An Investigation of the End Use Residential Water Consumption in the Galle Municipal Council Area


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Abstract: Investigation on residential end use water consumption aid to encounter the water scarcity problems by using alternative sources. Both dry and wet seasons were compared as seasons while both urban and semi urban areas were considered as regional. The recent study carried out with 100 selected households through snowball sampling method in Galle area where direct metering method was applied. As per the results average total water consumption for both dry and wet season were 124 l/capita/d and 106 l/capita/d respectively. Average total water consumption for both urban and semi urban areas were 125 l/capita/d and 112 l/capita/d. According to seasonal variation toilet, kitchen, clothes washing, bathing and outdoor end use consumption was 18, 23, 30, 34 and 2 for dry season and 14, 18, 30, 22 and 2 l/capita/d for the rainy season. The regional variation was accounted for 22.5, 25, 28, 32 and 4.4 in urban area while semi urban accounted for 15, 18.5, 33, 27 and 1 l/capita/d. However, it was found that the toilet and kitchen water use pattern was statistically significant with the season, while only total water use pattern was statistically significant with the region.

Keywords: Direct metering, end use, Galle, pressure, regional variation, seasonal variation.

1. INTRODUCTION

Though nearly 71% of the earth surface is covered by water, approximately 97.5% accounted as saline while remaining 2.5% accounted as fresh water. Only 0.3% of fresh water is accessible for the human consumption (Taikan & Shinnjro 2016). With the increment of the population and development of the world, available water is trend to decrease due to over usage. Therefore, it is important to sustainable usage of available fresh water sources. End use approach, a novel method for quantification of water (Otakiet et al. 2017) which has been growing interest in micro component approaches since the mid-1990s (Parker & Wilby 2013). End use water consumption means the disaggregation of total consumption of individual household water in to number of end use such as toilet, kitchen, bathroom, clothes washing and outdoor (Mukheibir et al. 2013). Simply end use represents the breakdown of water consumption activities in day to day life (Shan et al. 2015). Quantification of water is mainly restricted for capital cities in the world and most of researches had been conducted in order to estimate total water use. Among the various methods of estimating end use water consumption, estimations with measured data and without measured data were described in a previous studies (Otaki et al. 2017). Water flow pattern analysis and the direct metering was used under the method with measured data. Owing to it’s low cost and less time consumption, questionnaire surveys, diary, recall and prompted recall methods are frequently has been used for the estimation of end use measurement as methods without measured data (Otaki et al. 2017).

As per one of the study conducted in Netherland, the end use consumption 40%, 28% and 12% were accounted for shower, toilet and clothes washing end use respectively. According to study conducted in North American residential, 58.7% water used accounted for outdoor activities such as irrigation and use for swimming pool, whereas 26.7% is used for toilet flushing, 21.7% for clothes washing and 16.5% for showering with regards to the indoor water consumption (Shan et al. 2015). Furthermore it was found that 18.6, 15.7, 16.2 and 10.4 l/capita/d accounted for toilet, kitchen, clothes washing and outdoor respectively in Hanoi, Vietnam. Moreover, the end use values of Chiang Mai, Thailand was 15, 19, 18 and 25 l/capita/d respectively (Otaki et al. 2013).
However, a gap of research knowledge is still remained on end use quantification in Sri Lanka. Therefore, this study was mainly aimed to estimate end use water consumption in Galle, Sri Lanka. This study would not only provide and enhance the discipline of planning and management of water resources in study area by initiating demand management programs, but also it would provide numerous opportunities to develop the policies on sustainable water consumption.

2. METHODOLOGY

2.1. Selection of the locations in Sri Lanka

Recent research study was carried out with selected households in Galle representing both the urban and semi urban areas. Since Galle is the 3rd largest city in Sri Lanka, it was expected that the results produced through this research could be generalized to the other populated cities of the country. Thereby, Galle area was selected to conduct the research study (Figure 1). Recently the study was conducted in selected 100 households by covering urban (Galle) and semi urban (Ahangama) areas in Galle district.

![Figure 1 Location of Sampling Households](image)

2.2. Direct metering

As per the rainfall pattern of Galle area, 53 samples (households) out of 100 were identified as in dry season (end of June to end of August), while 47 samples (households) were included in the wet season (September to late of October). The study was conducted in both urban (Galle) and semi urban (Ahangama) areas. About 30 households were selected from Galle, which was considered as urban and 70 households were selected from Kabalana, Ahangama area, were considered as semi urban. Digital flow meter model 6710M (Figure 2) was used to quantify the water consumption and flow rate of eachend use type.

![Figure 2 Digital Meter](image)
The detailed procedure followed in this research is shown in Figure 3. The end use of water was measured through the installed flow meter for each tap/faucet in each selected household. Thereby the water consumption for toilet flushing, showering, kitchen, clothes washing and outdoor were monitored. Totally, nine meter installation sessions were conducted during this period to complete the targeted 100 households. For each sample household minimum of two weeks period was monitored. Subsequently, data recording were done weekly.

Weekly end use water consumptions for installed households were obtained as end use water consumption per family per week and subsequently end use water consumption per person per day values were calculated.

![Diagram showing the procedure of direct metering](image)

**Figure 3 Procedure of Direct Metering**

### 3. RESULTS AND DISCUSSION

The distribution of end use water consumption was checked for normality using Anderson – Darling test where the distributions appears to be log normal distribution with the p value. Seasonal variation and the regional variation of the end use water consumption of the Galle area were also analyzed. However, being a very congested and industrialized city, the capital Colombo city could not be generalized by these results. Moreover, very rural areas could not also be generalized by these results.

#### 3.1. Total water consumption

##### 3.1.1. Seasonal variation of total water consumption

The total water consumption for dry season was 124 l/capita/d while wet season accounted as 106 l/capita/d. When checking for the influence of seasonal variation in the total water consumption using two sample t-test, the p value was 0.016 (p<0.05) which reveals that total water consumption is influenced by the season. Figure 4 shows histogram of the distribution of of total water consumption separately for dry and wet season.
3.1.2. Regional variation of total water consumption

The average value for the total consumption in semi urban area was 112 l/capita/d while urban area accounted as 125 l/capita/d. When testing the influence of the region on total water consumption using two sample t-test, the value was 0.276 (p>0.05) which shows there was no any significant difference in the total water consumption due to the regional difference. Figure 5 shows the distribution of total water consumption in histogram with urban and semi urban area.

Based on previous studies conducted in Europe, South East Queensland was accounted 143 l/capita/d (Cobos et al. 2011). At the same time, in Oceania Gold Coast accounted as 157.2 l/capita/d consumption while Kapiti Coast in New Zealand accounted for 184 l/capita/d (Heinrich 2007). When it moves to the South East Asian countries, 77 l/capita/d water use was recorded in Chiang Mai, Thailand (Otaki et al. 2008) and 70 l/capita/d water use accounted in Hanoi, Vietnam (Otaki et al. 2013).

3.2. End use water consumption with seasonal variation

3.2.1. Water consumption for toilets

The typical toilet types in Galle are flush type toilets and squat type toilets. Squat type toilets accounted for 74%. In some certain cases both the flush type and squat type toilets were used. According to previous studies, it was found that squat type toilets consume less water compared with the flush type toilets (Otaki et al. 2008)
Figure 6 Histogram for Toilet Water Consumption

As per the Figure 6, the average toilet water consumption in Galle in dry season was 18 l/capita/d and that of in rainy season was recorded as 14 l/capita/d. The influence of seasonal variation of the toilet water consumption was checked using the two sample t-test and the p value was found to be 0.01 (p<0.05) which showed a significant difference in the consumption pattern for toilet with respect to the seasonal variations.

As per the results of previous studies conducted in Thailand, there was no significant difference between toilet water consumption in dry and wet season. Simply water consumption for toilet was 15 and 11 l/capita/d for dry and wet season respectively (Otaki et al. 2008).

3.2.2. Water consumption for kitchen

Figure 7 Histogram for Kitchen Water Consumption

According to Figure 7, the average kitchen water consumption in dry season was 23 l/capita/d and 18 l/capita/d in rainy season. When analyzing the relation between kitchen water consumption and the seasonal variation using two sample t-test the p value was 0.001 (p<0.05). Which shows there was a significant difference in kitchen water consumption due to the seasonal variation. According to Otaki et al. 2008 there was no significant difference between dry and wet season, while 80% of households used under 30 l/capita/d for kitchen. Queensland study has proven that the only 2.5 l/capita/d needed for dishwashers (Cobos et al. 2011). According to previous studies, the average water consumption for kitchen in Bangkok was 4 l/capita/d, because usually they do not cook at home.

3.2.3. Water consumption for washing clothes

Both washing machine and shower tap were used for washing clothes in Galle area. Through the survey it was found that about 22% of households were using washing machine while the rest is done by hand. However, both of these types were considered under washing clothes. The average value of water consumption for washing clothes in both dry and wet season was 30 l/capita/d. The variation of water
consumption for washing clothes with the seasonal variation was checked using two sample t-test. The p value was 0.277 (p>0.05) which revealed that there was no any significant difference in washing clothes with the seasonal variation. According to past studies in Chiang Mai, Thailand, it was found that, they used 18 l/capita/d in dry season and 19 l/capita/d in wet season. Almost all the households were used under 30 l/capita/d for clothes washing water consumption.

3.2.4. Water consumption for bath

As per the results, most of the households used less than 40 l/capita/d in dry season and less than 20 l/capita/d in wet season for bath. The average water consumption for bath was 34 l/capita/d in dry season and 22 l/capita/d recorded in wet season. Influence of the seasons was checked using two sample t-test. The p value of the test was 0.071 (p>0.05) which there was no any significant difference in consumption pattern with the seasonal variations. Considering previous studies, bath water consumption was recorded under 20-30 l/capita/d in Chiang Mai, Thailand (Otaki et al. 2008) similar to European countries.

3.2.5. Outdoor water consumption

Outdoor taps were used often for several purposes such as gardening and washing vehicles. It was identified that the most of the households used less amount of water for outdoor.

The average value for outdoor water consumption in both dry and rainy season was 2 l/capita/d. However, that of usually remains as less than 10 l/capita/d. The variation in outdoor water consumption was checked using two sample t-test and the p value was 0.422 (p>0.05) which showed that there was no any significant variation in the outdoor consumption based on seasonal variation.

3.3. End use water consumption with regional variation

3.3.1. Toilet water consumption

The average water consumption of toilet for urban area and semi urban are were 22.5 l/capita/d and 15 l/capita/d respectively. In order to find out whether there was a regional difference with regards to the toilet water consumption, a two sample t- test was performed. It was recorded that the p value for the certain incident was 0.07 (p>0.05). Thereby, it was proven that there was a significant difference between the toilet water consumption with the region. The variation of water consumption of toilet was due to the type of toilet, though most of urban households used flush type toilets that consume more water than squat type toilets used in semi urban areas.

3.3.2. Water consumption for kitchen

The average urban water consumption for kitchen was recorded as 25 l/capita/d where that of the value for semi urban kitchen water consumption was 18.5 l/capita/d. Through two sample t-test it was understood that there wasn’t any significant difference between the kitchen water consumption and the regional variation (p = 0.248). Results revealed that urban households used more water than semi urban areas.

3.3.3. Water consumption for washing clothes

The average value for water consumption for washing clothes in urban area was 28 l/capita/d and 33 l/capita/d for semi urban area. The two sample t-test revealed that there was no significant difference in the water consumption pattern for washing clothes with the regional variation (p = 0.238).
3.3.4. Water consumption for bath

The average value for water consumption for bath in urban areas was 32 l/capita/d and the average value of water consumption for bath in semi urban area was 27 l/capita/d. When checking for the variation of water consumption for bathing with the regional variation using two sample t-test, the p value was 0.610 (p>0.05) which reveals that there was no any significant variation due to regional variation in water consumption for bathing. Though there was no influence of regional variation urban areas consumed more water than semi urban areas as because of number of available bathrooms in their households.

3.3.5. Water consumption for outdoor

Some houses in the urban area consumed more water for outdoor activities like gardening. The average value for the outdoor water consumption in urban area was 4.4 l/capita/d while the average value for the outdoor water consumption in semi urban area recorded as 1 l/capita/d . When checking for the variation of outdoor consumption based on region using two sample t-test the p value was 0.473 (p>0.05). It was proven that there was no any significant variation in outdoor water consumption with the regional variation.

3.4. Variation with total water consumption and pressure

Pressure values obtained through pressure gauge were presented against the total water consumption as in Figure 8. According to the statistical analysis Pearson correlation for pressure and total consumption was 0.068, thus there was no any linearity relationship identified.

![Figure 8 Total Water Consumption and Water Pressure](image)

4. CONCLUSIONS

The average total water consumptions for both urban and semi urban areas were 125 l/capita/d and 112 l/capita/d. It was found that the seasonal variation had significant influence in the water usage pattern. As per the results, the average total water consumption for both dry and wet seasons were 124 l/capita/d and 106 l/capita/d respectively. According to the seasonal variation toilet, kitchen, clothes washing, bathing and outdoor end use consumption were 18, 23, 30, 34 and 2 l/capita/d for dry season and 14, 18, 30, 22 and 2 l/capita/d for the rainy season. However it was found that the toilet and kitchen water uses were statistically significant with the season, while only total water use was statistically
significant with the region. It was also found that the total water consumption has no relationship with the water pressure.

5. ACKNOWLEDGEMENT

This work was supported by Hitotsubashi University and Ochanomizu University in Japan.

6. REFERENCES


