3
	I rinse the vegetables in running water.	d4
	I wash all the dishes and kitchen utensils together.	d5
	I use the plants, which need watering less frequently in the garden.	d6
	I water the garden when necessary only.	d7
	I regularly check for the water leaks through appliances.	d8
Water conservation behaviours	I am careful to turn off taps tightly/completely.	d9
	When I see a water leakage in a roadside (pipe burst/leakage), I inform NWSDB.	e1
	When I see a tap running in a public place, I turn off.	e2
	I am aware on water conservation and I try to conserve water whenever possible.	e3
	I inform relevant authorities when I see water leakages in public places.	e4

Out of the 265 surveys conducted, only 231 usable responses were received, representing an effective response rate of 88%. For other users, problems were encountered related to their water consumption data. Either the water consumption account number was

invalid, or consumption patterns were not stable. Descriptive statistical analysis was performed on full dataset to examine the mean, standard deviation and the reliability of the measurement scale used in the questionnaire. The results are shown in Table 3. The

Cronbach’s alpha coefficient of 0.83 indicates that the data set has a high internal consistency (Willis et al., 2011).

Table 3: Mean score and standard deviation for measurement items based on the answers given by respondents on four point Likert scale, that was adopted for rating the response on attitudinal items, with 4–very often, 3–mostly, 2–seldom and 1–never items.

Measurement item	Mean	SD
d1	3.54	0.54
d2	3.45	0.64
d3	3.44	0.57
d4	3.37	0.65
d5	3.33	0.57
d6	3.21	0.70
d7	3.21	0.71
d8	3.18	0.67
d9	3.30	0.70
e1	3.24	0.71
e2	3.27	0.68
e3	3.27	0.78
e4	3.25	0.62

Note: Cronbach’s alpha = 0.83 for 13 items

**Factor analysis**

A multiple correspondence analysis was conducted on data to identify the underline structures of the dataset. Water conservation behaviors and water use habits were categorized under two factors in the factor analysis similar to the predictions. First factor explained 26.92% of the variance observed in the data while the second factor explained 17.43% of the variance. Measurement items named d1 – d9 had high

loadings on the factor 1 while e1-e4 had higher loadings on factor 2 (Figure 1). All the components had positive loadings on each factor. Hence, factor 1 was identified as the routine household water use behaviors and factor 2 was identified as water conservation behaviors. Factor scores obtained from the analysis was used in the cluster analysis.

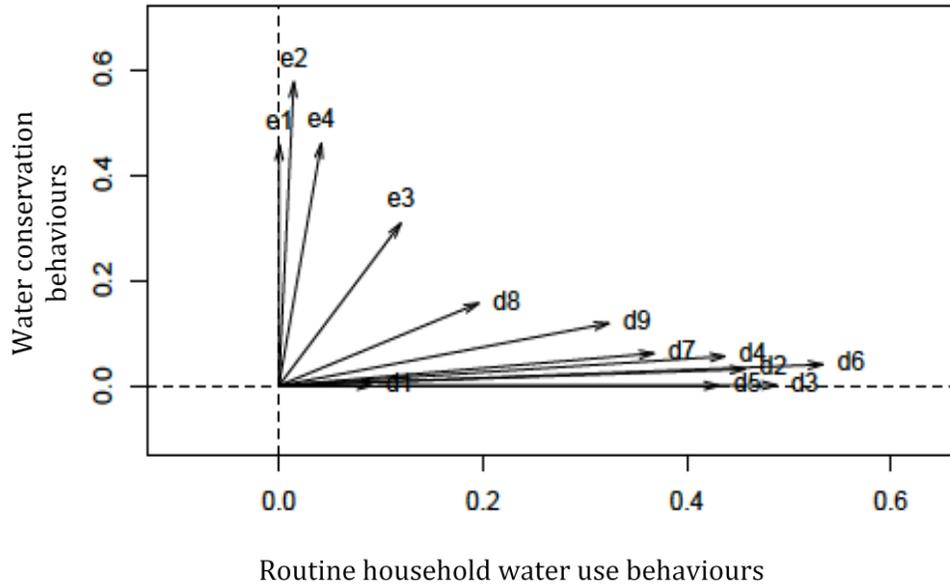


Figure 1: Squared loadings after rotation

**Clustered comparative analysis**

Cluster analysis was conducted using Ward’s method. The visual inspection of the cluster dendrogram showed that the data could be divided into two major clusters. Figure 2 shows the mean value of the responses given by respondents clustered under two clusters. The mean of the responses was considered as the item centroids for each cluster. Item centroids for two clusters were subjected to One-way Analysis of Variance (ANOVA) test and results showed that the final centroids of both clusters were significantly different ( $F=2.485, P<0.04$ ). Cluster 1 which had lower item centroids and it was identified as respondents with moderately positive behaviors (MPB) and the cluster 2 was identified as highly positive behaviors (HPB). Residents clustered into HPB cluster showed higher item centroids and were

consistently similar for all the measurement items (Fig. 2). In contrast, item centroids and consistency both are less in MPB cluster. For example, regarding item d1 and e1 the item centroids were close to HPB while others were not.

Average water consumption of MPB cluster was 137 L/p/d while it was 122 L/p/d regarding HPB cluster. A similar difference between very high concern and moderate concern was observed by (Willis et al., 2011) after clustering a group of consumers based on environmental concern. Further, the highest consumptions in these two clusters had an approximate difference of 100 L/p/d. Therefore, people with positive self-reported behaviors seems to consume comparatively less water than the people with relatively negative behaviors.

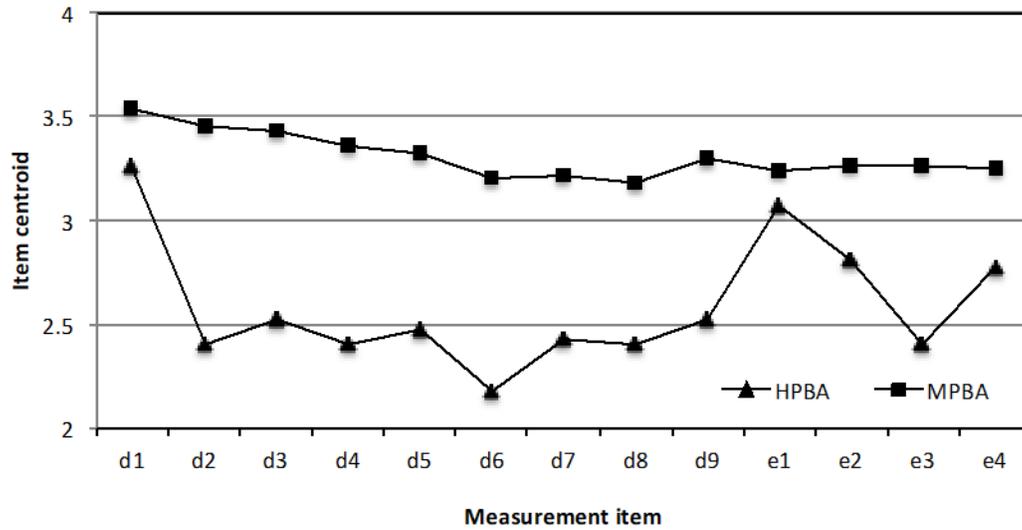


Figure 2: Profiles of final cluster centroids

**Alternative source availability**

Our study revealed that 70% of families had access to an alternative water source such as shallow wells or tube wells. After clustering, we again found that approximately 70% in each cluster also have alternative water sources. Therefore, alternative water source availability does not seem to influence on water use behavior. More than 98% of alternative resources were ground water, only few had access to usable surface water sources such as streams, located near their residence. Some claimed that their groundwater source is suitable for drinking also. However, they do not use the alternative sources regularly, since pipe borne water is easily accessible for them. Even though many people had alternative sources, every households interviewed had a household overhead tank for storing pipe borne water. The tank capacity varied from 500 L to 2500 L. It provides evidence on people’s tendency to rely on pipe borne water whenever possible.

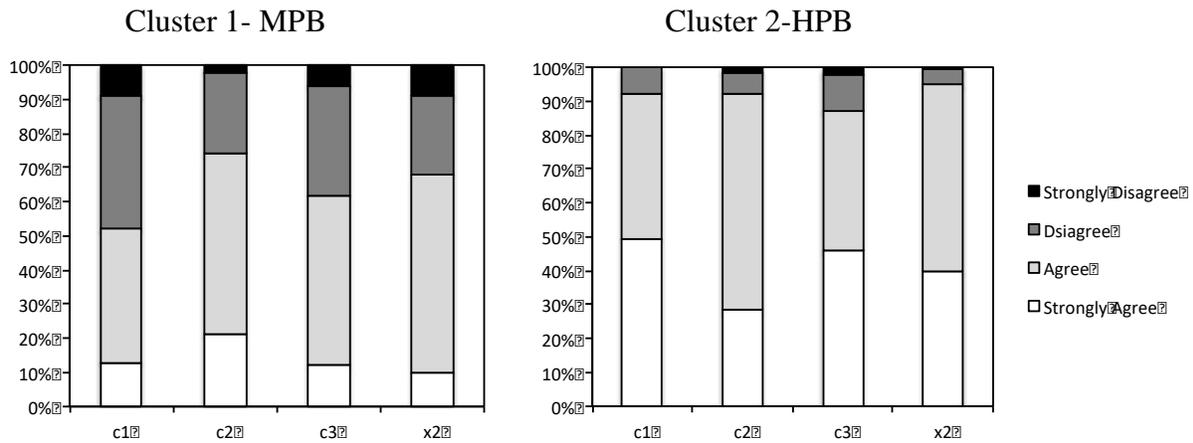
**Socio-demographic characteristics**

Socio-demographic patterns between different clusters were studied separately. In MPB cluster, 19% are graduates, while it was 31% in HPB cluster. Approximately, 51% of households in MPB and 69% households in HPB were families earning more than 50000 LKR per month. All two-member families had no children, i.e. only comprising of adults. MPB cluster had a higher percentage (63%) of large families (>= 5 members), while it was only 41% in HPB cluster. In the meantime, most of the large families had children. They were comprised of composite families, which had members belong to three generations. In contrast, percentage of small families (<= 4 members) with no children was higher. Therefore, it seems large families with children consume more water compared to the small families. Socio economic context should be studied further related to these trends.

Table 4: Distribution of family size in clusters

	MPB (%)	HPB (%)
2 members (Families which had only adults)	1(100)	6(100)
3 members (Families which had only adults)	11(18)	14(36)
4 members (Families which had only adults)	25 (40)	34(24)
5 members (Families which had only adults)	23(4)	20(10)
6 members (Families which had only adults)	27 (4)	13(8)
Members 7-10 (Families which had only adults)	13 (0)	8(13)

Numbers in the parenthesis are percentage of families with no children in each category, while the numbers out of the parenthesis are total percentage of families in each category.



c1= I am aware on how my water bill is prepared.

c2= Water consumption in my home is sensitive to the water bill.

c3= I check water meter reading often and it helps me in controlling water consumption and detecting whether there are any water leaks in my house.

x2=I am aware on water efficient appliances.

Figure 3: Awareness of water tariff system, water metering and water efficient appliances

**Awareness on the water tariff system and water efficient appliances**

More than 90% of respondents in the HPB cluster were aware on the billing procedure, while it was approximately 50% in MPB cluster. Similarly, the

awareness of water efficient appliances is also varied between two clusters (Fig. 3).

**Awareness on the water treatment process and associated costs**

Table 5 shows the summary of responses (% Yes) received from each cluster regarding the water treatment process and some concepts regarding water conservation. Paired sample t- test was applied for two groups and the means are different for two groups. The awareness on above aspects between two groups are significantly different ( $t_{(2,3)} = 5.56, P < 0.001$ ). The cost of production is 27.73 LKR/m<sup>3</sup> of purified water at the point of receiving (NWSDB, 2017). Approximately, 50% of consumers underestimate the cost of production. Unfortunately, 20% of consumers

believe the cost of production to be as low as 10 LKR /m<sup>3</sup>. Further discussions revealed that unawareness on the activities to be carried out in the water treatment process cause the service to be undervalued. If we consider the variation of the awareness between the clusters, the awareness on the tariff system is considerably less in MPB cluster. Further, the awareness of respondents on underuse of water is comparatively less than other parameters we checked. It was commonly seen in both clusters, although it was 10% less in MPB cluster than HPB cluster.

Table 5: Awareness of consumers on water conservation, water treatment process

Questions used for evaluation	Percentage of people with positive responses (% YES)	
	HPB	MPB
Have you heard on		
Water resources conservation	95	86
Minimizing water wastage	98	95
Minimizing water consumption through water efficient appliances	92	79
Underuse of potable water for vehicle washing	74	65
Underuse of potable water for gardening	75	66
In your opinion NWSDB staff routinely conduct		
Source water quality analysis	89	85
Analysis of chemical requirement for water purification	94	89
Treatment plant operation and maintenance	82	67
Cleaning treatment units (tanks)	68	55
Treated water quality analysis	90	80
Maintenance of distribution network	76	82
Water quality analysis on distribution	67	65
In your opinion, associated costs for water supply are		
Cost for chemical – Alum, chlorine etc.	92	81
Operation and maintenance costs	94	88
Pumping costs	90	84

Costs for staff payments	89	79
Costs for distribution	76	74
<b>Reasons for intermittent water supply</b>		
Limitation of source water	75	78
Limitation of treatment plant capacity	82	78
Saltwater intrusion in to the intake	67	46
Water leakages	73	69
Pipe bursting and damages/Repairs	88	77
Pressure drops	75	72
Overuse of water by you/your neighbors	77	76

## Discussion

According to the results of the cluster analysis people with highly positive self-reported behaviors (HPB) consume less water than moderately positive self-reported behaviors. As hypothesized, residents belong to HPB cluster consume less water than residents in MPB cluster. The difference between average consumption in two clusters was 15 L/p/D. However, this difference can contribute to save 1.8 m<sup>3</sup> of water in a family with 4 members per month. Further, NWSDB calculate the average water consumption in a family living in Southern province (outside of the Western province) to be 12.48 m<sup>3</sup> per month (NWSDB, 2017), hence if 50% of families living in Galle and Matara districts reduce 1.8 m<sup>3</sup> per month, it will be enough to provide 7000 new connections in average. Therefore, development of positive water use behaviors has a significant impact on the water consumption.

More than 90% of HPB cluster, is aware on water tariff process and claim that household water consumption is responsive to the water bill. It is comparatively higher than the MPB cluster. Meanwhile, (Dharmaratna & Harris, 2012) report that water consumption in Sri Lanka is not very responsive to the price changes. Further, they estimate that, price inelastic component of domestic water use in Sri Lanka is between 0.64 - 1.06 m<sup>3</sup> per month and it is a very small value compared to the other parts of the

world. Further, the income elasticity is also relatively small and may be because it comprises a very small component of the household budget (Dharmaratna & Harris, 2012). Hence, we assume that although households are not responsive on price changes in general, they might try to keep their water consumption constant at least. However, since the price elasticity is small the reduction of consumption is to be achieved by increasing the awareness.

Increasing the awareness of respondents on the underuse of water is a major area, which need attention. Increasing the awareness on the underuse of water will be very important in Sri Lankan context, because about 70% of households we interviewed had an alternative water resource. Households with an alternative water resource may reduce the underuse of potable water. This is not the case in many other countries, which targeted on the conservation of water through reduction of domestic demand. But extracting groundwater needs manpower or a pumping system. Households are not willing to do either of that may be because the domestic water tariff in Sri Lanka is relatively low compared to the other countries in the region (Asian Development Bank, 2004). This was clearly observed by having household water storage tanks in every household interviewed. Average per capita storage was 250 L in MPB while it was 280 L in HPB. Further, increasing awareness on the water efficient appliances will also play a significant role in water conservation. For example, water efficient

showers can contribute up to 50% of water saving compared to traditional devices (Willis et al., 2013). Residents clustered under MPB had lower awareness on the water efficient appliances than who belonged to HPB cluster. However, initial cost of the appliances might play a significant role in the decision-making process.

As the respondents clustered under MPB had a relatively lower awareness on water treatment process and associated costs compared to who clustered under HPB, awareness has a considerable influence in reducing water consumption. Increasing awareness on water treatment process and associated costs will contribute in appreciating the water supply service. Discussions revealed that low awareness in the treatment process cause them to undervalue the service. It is clearly visible on their estimation of production cost of treated water. Further, since people consider it as a commodity, they might undervalue it just because the tariff is less. For example, the first 5 m<sup>3</sup> tier is priced as 5 LKR /m<sup>3</sup> and the second 5 m<sup>3</sup> tier is charged 10 LKR /m<sup>3</sup> while the production cost is 27.73 LKR/ m<sup>3</sup>. Therefore, this study suggest that water use behavior, awareness and metered water consumption is needed to be interrelated in Sri Lanka. Hence, development of positive water use behaviors should be achieved through introduction of water efficient appliances, raising awareness on underuse of water, water tariff system and water treatment system and associated costs. However, further studies should be carried out to identify potential groups who may need more attention in awareness campaigns.

### Conclusion

This study exhibits that self-reported water use behavior and actual water consumption has an interrelationship. Households with highly positive behaviors were recorded to have low consumption of water. Further, they are aware on the water tariff system and water efficient devices than the other group. In general, the awareness of consumers on underuse of potable water in gardening and vehicle washing is less. Increasing their awareness regarding underuse of water is very important in Sri Lanka because of the availability of alternative water resources. In addition, improving the public awareness

on the water treatment process may help them to appreciate the cost and effort made. It is very important to aware the people on the actual production cost of a meter cube of treated water, since the NWS&DB provide water in a relatively low rate to make it affordable for all the people living in the country. Shifting people towards positive water use behaviors and water efficient appliances can contribute in the reduction of domestic water demand considerably in Sri Lanka.

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