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.
### Table 1. Mosaic Hong Kong Groups [4].

| Mosaic Group | 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 Class | 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 ($p \leq 0.05$, $t$-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 | B      | C      | D      | E      | F      | G      | H      | Sample Size |
|--------------|--------|--------|--------|--------|--------|--------|--------|-------------|
| i            |        |        |        |        |        |        |        |             |
| 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 | 0.0837 | 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 $\phi$ in table 1, the average $V$ is estimated to be 139.3 L/hd/d with an expression shown below,

$$V = \frac{\sum_i \phi_i V_i}{\sum_i \phi_i}$$  \hspace{1cm} (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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References
[1] Lazarova V, Hills S and Birks R 2003 Using recycled water for non-potable, urban uses: a review with particular reference to toilet flushing. Water Sci Tech—W Sup 2003 3(4) 60–77
[2] Willis RM, Stewart RA and Giurco DP 2010 End use water consumption in households: impact of socio-demographic factors and efficient devices. J Clean Prod. 60 107–15
[3] Mui KW, Wong LT and Law LY 2007 Domestic water consumption benchmark development for Hong Kong. Build Serv Eng Res T 28(4) 329–35
[4] Experian Mosaic Hong Kong 2010 Mosaic Global, UK. Available: http://www.experian.com.hk/assets/mosaic/mosaic-brochure-hong-kong.pdf (Accessed on 1 October 2016)
[5] Bergel T, Kotowski T and Woyciechowska O 2016 Daily water consumption for household purposes and its variability in a rural household J Ecol Engg. 17(3) 47–52
[6] Toyosada K 2016 The state of Vietnamese household plumbing equipment and related issues The 3rd Asian Plumbing System Symposium of Japan Society of Plumbing Engineers (NPO-JSPE) 21 Nov. Tokyo Japan 100–3
[7] Wu H, Wang X, Shahid S, and Ye M 2016 Changing characteristics of the water consumption structure in Nanjing City, Southern China Water 8 314–28
[8] Morote AF, Hernández M, Rico AM 2016 Causes of Domestic Water Consumption Trends in the City of Alicante: Exploring the Links between the Housing Bubble the Types of Housing and the Socio-Economic Factors Water 8 374–92
[9] Klassert C, Sigel K, Gawel E, and Klauer B 2015 Modeling Residential Water Consumption in Amman: The Role of Intermittency, Storage, and Pricing for Piped and Tanker Water Water 7 3643–70
[10] Wong LT and Liu WY 2008 Demand analysis for residential water supply systems in Hong Kong HKIE Trans 15(2) 24–8
[11] Wong LT and Mui KW 2007 Modeling water consumption and flow rates for flushing water systems in high-rise residential buildings in Hong Kong Build Environ 42(5) 2024–34
[12] Hong Kong Water Supplies Department 2011 Domestic Water Consumption Survey—Key Survey Findings—Fact Sheet Hong Kong Government: Hong Kong, China