Mosaic analysis for personal water consumption in residential buildings in Hong Kong

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Abstract. This paper investigates the daily per capita residential water use based on the demographic and socio-economic factors described by Mosaic Hong Kong and provides insights into future water supply planning. A survey was conducted to collect information on household water use behaviours and water consumption patterns. The survey results indicate that considerable consumption differences (in the range of 115.6 to 167.7 litres per person per day) exist among the Mosaic Groups, and the average daily per capita residential water consumption is estimated to be 139.6 litres per person per day. The results also reveal that the daily per capita water consumption is inversely proportional to household size in the range of 2 to 6. Moreover, consumption differences among housing types and districts are reported.

1. Introduction

Water is an essential resource for residential uses including drinking, cooking and sanitation. As populations grow, the demand for water mounts. Key determinants of household water use include a range of socio-demographic factors such as household income, location, occupancy, and water appliance characteristics [1, 2]. An important indicator for the management of urban water resources is domestic water consumption per capita [3]. The reported amounts of domestic water consumed per capita per day (excluding toilet flushing) vary from place to place, e.g. 65 to 175 litres in some European countries, 105 to 237 litres in USA, and 120 to 500 litres in some high-rise Asian cities [5].

Subgroup demographic data is informative for demand side management of water resources. In Japan, the targeted per capita per day consumption values are 120 litres and 100 litres for urban and village areas [6]. Wu *et al.* [7] indicated water saving measures were contributors to water consumption structure. Morote *et al.* [8] reported per-resident daily water consumptions of various income groups ranged between 72–149 litres. Urban typology would be a factor contributing to the water consumption. Water demand management relies on geo-demographic water consumption patterns [9].

In this study, the daily per capita residential water use based on the Mosaic Hong Kong is investigated. Mosaic Hong Kong is a geo-demographic segmentation system that classifies all Hong Kong households and neighbourhoods into 10 groupings that share similar demographic and socio-economic characteristics with explanation shown in table 1 [4]. The system is well-developed with socio-economic data available. This paper investigates the daily per capita residential water use based on the demographic and socio-economic factors described by Mosaic Hong Kong.

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Table 1. Mosaic Hong Kong Groups [4].

Mosaic Group *i*	Description	Details	Percentage Population ϕ
A	Upper Echelons	wealthy families with an upscale and privileged lifestyle	11.0%
B	Well-to-do	well-off couples and families enjoying a comfortable lifestyle	5.2%
C	Emerging Middle Cass	stable and educated families of moderate affluence	15.2%
D	Suburban Locals	diverse income households in old towns and suburban outskirts	11.5%
E	Compact City Life	families focused on budget in high density city areas	8.2%
F	Comfy Subsidized Homes	mid-to-low income families living in urban and suburban subsidized homes	17.0%
G	Grass Roots Living	average families in affordable public blocks	10.9%
H	Community Challenge	unskilled older families living in urban public housing complexes	10.1%
I	Grey Perspectives	modest seniors and retirees in very old public blocks and communities	10.2%
J	Communal Homes	non-income earning communities including elderly homes, monasteries, prisons and university residences	0.7%

2. Survey study

An interview survey of household water use based on a method from previous studies was conducted in this study [10, 11]. Randomly selected residents of some high-rise residential buildings in Hong Kong were invited. The number of respondents was 61 and the survey period was six months from October 2016 to March 2017. The survey covered: (1) personal information of the respondents; (2) water use behaviours; and (3) water consumption patterns for shower, tap and washing machine.

In the survey, personal information was collected to determine the demographic and socio-economic characteristics of all respondents. Besides, respondents were asked not only to provide information of the appliance usage patterns on the day prior to the interview, but also to record the hourly appliance usage patterns on weekdays, Sundays and holidays. For each installed appliance, its type, physical size, brand name and usage frequency were recorded. The average time between appliance demands was surveyed. Average flow rates of water taps installed at the kitchen sink, washbasin, shower and bath were measured with simple operations by the respondents; refilling times of each water closet (WC) cistern were measured as well. Floor area of each apartment was obtained from the facilities management, direct measurement, or record drawings of piping arrangements. To ensure data quality, repeated surveys were performed on the showerheads, water taps and washing machines.

3. Results and discussion

Figure 1 shows the demographic and socio-economic characteristics of the respondents according definition of Mosaic Hong Kong [4]. No respondents from Mosaic group A, which monthly employment earnings per family was over US$10,000, were surveyed. Nearly half of the respondents (48%) were living in public rental housing, while 26% of them were living in subsidized home ownership housing and another 26% in private permanent housing. The household size ranged from 2 to 6 persons (denoted as head, ‘hd’). The average household size, which was 3.98 hd with a standard deviation (sd) of 0.87 hd, was slightly lower (p<0.05, t-test) than the figure of 4.45 hd (sd=1.3 hd) from a survey performed 10 years ago [10]. Moreover, 60%, 24% and 16% of the respondents were

living in the New Territories, Kowloon and on Hong Kong Island respectively. A majority of respondents (29%) were in Mosaic Group G (i.e. Grass Roots Living); and both Groups F (i.e. Comfy Subsidized Homes) and H (i.e. Community Challenge) consisted of 16% of the respondents. As illustrated in figure 1(d), the survey sample comprised Mosaic Groups B to H and that represented 78% of the Hong Kong population.

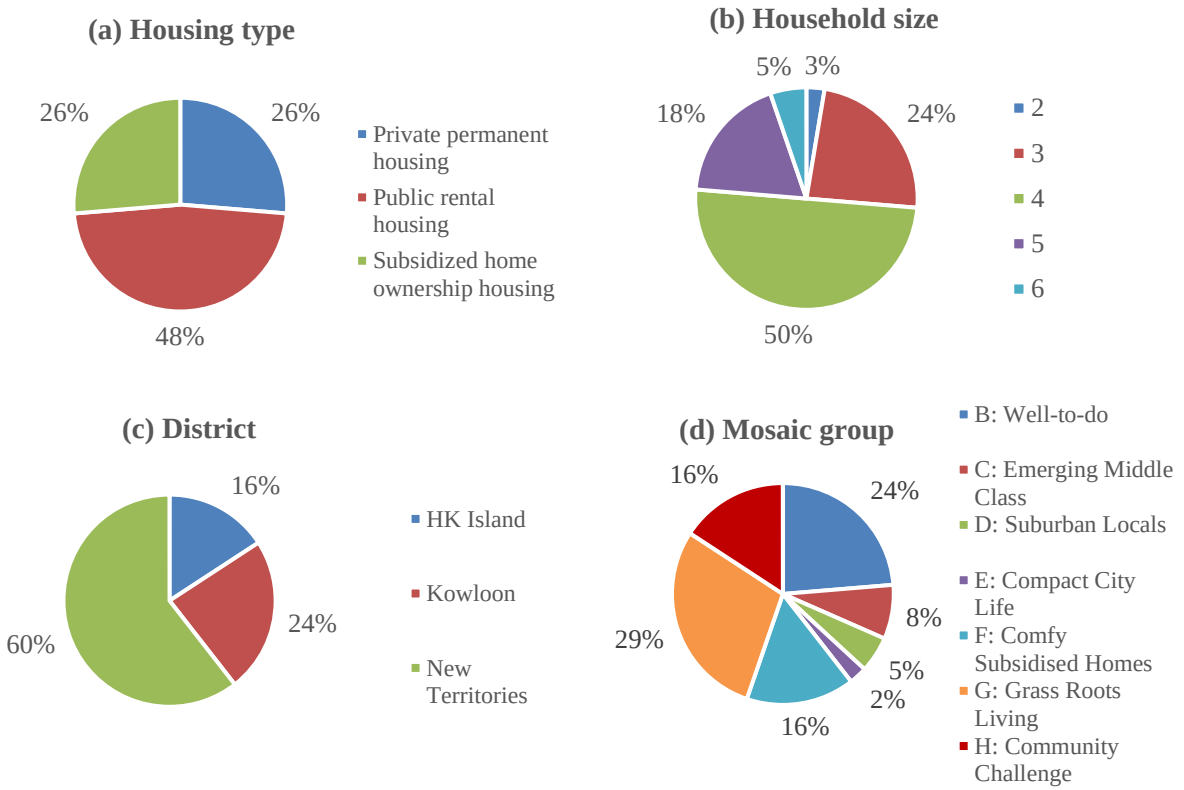

Figure 1. Demographic and socio-economic characteristics of the respondents.

The daily per capita residential water use can be determined from the total household water consumption recorded in the survey period divided by the household size and the number of days in that period. The results ranged from 63 to 272 litres per head per day (L/hd/d), with an average value of 140.9 L/hd/d (sd=47.4 L/hd/d); and they were found to be lognormally distributed ($p>0.05$, *w*/*s* test). The survey year-round average of this study (i.e. 140.9 L/hd/d) was significantly greater than the survey average (130 L/hd/d) in four winter months reported by the Hong Kong Water Supplies Department in 2011 ($p<0.05$, *t*-test) [12].

Figure 2 exhibits the daily per capita residential water consumption values V for different housing types, household sizes and districts. Consumption differences can be seen among housing types and districts ($p\leq0.05$, *t*-test). A significant downward trend of V against household size can also be seen in figure 2 (correlation coefficient $R=-0.998$; $p<0.01$, *t*-test). This study reported that the per capita water consumption decreased with household size at an average reduction rate of 20 litres per extra household member per day.

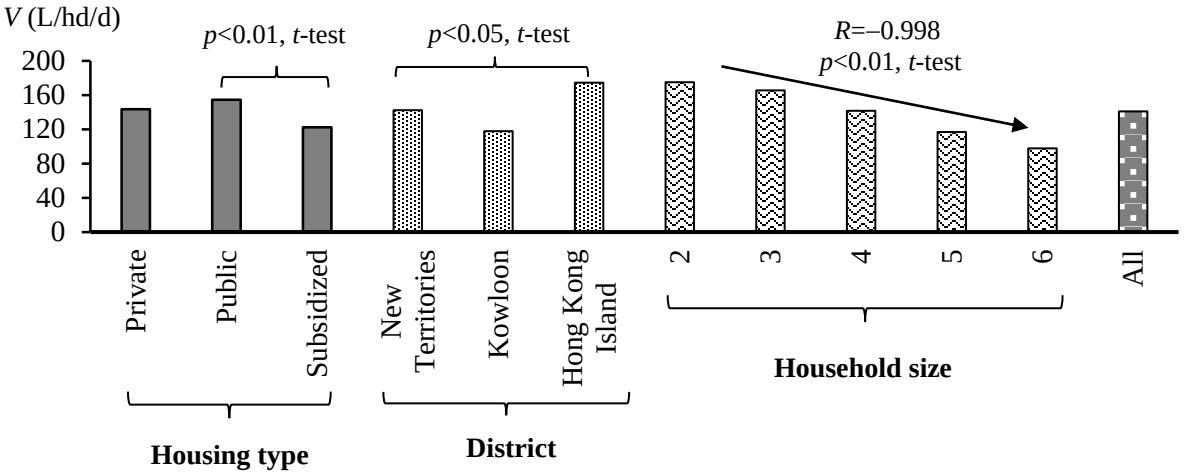

Figure 2. Daily per capita residential water consumption *V*.

Table 2. Daily per capita residential water consumption values *V* for Mosaic Groups.

Mosaic Group *i*	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Sample Size**
B	60.6	0.1366	0.4693$^{\#}$	0.3788	0.3954	0.4474	0.1416	11
C	1.1294	22.7	0.1252	0.0097**	0.0624*	0.0974*	0.0059**	9
D	0.0788	1.2286	5.3	0.1423	0.4649$^{\#}$	0.4387	0.2081	2
E	0.3157	2.7814	1.2999	21.3	0.1109	0.3430	0.3690	3
F	0.2689	1.6099	0.0902	1.2889	28.2	0.3293	0.0382**	11
G	0.1335	1.3352	0.1567	0.4112	0.4472	58.4	0.1478	16
H	1.1060	2.8426	0.8520	0.3439	1.8795	1.0703	50.1	9
Average V_i	139.8	115.6	136.3	157.2	134.4	142.9	167.7	140.9

Upper: *p*-value, 1-tail *t*-test; $^{*}p<0.1$, $^{**}p<0.05$, $^{\#}p>0.9$, 2-tail *t*-test. Lower: *t*-test absolute value. Diagonal: standard deviation.

Table 2 summarizes the daily per capita residential water consumption values for Mosaic Groups B to H, with group averages V_i range from 115.6 L/hd/d to 167.7 L/hd/d. Significant different consumptions are reported for Mosaic group C from groups E, F, G, H ($p<0.1$, *t*-test) but no difference between groups B&D and between groups D&F are found ($p>0.9$, *t*-test). The result shows significant variations probably associated with Mosaic groups although the sample size is too small to make conclusive judgement. A more extensive investigation on Mosaic water consumptions is thus recommended.

By applying weighting of the proportion of population ϕ in table 1, the average *V* is estimated to be 139.3 L/hd/d with an expression shown below,

$$V = \frac{\sum_i \phi_i V_i}{\sum_i \phi_i} \quad (1)$$

It is higher than the one used in Japan cities (120 L/hd/d) but compatible to survey figures made to some cities in Germany (129 L/hd/d) and Koszalin (129.3 L/hd/d) [5, 6].

4. Conclusions

This paper investigated the daily per capita residential water use based on the demographic and socio-economic factors described by Mosaic Hong Kong. A survey was conducted to collect information on household water use behaviours and water consumption patterns. The survey results indicated that there were considerable consumption differences (in the range of 115.6 to 167.7 litres per person per day) among the Mosaic Groups, and the average daily per capita residential water consumption was estimated to be 139.6 litres per person per day. The results also revealed that the daily per capita water consumption was inversely proportional to household size in the range of 2 to 6. Moreover, consumption differences among housing types and districts were reported. Despite the small survey sample size, the findings of this paper provide insights into future water supply planning. A more extensive investigation on Mosaic water consumptions is thus recommended.

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