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Barriers to Adoption of Water-Saving Habits in Residential Buildings in Hong Kong

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Abstract: The fresh water supply is finite, but the fresh water demand is infinite. A sustainable supply of fresh water is emerging as one of the most critical resource issues in the world. Hong Kong is one of the highest per capita fresh water users in the world. This has led to many government initiatives to promote water-saving habits in Hong Kong. However, after almost a decade of efforts, there has been no obvious reduction in consumption. Little has been done to identify the reason for this. Through the use of questionnaire surveys, site measurements, and controlled experiments, the aim of this study is to investigate the level of adoption of different water-saving habits, the most influential water-saving habits, and the barriers to the adoption of water-saving habits in residential buildings in Hong Kong. It was found that if the policies are targeted to break the identified barriers, then there is a potential for reducing the total domestic fresh water consumption in Hong Kong by 14.7%. It was also found that the knowledge of water scarcity and good water use habits are not the barriers to the adoption of water-saving habits in Hong Kong households. Rather, the government should draw public's attention to the environmental impact of water usage and the high fresh water consumption level of Hong Kong people to break the knowledge barrier and should re-examine the water tariff to break the motivation barrier. The results of this study provide useful information for decision makers in the context of water conservation in Hong Kong as well as elsewhere in the world.

Keywords: domestic fresh water consumption; water-saving habits; potential savings; barriers; policy gap

1. Introduction

The fresh water supply is finite, but the fresh water demand is infinite. A sustainable supply of fresh water is emerging as one of the most critical resource issues in the world [1]. Previous studies are focused on investigating measures to reduce water consumption [2–4] and to increase water supply [5–7]. Amongst measures to reduce water consumption, campaigns to encourage the adoption of water-saving habits has been identified as an effective policy.

Water scarcity is a big problem in Hong Kong. In 2015, Hong Kong's per capita water resources were 133 m^3 [8], while in mainland China it was 2039.2 m^3 [9]. Hence, the supply of water from Dongjiang in mainland China was started in 1965, and these supplies now account for about 74% of the total water supply [10]. Despite Hong Kong relying heavily on Dongjiang for stable water supply, Hong Kong's domestic per capita water consumption was high at 124.7 Litre/day (L/d) in 2012. The figure was higher than many other global cities like Singapore, Sydney, and Madrid, in which the average water consumption was 110 L/d at the same time.

In 2008, the Hong Kong Water Supplies Department (WSD) introduced a territory-wide total water management strategy [11,12]. The strategy is to encourage the adoption of water-saving habits. A follow-up survey was conducted in 2011, and 98.8% of the households claimed that they supported a consumption cut [13]. At the end of 2014, expert consultants were employed to review the total water management strategy, but it had not yet been completed at the time of writing [14]. However, what can be seen is that after seven years of implementation, the per capita fresh water consumption figure was increased to 132 L/d in 2015. This corresponds to a total growth rate of 5.9 % (124.7 vs. 132 L/d) [8,10]. The figure clearly shows that the efforts made are not sufficient to reduce water consumption in Hong Kong.

To achieve water savings, many studies have suggested encouraging the adoption of water-saving habits [15,16]. Habit is the usual way of behaving or a fixed way of reaction that tends to repeat regularly and occur unconsciously [17]. Kiang conducted a study in Singapore and identified a strong linkage between users' habits and water conservation [18]. Randolph and Troy used telephone interview surveys supplemented by focused group interviews to search for ways to reduce water use in Australia. It was found that raising public consciousness on this issue so as to change the habits can be an effective measure [19]. Adams [20] conducted an evaluation based on data collected from the 2010 General Social Survey in the United States. It was concluded that people who have pro-environmental behavior have a greater tendency to conserve water compared to those who are not. Gilg and Barr [21] employed a questionnaire to identify the British people's environmental habits and concluded that water saving policies and initiatives should take into account people's lifestyles and behaviors. Domene and Saurí [22] conducted a case study in the Metropolitan region of Barcelona to investigate the relationships between urbanization and residential water use. The results confirmed that user habits play an important role in domestic water use. Jorgensen et al. developed a water use model to investigate the influence of previous and current behaviors on water use in Australia and concluded that factors affecting water use habits should be the future research focus [23].

To drive for habit change, Martínez-Espiñeira and García-Valiñas [24] identified the need for more educational campaigns. Seyranian et al. [25] also identified that knowledge deficit is one major barrier. Levin and Muehleisen [26], however, categorized the obstacles as knowledge barriers and motivation barriers.

Habit formation is a long process. It is socio-demographically dependent [27,28]. To encourage adoption of water-saving habits to solve the water scarcity problem in Hong Kong, there is a need to identify the most influential water-saving habits to target Hong Kong households, the associated savings, and the barriers to their adoption. Apparently, this information is not available in published literature.

Through the use of questionnaire surveys, site measurements, controlled experiments, and statistical analyses, the aim of this study is to investigate the adoption of water-saving habits in residential buildings in Hong Kong. The focus was on water use of showerheads and kitchen and toilet faucets because they contribute to 46.6% and 43.3% of the domestic fresh water consumption in Hong Kong, respectively [13]. The results of this study provide useful information for decision makers in the context of water conservation in Hong Kong as well as elsewhere in the world.

2. Methods

2.1. Questionnaire Survey

Questionnaire surveys were carried out from October 2015 to February 2016 with due consideration of the ethical issues. In the surveys, the convenience sampling approach was adopted for selecting households for participation [29]. Conducting the survey on a household basis is according to a study by Fielding et al. [15] concluding that the dynamics of the household play an important part in domestic water use. In the convenience sampling, families of undergraduate students of the Hong Kong Polytechnic University were selected as the candidate households to participate in the survey because they reside almost everywhere in Hong Kong. A total of 216 undergraduate students from different academic departments of the university volunteered to serve as candidate household. They were briefed on the contents and the objectives of the questionnaires and were asked to clarify any misunderstanding. They were also informed about their right to terminate the survey at any time and the confidentiality of their personal data.

To ensure the respondents were aware that they were treated as the representative households and the majority view shall be taken as the response, a self-declaration statement was added.

2.1.1. Minimum Sample Size

The minimum sample size was determined based on Equation (1) as recommended by Franklin [30]. This equation has been widely used in similar research studies [31–33]. Based on the number of domestic households in Hong Kong, that is, 2.504 million [34], and the number of undergraduate students, that is, 120,000 in 2015/16 [35], the probability of a household with an undergraduate student (p) is 0.048. Assuming the sampling error (e) to be ±5 %, and for achieving confidence of 95%, the minimum sample size ($S_{\min}$) can be estimated by Equation (1), which is 70.

$$S_{\min} = (Z^2 \cdot p \cdot (1 - p))/e^2 \tag{1}$$

p = probability of a household with undergraduate students
Z = test statistic which is 1.96 for 95% confidence level

Representativeness of the responding households is checked by a statistical test of significance. Due consideration is given to the existence of single-person households in Hong Kong.

2.1.2. Survey Questions

The questionnaire was written in Chinese and was divided into four parts, aiming to ascertain the adoption level of water-saving habits of Hong Kong households and the barriers to their adoptions. Water-saving habits are good practices promoted by the Hong Kong Government and elsewhere in the world [21,23], which are summarized in Table 1.

Table 1. Water-saving habits.

No.	Habits
H1	Turn off the tap while cleaning teeth
H2	Washing face by filling up the wash basin instead of using running water
H3	Take showers instead of baths
H4	Take quick showers
H5	Turn off the shower while soaping
H6	Defrost food early instead of thawing food under running water
H7	Wash dishes in a pan of water instead of under running water
H8	Wash vegetables and fruits in a pan of water instead of under running water
H9	Run washing machine with a full load
H10	Adjust the washing time/water level for different types/amounts of clothes

The questions were constructed either in forced-choice format or in numeric response format for collection of both quantitative and qualitative data of the studied households. A pilot test on the questionnaire was carried out with 11 households to modify and refine the questionnaire. After refining, 216 copies of the questionnaires were sent to candidate households of which 72 households responded, which satisfied the minimum sample size requirement.

Part 1 collects their demographic characteristics which include the household size and the housing district. Part 2 gathers their adoption of water-saving habits. Part 3 collects the water bills. Part 4 is to find out the barriers for adoption of water-saving habits. Based on the results in Part 2, and the water bills collected in Part 3, the take-up rate of water-saving habits and the influential water-saving habits that suit Hong Kong people's socio-demographic characteristics can be ascertained.

While for Part 4, it has been pointed out that the key barriers to the adoption of water-saving habits are the knowledge [24–26] and motivation barriers [26]. However, as habits tend to occur subconsciously, people may not know why and how they have acquired the habits [36]. Thus, instead of asking the respondents to name the barriers, the questions were structured to identify the barriers from their consumption patterns.

According to studies, knowledge barriers include a lack of awareness of the following issues: (1) water scarcity [24]; (2) actual consumption; (3) environmental impact [37]; (4) good water use habits [15]. The motivation barrier may arise due to the relatively low water tariff as compared to other utility bills [26]. It is because the water supply is considered as one of the social amenities and services, so it is often heavily subsidized [26].

Mapping of barriers to the survey questions (Part 4) is shown in Figure 1. It can be seen that there are altogether nine questions. All questions were structured in a forced-choice format for the collection of quantitative data. The respondents were required to indicate "Yes" and "No" to indicate their agreement with the statement.

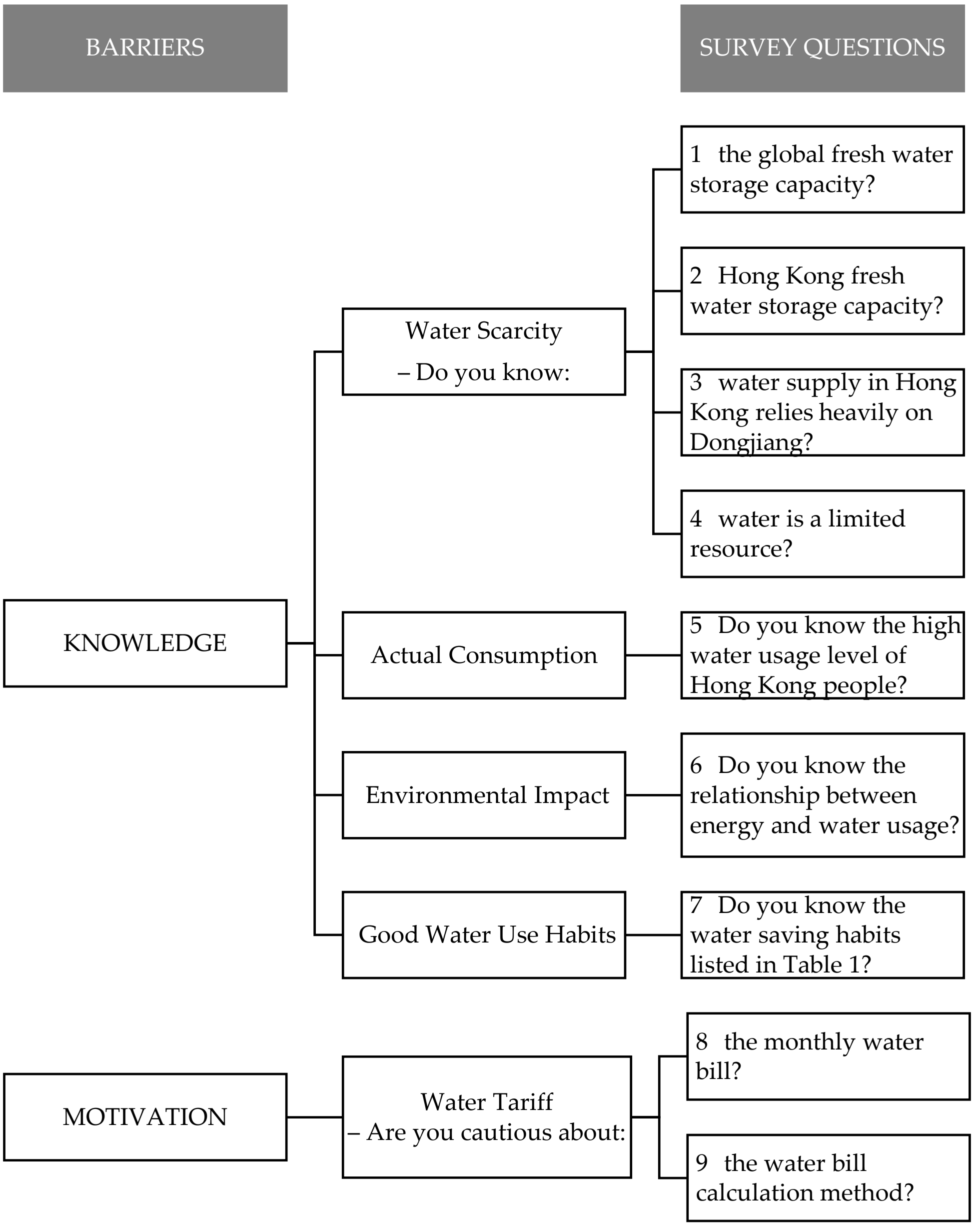

Figure 1. Mapping of the barriers to the survey questions (Part 4).

2.2. Controlled Experiments and Site Measurements

Controlled experiments and site measurements were used to ascertain the potential territory-wide water saving associated with the adoption of water-saving habits.

The potential territory-wide habits-related water saving can be determined by Equation (2):

$$S_T = N \sum_{i=1}^{n} (H_i \cdot (1 - R_i)) \quad (2)$$

where S_T is the habits-related water-saving potential in Hong Kong (m^3/d); N is the total number of domestic households in Hong Kong (=2.504 million) [34]; ΔH_i is the amount of saving achieved by the adoption of the influential water-saving habit i (m^3 per day per household); R_i is the take-up rate of the influential water-saving habit i determined in the questionnaire survey, and n is the number of influential water-saving habits.

To determine ΔH_i, a family of four from among the responding households was selected for a controlled experiment and site measurement. The family was selected because they had the typical characteristics of households in Hong Kong, which are: (1) household size of four; (2) composed of parents and 2 unmarried children in an age range of 20 to 54; (3) residing in public housing; (4) flat area less than 40 m^2 [38]. To ensure accuracy in the controlled experiment and site measurement, all measurements were repeated three times [39].

The controlled experiment was conducted in February-March 2016 for a period of four weeks. The family members were requested to adopt the influential water-saving habits identified in the habit survey in the first two weeks and the water-inefficient habits in the following two weeks. The daily water consumption was recorded by a water meter connected to the main water supply point. The water meter was installed according to WSD's requirements [40]. The metered consumption was down to 0.1 L.

The family members were also asked to record their frequency and duration of use for different activities. Together with the flow rates ascertained by site measurements, water consumption for the two studied periods was calculated.

A direct reading plastic rotameter was used to measure the flow rate (L/min) of the showerhead when individual family members were taking a shower. A stopwatch was used to record the showering and soaping durations. A simple container, a measuring cylinder, and a stopwatch were used to measure the flow rate of the kitchen and toilet faucets. Container volumes were determined by filling up the measuring cylinder. Prior to the measurements, the family members were invited to regulate the faucets to their usual level.

The metered readings were used to validate the calculated results.

The accuracy of the measurement instruments is summarized in Table 2.

Table 2. Instruments used for in-situ measurement.

Parameters	Instrument	Brand *	Model	Accuracy *
Water Consumption	Water Meter	WSD approved	M08-218656	±3%
Water Flow Rate	Plastic Rotameter	Omega	FL-86C	±6% FS/± 1%

* WSD is Water Supply Department and FS is Full Scale.

3. Results and Discussions

3.1. Representativeness of the Responding Households

The demographic characteristics of the responding households are summarized in Table 3. The collected data were codified and summarized for a preliminary analysis. The preliminary analysis was to confirm if the responding households can collectively represent households in Hong Kong. A statistical test of significance was employed to compute the test statistics of the household size and the domestic per capita water consumption, as shown in Equation (3).

$$Z_i = \frac{\overline{x}_i - \mu_i}{\sigma_i / \sqrt{S}} \quad (3)$$

where,

$\overline{x}_i$ = sample mean of the ith parameter
μ_i = population mean of the ith parameter
σ_i = standard deviation of the ith parameter
S = number of samples
Z_i = test statistic of the ith parameter

Table 3. Demographic characteristics of the responding households.

Family Size		Housing District *				Daily Consumption (L/s.capita) *	
No. of Persons	Frequency	District	Frequency	District	Frequency		
6	1	Central	0	Islands	0	Maximum	304.8
5	3	Eastern	11	Kwai Tsing	1	Minimum	67.2
4	21	Southern	1	North	4	Median	125.5
3	31	Wan Chai	2	Sai Kung	4	Mean	136.8
2	16	Kowloon City	10	Sha Tin	4	Standard deviation	44.5
1	0	Kwun Tong	6	Tai Po	2		
		Sham Shui Po	2	Tsuen Wan	5		
		Yau Tsim Mong	3	Tuen Mun	11		
		Wong Tai Sin	0	Yuen Long	6		

* Hong Kong is geographically divided into 18 housing districts; L/s.capita is Litre/second.person.

In the analysis, it was hypothesized that there was no difference between the sample mean and the population mean to claim representativeness of the candidate households. Considering the sample data and the government statistics given in Table 4 [41], it can be seen that the computed Z values for household size (Z_{HZ}) and domestic per capita water consumption (Z_{CON}) are -0.19 and 0.915, respectively. Taking the generally stated significance level of 0.05 as being statistically significant, the corresponding critical region, as obtained from the cumulative normal distribution curve, is 1.96. It can be concluded that the computed Z_{HZ} and Z_{CON} fall beyond the critical region to support the claim, and the population mean can be used in the subsequent analysis, that is, household size equals to the Hong Kong average of 2.8. The domestic per capita water consumption is 132 L/d.

Table 4. Population and sample mean.

Parameter	Population Mean μ	Sample		No. of Samples S	Test Statistic Z
		Mean $\bar{x}$	Standard Deviation σ		
Household Size	3.21	3.19	0.88	72	-0.19
Domestic per Capita Water Consumption (Litre/day)	132	136.8	44.5	72	0.915

Note that the government statistics on household size (Table 4) have been adjusted to 3.21 by removing the 0.46 million single-person households (out of 2.504 million households) who have no affiliations with undergraduate students.

3.2. Take-Up Rate of Water-Saving Habits

The take-up rate (R_i in Equation (2)) of each of the ten water-saving habits is summarized in Table 5. It can be seen that amongst them, the highest is “Take showers instead of baths” (91.7%). This is reasonable because over 30% of the population in Hong Kong resides in public housing, where shower cubicle is a standard provision [42]. The lowest is “wash face by filling up the wash basin instead of using running water” (18.5%).

Table 5. Take-up rate of ten water-saving habits.

Abbreviation	Habit	Take-Up Rate R_i
H_T	Turn off the tap while cleaning teeth	45.8%
H_F	Washing face by filling up the wash basin instead of using running water	18.5%
H_S	Take showers instead of baths	91.7%
H_{QS}	Take quick shower	48.1%
H_{SP}	Turn the water off while soaping	63.7%
H_{DF}	Defrost the food early instead of thawing food under running water	88.9%
H_D	Wash dishes in a pan of water instead of under running water	43.1%
H_V	Wash vegetables and fruits in a pan of water instead of under running water	52.8%
H_W	Run washing machine with a full load	73.6%
H_{WT}	Adjust the washing time/water level for different types/amounts of clothes	59.3%

3.3. The Influential Water-Saving Habits

To identify water-saving habits that affect domestic fresh water consumption the most, the bivariate correlations procedure was employed to compute the Pearson correlation coefficients between each water-saving habit and per capita water consumption (L/d.capita). The value 0 or one was assigned to indicate the absence or presence of a water-saving habit.

According to Pearson correlation coefficients, at 0.01 significance level (two-tailed), correlations between per capita water consumption and "Turn off the tap while cleaning teeth" (H_T) (−0.697), "Take quick shower" (H_{QS}) (−0.567), "Turn the water off while soaping" (H_{SP}) (−0.491), and "Wash dishes in a pan of water instead of under running water" (H_D) (−0.587) were significant and confirmed that they are the four influential water-saving habits that impact domestic fresh water consumption. It can be seen that all correlation coefficients are negative. This is judged reasonable because the presence of a water-saving habit can obviously reduce domestic per capita water consumption. It is also reasonable to note that washing machine-related habits (H_W and H_{WT}) are not influential because water consumption of this activity contributes only 9% to the fresh water consumption in Hong Kong [13].

3.4. Prediction of Overall Saving in Hong Kong

The measured results are summarized in Table 6, illustrating the water consumption in the absence and presence of a water-saving habit and the associated savings. The frequency of use is determined based on the recorded usage pattern of the household members.

Table 6. Measured water consumption.

Influential Habit*	Water Consumption (L/use)		Saving (L/use)	Frequency of Use (times/d)	Saving ΔH_i (L/d)	
	Absence	Presence			Measured	Adjusted
H_T	6.608	0.975	5.633	8	45.1	31.5
H_{QS}	33.615	27.69	5.925	4	23.7	16.6
H_{SP}	7.5	0	7.500	4	30.0	21.0
H_D	42	14.859	27.141	2	54.3	38.0
Total					153.0	107.1

H_T: Turn off the tap while cleaning teeth; H_{QS}: Take quick shower; H_{SP}: Turn the water off while soaping; H_D: Wash dishes in a pan of water instead of under running water.

The metered readings, as recorded by the water meter from midnight to midnight each day, of the two controlled experiment periods are summarized in Table 7 and compared in Figure 2. It can be seen that the total consumption in the two periods is 4.67 m^3 and 6.78 m^3, respectively, indicating a total saving of 2.11 m^3 over a period of two weeks when the four influential water-saving habits are present. This corresponds to a saving of 151 L/d.

The small difference in the measured and metered results (151 L vs. 153.1 L) confirms the reliability of the measured saving for each individual water-saving habit.

Table 7. Metered readings.

Water-Saving Habits				Water-Inefficient Habits			
Date	Meter Reading *	Consumption (L)	Cumulative Consumption (m^3)	Date	Meter Reading *	Consumption (L)	Cumulative Consumption (m^3)
23-Feb	11864100		0	10-Mar	11917260	621.0	0.621
24-Feb	11867514	341.4	0.3414	11-Mar	11923470	408.4	1.0294
25-Feb	11871127	361.3	0.7027	12-Mar	11927554	481.1	1.5105
26-Feb	11874232	310.5	1.0132	13-Mar	11932365	443.3	1.9538
27-Feb	11877647	341.5	1.3547	14-Mar	11936798	508.6	2.4624
28-Feb	11881461	381.4	1.7361	15-Mar	11941884	422.6	2.885
1-Mar	11885159	369.8	2.1059	16-Mar	11946110	381.8	3.2668
2-Mar	11888275	311.6	2.4175	17-Mar	11949928	447.7	3.7145
3-Mar	11892032	375.7	2.7932	18-Mar	11954405	424.3	4.1388
4-Mar	11894464	243.2	3.0364	19-Mar	11958648	535.2	4.674
5-Mar	11898219	375.5	3.4119	20-Mar	11964000	514.8	5.1888
6-Mar	11901441	322.2	3.7341	21-Mar	11969148	540.4	5.7292
7-Mar	11905399	395.8	4.1299	22-Mar	11974552	510.4	6.2396
8-Mar	11908661	326.2	4.4561	23-Mar	11979656	541.6	6.7812
9-Mar	11910771	211.0	4.6671	24-Mar	11985072		

* 8-digit number shown on the water meter. Water consumption in a period is the difference between two metered readings.

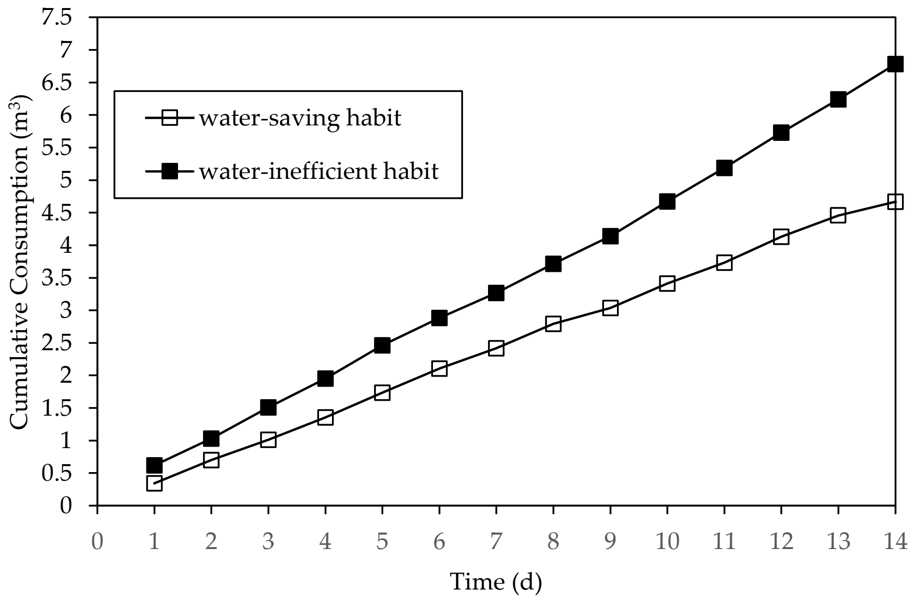

Figure 2. Metered consumption for the two two-week measurement periods.

As the savings (L/d) were derived from a family of four members, they were therefore adjusted according to average household size (=2.8 people) to become ΔH_i (Table 6) for prediction of the overall saving in Hong Kong by Equation (2). Results are summarized in Table 8. It can be seen that the overall savings amount to 14.7% of the total domestic fresh water consumption in Hong Kong.

Table 8. Prediction of overall water-saving.

Influential Habit	Saving ΔH_i (L/d)	Take-Up Rate R_i	Saving for 2.504 Million Households (m^3/d)
H_T	31.5	45.80%	42,818.4
H_{QS}	16.6	48.10%	21,563.4
H_{SP}	21.0	63.70%	19,091.0
H_D	38.0	43.10%	54,146.4
Total Saving S_T			137,619.2
% of Saving = 137,619.2/939,066 # × 100% =14.7%			

Total annual domestic fresh water consumption of the residential sector in Hong Kong = 132/1000 (m^3 /person) × 711,4136 (population of Hong Kong) = 939,066 m^3. H_T: Turn off the tap while cleaning teeth; H_{QS}: Take quick shower; H_{SP}: Turn the water off while soaping; H_D: Wash dishes in a pan of water instead of under running water.

It is interesting to note that if Hong Kong people are encouraged to adopt the four influential water-saving habits to realize the 14.7% saving ($132 \times 0.853 = 112.6$ L/d), the domestic per capita consumption will just be comparable to other global cities of 110 L/d on average.

3.5. Barriers to the Adoption of Water-Saving Habits

Pearson correlation analysis was again employed to examine the correlations between the responses of the respondents in Part 4 and per capita water consumption. The value one or 0 was assigned to indicate "Yes" or "No" response.

It is noted that at a significance level of 0.01 (two-tailed), the correlations between per capita water consumption and "Q6—aware of the relationship between energy and water usage" (−0.631), "aware of the high water usage level of Hong Kong people" (−0.563), and "cautious about the monthly water bill" (−0.556) were significant and confirmed that they are the three most influential issues related to the adoption of water-saving habits. It can be seen that the correlation coefficients are negative. This is judged reasonable because an awareness of the identified issues can obviously reduce per capita water consumption. A relatively weak correlation is observed for other issues.

It can, therefore, be concluded that possessing the knowledge about water scarcity and good water use habits are not barriers to the adoption of water-saving habits. While knowing the actual consumption, the environmental impact, and a cautious attitude about the water bill amount are the three influential issues. Measures and policies should, therefore, be established to break these knowledge and motivation barriers.

3.6. Policy Gap

To break the barriers to adoption of water-saving habits in Hong Kong, a review on the government's initiatives has been done. It is noted that government initiatives are mainly educational and promotional activities undertaken by the WSD. The activities aim to boost public awareness of water scarcity and good water use habits [12]. On water scarcity, there are educational materials prepared for students of different learning levels from kindergarten to secondary school [43]. On good water use habits, water-saving tips are promoted on WSD's website [44] by a mascot called Water Save Dave [45], and there are a series of campaigns like "let's save 10 L water" and "water conservation week" [8]. However, little has been said about the high fresh water consumption level of Hong Kong people, the inter-relationship between energy and water usage, and the fact that water tariff in Hong Kong is heavily subsidized.

The review explains the knowledge and motivation barriers identified in Section 3.3 and reveals the need to boost public awareness on energy consumption related to water usage and the high fresh water consumption level of Hong Kong people to break the knowledge barrier and to re-examine the water tariff to break motivation barrier. As reflected from the success in raising the public's awareness of water scarcity and good water use habit, breaking the knowledge barrier will not be a difficult task. The concern is water tariff. Domestic consumers in Hong Kong are billed for their water charges every four months (121.64 days). The tariff structure consists of four tiers with progressively increasing prices of which the first tier of 12 m^3 is free of charge, the second tier of 31 m^3 is charged at HK\$4.16/m^3, the third tier of 19 m^3 is charged at HK\$6.45/m^3, and the fourth tier for any consumption above the level of 62 m^3 (summation of consumption in the first three tiers = 12 + 31 + 19) is charged at HK\$9.05/m^3 [46].

To re-examine the water tariff, there is a need to identify the true water production costs from source to waste treatment. However, such information has never been made known to the public. An attempt has been made to estimate the water production cost in Hong Kong based on the discrete information collected from different sources [46–49]. Results are shown in Table 9. It can be seen that water production cost (excluding waste treatment) is estimated at HK\$23.34/m^3, while the water price based on average consumption of households in Hong Kong (Table 10) is only HK\$3.15/m^3, which is less than one-seventh of the true water production costs.

Table 9. Water production costs in Hong Kong.

Production Costs		HK$/yr	HK$/yr/household	HK$/m^3		Remarks
Capital investment [47]		5062 million	2021.6 [1]	15.0 [2]		[1] Total number of households in Hong Kong = 2.504 million
Raw water [46,48]	Dongjiang (79%)			8.6	7.6 (Average)	[2] Consumption per year per household = 132 L/capita.d × 2.8 persons/household × 365 days = 135 m^3/year/household
	Local rainwater (21%)			4		
Energy cost for distribution system [49]				0.74 [3]		[3] Energy cost = 0.568 kWh/m^3 and Electricity Tariff = 1.3 HK$/kWh
Total Production Cost (HK$/m^3)				23.34 (= 8.34 if capital investment is excluded)		

Table 10. Water price and government subsidy in Hong Kong.

Water Price [46]	HK$/4-month	HK$/4-month	HK$/m^3	Remarks
	(Based on consumption of 45 m^3/household for 4-month) [1]			
first tier 12 m^3 free	0	141.9 (Total)	3.15	[1] Consumption per household for 4-month = 132 L/capita.d × 2.8 persons/household × 121.64 days = 45.0 m^3/household for 4-month
second tier (31 m^3 at HK$4.16/m^3)	31 × 4.16 = 129			
third tier (19 m^3 at HK$6.45/m^3)	(45 − 31 − 12) × 6.45 = 12.9			
fourth tier (above 62 m^3 at HK$9.05/m^3)	0			
Total Water Price (HK$/m^3)			3.15	
Government Subsidy (HK$/m^3) = Production Cost (Table 9) − Water Price			= 23.34 − 3.15 = 20.19 = 8.34 − 3.15 = 5.19 (if exclude capital investment)	

The raw water cost covers water treatment and water distribution cost in mainland China. The energy cost, which is rarely mentioned in literature, refers to the energy used in Hong Kong across the entire chain of operations for supplying water to consumers. The capital investment includes upgrading works of the slope in the reservoir areas [49], which have been designated as country parks for the purposes of nature conservation, countryside recreation, and outdoor education [50]. Thus, whether the expenses should be included in the production costs calculation is subject to debate. However, even after excluding this amount from the cost calculation, the government subsidy is still about two times the water price (8.34 vs. 3.15 HK$/m^3).

How the water tariff should be reformed is beyond the scope of this study. However, the government should take the initiative to carry out a comprehensive audit of Hong Kong's full water costs and to re-examine its water tariff.

4. Conclusions

Hong Kong, as one of the most densely populated cities in the world, is well known for its high-rise high-density residential buildings. Concerns about the high domestic fresh water consumption of Hong Kong households has increased in the last decade and has led to the introduction of a territory-wide total water management strategy by the government. However, almost a decade after the introduction, no obvious reduction in consumption has been observed. In this study, questionnaires were sent to 216 households, a controlled experiment was conducted at one of the representative households, and site measurements were conducted at 72 responding households to collect water use information. Representativeness of the 72 responding households was verified by statistical analysis. Based on the collected information, the adoption level of different water-saving habits was ascertained. The four most influential water-saving habits were identified, and the barriers to the adoption of the water-saving habits were determined. It was found that if the measures and policies are introduced to break the identified barriers, then there will be a potential saving of 14.7% of the total domestic fresh water consumption in Hong Kong. It was also found that the knowledge of water scarcity and good water use habits are not barriers to the adoption of water-saving habits in Hong Kong households. It was identified that the government should boost public awareness of environmental impact of water usage and the high fresh water consumption level of Hong Kong people to break the knowledge barrier and should re-examine the water tariff to break the motivation barrier. The results of this study provide useful information for decision makers in the context of water conservation in Hong Kong as well as elsewhere in the world.

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