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Development of a self-rating system for domestic water consumption in Malaysia

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Abstract. A positive growth in the global population would increase the need for clean water. Therefore, continuous, adequate, and sustainable clean water supply is a major concern in modern society. A highly effective approach to resolve this concern is to instil self-awareness in consumers. This study established a simple self-rating system for consumers to evaluate their domestic water usage. The rating classifications are 'Poor', 'Fair', 'Average', 'Good', and 'Excellent', based on a score established using statistical analysis. A high percentage of respondents received an Average (41.3%) or a Good (49.7%) rating. A lower percentage of respondents received a Fair (5.3%) or an Excellent (3.7%) rating. Minimising the frequency of indoor and outdoor activities, practising good water habits, including the use of water saving appliances such as dual-pump cisterns, buckets for showering and bathing, and rainwater harvesting systems are factors that contributed primarily to an Excellent rating. No respondent received a Poor rating, which suggests that there is intrinsic behaviour of good water usage and efforts to conserve water in the community. Consumers can become more aware of and motivated to use water saving practices when they can quantitatively rate their domestic water consumption thru the self-rating system developed in this study.

1. Introduction

Basin-based studies have focused on floods [1-4], droughts [5], and alternative water resources, particularly rainwater harvesting [6]. Such studies concluded that an increase in the global population would increase the need for food and clean water, shortages of which may deteriorate human health, ecosystems, and natural resources in specific areas [7]. Currently, a major concern of modern society is to ensure a continuous, adequate, and sustainable supply of water. The discussion on water supply also includes the aspects of quantity [8] and quality [9,10]. Studies on water quantity on a global or regional scale include water productivity scoring [11], water scarcity [7], and the impact of climate change on water quantity [12].

Scoring and rating systems for domestic water consumption usually concentrate on water appliances, square footage, and household composition. For example, the United States Environmental Protection Agency (USEPA) has developed WaterSense multifamily housing water assessment worksheet. This



scoring system assesses water usage per building or property by collecting input data such as property information; metering and billing; bathrooms, kitchens, and laundry facilities; landscaping and irrigation; pools; heating, ventilation and air conditioning (HVAC); and mechanical systems [13]. Another popular concept used primarily by architects, engineers, and town planners is the Green Building Index, which promotes healthier indoor environments and energy and water conservation.

Although building and property characteristics are important, one of the most significant factors contributing to water consumption is consumer behaviour at home. Therefore, self-awareness is essential for establishing sustainable, long-term, and effective water conservation behaviours [14]. Additionally, home water usage habits affect water usage in other facilities, such as schools, offices, and public amenities. Children typically learn water usage habits from their parents. Consequently, parents should lead by example, practising and nurturing good water habits at home.

To address this knowledge gap of consumer self-awareness about water usage habits, we developed a self-rating system to measure an individual's domestic indoor and outdoor water consumption and water saving elements. The proposed self-rating system enable a consumer to evaluate their domestic water consumption. The study area is a small suburban community that is comprised primarily of single-storey terrace houses, single- and two-storey shophouses, bungalows, semi-detached houses, and two-storey houses. There are 1,257 active consumers in the study area, making it a sizeable and suitable region in which to conduct this study. Similar communities exist throughout the country.

2. Methodology – Questionnaire development and survey management

This study collected qualitative and quantitative data. Statistical analysis was conducted based on the data collected from questionnaires to examine the residents' domestic water consumption and behaviour. A self-rating system was then developed to provide a rating to each respondent. The ratings were 'Poor', 'Fair', 'Average', 'Good', and 'Excellent', based on daily and weekly water-use activities.

Domestic indoor and outdoor water usage activities considered in this study are cooking, dishwashing, bathing/showering, toilet usage, laundry, plant watering, car washing, and general house cleaning. These items are based on observations by the authors and published findings [15].

The efforts of respondents to reduce water wastage were also examined by asking them to estimate average bathing/showering duration and whether they allow water to flow while brushing teeth, dishwashing, and other activities. For average bathing/showering duration, the two options were 5–10 minutes and more than 10 minutes, and the respondent was limited to one answer. The response options regarding water flow were 'YES' or 'NO' for each activity.

Special consideration was given to households that showed efforts to use simple and common water saving equipment for bathing/showering, rainwater harvesting, and toilet flushing (e.g., single- or dual-pump cisterns). These components were selected based on our observations and are supported by published studies [16]. Response options to indicate the use of rainwater harvesting and toilet-flushing systems were YES and NO, and for bathing/showering equipment, the three options were 'bucket', 'showerhead', and 'both'.

Random face-to-face interviews were carried out, and most respondents needed 15 minutes or less to complete the questionnaire. This method was chosen because it maximises the number of responses collected in a short time. Furthermore, respondents can receive clarification on questions, which increases the quality of answers and data collected. A sample size of 300 respondents was considered suitable for this study, based on the 1,257 active domestic households in the study area. The estimation of sample size is based on the Cochran formula [17].

3. Results and discussions

Detailed discussion of the development of the self-rating system, frequencies of water usage activities and water saving elements are provided in the subsections below.

3.1. Development of the self-rating system

The score for each activity was developed based on statistical analysis, as presented in table 1. For indoor and outdoor domestic water consumption, the mode and mean of frequency responses were used to establish this score. For optimal domestic water consumption, a consumer is expected to use water wisely and minimize the frequency of indoor and outdoor activities. Consequently, the lower the frequency, the higher the score the consumer receives. The given score is validated using the mean frequency that the respondent conducted each daily or weekly water usage activity. For example, the highest score is assigned to respondents who cook 1–2 times daily, and the lowest score is assigned to those who cook more than 4 times per day. The statistical analysis was performed using IBM SPSS Software 23.

Table 1. Statistical data of the frequency of indoor and outdoor domestic water consumption.

Activities	Mean	Median	Mode
Cooking	1.88	2	2
Showering/bathing	2.27	2	2
Toilet usage	2.30	2	2
Dishwashing	2.13	2	2
Laundry	1.34	1	1
Watering plants	1.49	1	1
Car washing	1.27	1	1
House cleaning	1.31	1	1

Note: Sample size (N = 300)

Three major water saving appliances are considered in this study: buckets for showering/bathing, rainwater harvesting systems, and cisterns for toilet flushing. More points are given to respondents who use these appliances. Using these appliances demonstrates that the consumer practices good water-savings habits and attempts to reduce their treated water usage for non-potable uses such as gardening and general cleaning. The details for each item measured in this self-rating system are presented in table 2.

The aim of the proposed self-rating system is to rate respondents' domestic water consumption into five categories: Poor, Fair, Average, Good, and Excellent. The highest possible score is 50, and classification is based on a 5-quantile concept. Therefore, the ratings are based on the total score are as follows: Poor, 0–10; Fair, 11–20; Average, 21–30; Good, 31–40; and Excellent, 41–50. Round numbers are used to simplify score calculation for the self-awareness/evaluation process and because they are easy to be applied and understood by consumers, the target user of the proposed self-rating system. In general, a high percentage of respondents received an Average (124 respondents, 41.3%) or a Good (149 respondents, 49.7%) rating. A lower percentage of respondents received a Fair (16 respondents, 5.3%) or an Excellent (11 respondents, 3.7%) rating. No respondent received a Poor rating.

The frequencies of water usage for daily indoor activities and weekly outdoor activities are summarised in table 3. For daily activities, more than 85% of respondents report a frequency of at least 3 for showering/bathing, toilet usage, and dishwashing. This domestic water consumption pattern is similar to findings reported by Muthukumaran [18]. Malaysians live in a tropical climate throughout the year; therefore, the ambient environment is hot and humid much of the time. Consequently, it is typical for each individual in a household to shower or bathe twice a day. The percentage of respondents who did laundry 1–2 times per day (74%) is the highest among reported frequencies for all daily activities.

Table 2. Self-rating system to measure domestic water consumption.

Self-rating elements	Frequency		
	1–2	3–4	> 4
<i>Domestic water consumption elements</i>			
Daily Activity (Indoor)	Score		
Cooking	3	2	1
Showering/Bathing	3	2	1
Toilet flushing	3	2	1
Dishwashing	3	2	1
Laundry	3	2	1
Weekly Activity (Outdoor)	Score		
Watering plants	3	2	1
Car washing	3	2	1
House cleaning	3	2	1
<i>Water saving elements</i>			
Bathing equipment	Score		
Bucket	2		
Showerhead	1		
Bucket and showerhead (Both)	0		
Average showering/bathing time	Score		
Less than 5 minutes	5		
More than 5 minutes	0		
	Yes	No	
Rainwater harvesting	5	0	
Dual flushing	5	0	
Letting water flow			
Dish washing	0	3	
Tooth brushing	0	3	
Other activities	0	3	

Table 3. Percentage of respondents who conduct daily and weekly activities by frequency category.

Activities	Frequency (%)		
	1–2	3–4	> 4
Indoor			
<i>Daily</i>			
Cooking	36.3	39.3	24.4
Showering/Bathing	13.7	45.7	40.6
Toilet usage	11.0	48.3	40.7
Dishwashing	19.7	48.0	32.3
Laundry	74.0	18.0	8.0
Outdoor			
<i>Weekly</i>			
Watering plants	62.3	26.0	11.7
Car washing	80.7	12.0	7.3
House cleaning	77.3	14.3	8.4

For weekly outdoor domestic water consumption activities, most respondents said that they watered plants, washed cars, and cleaned houses 1–2 times per week. These results indicate that most respondents use more water for indoor activities than outdoor activities because they enjoy living in comfortable, clean, and neat indoor environments.

3.2. Analysis of domestic water consumption

The results of domestic water consumption with respect to the rating are presented in figure 1. This figure is plotted to determine how water usage contributes to the rating classification of Poor, Fair, Average, Good, or Excellent. Most respondents rated as Excellent (see the blue bars in figure 4) practice water conservation by taking showers or baths for less than 10 minutes per day and did not allow water flow during tooth brushing, dishwashing, and other activities. They also used a dual-pump cistern type for toilet flushing. Other activities in this context are performed outdoors, such as car washing and watering plants. Rainwater harvesting systems reduce the use of treated water for non-potable purposes, such as watering plants and house cleaning. This practice was also reported by previous studies [18]. Adopting these two systems (i.e., a dual-pump cistern and rainwater harvesting system) contribute to a high score and an Excellent rating.

Respondents who received a Fair rating take showers or baths for more than 10 minutes per day and use buckets and showerheads as showering/bathing equipment (see the red bars in figure 1). These respondents tend to use a showerhead and then a bucket to finish their shower/bath before leaving the bathroom. They also allow water to run during tooth brushing and dishwashing. Most use a single-pump cistern type and do not have rainwater harvesting systems.

Respondents who received Average and Good ratings practice a mixed-mode of water consumption. In general, these groups practice good water usage habits for showering/bathing, tooth brushing, dishwashing, and other outdoor activities, as shown in figure 1 (see yellow and green bars, respectively). This group could receive Excellent ratings if they used a dual-pump cistern and rainwater harvesting system, as do the respondents who received an Excellent rating.

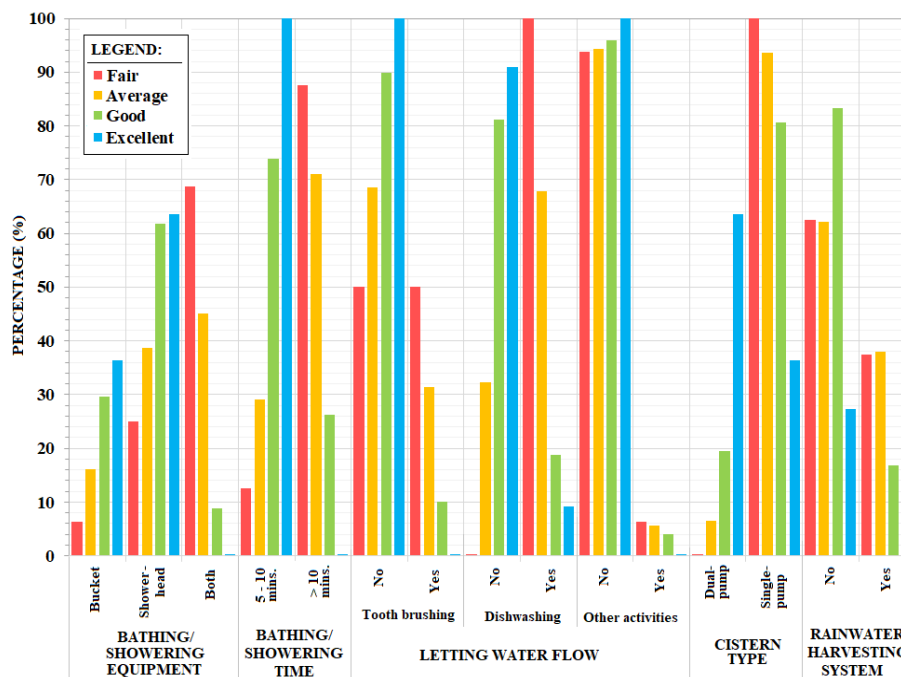


Figure 1. Percentage of ratings based on domestic water usage and equipment.

3.3. Validation of the self-rating curve

This section presents the results of frequency analysis for indoor and outdoor activities to validate the self-rating system developed in this study, as shown by the radar charts presented in figure 2(a) - (c). In these radar charts, the frequency of indoor and outdoor activities is presented in terms of the percentage of respondents who received Fair, Average, Good, and Excellent ratings.

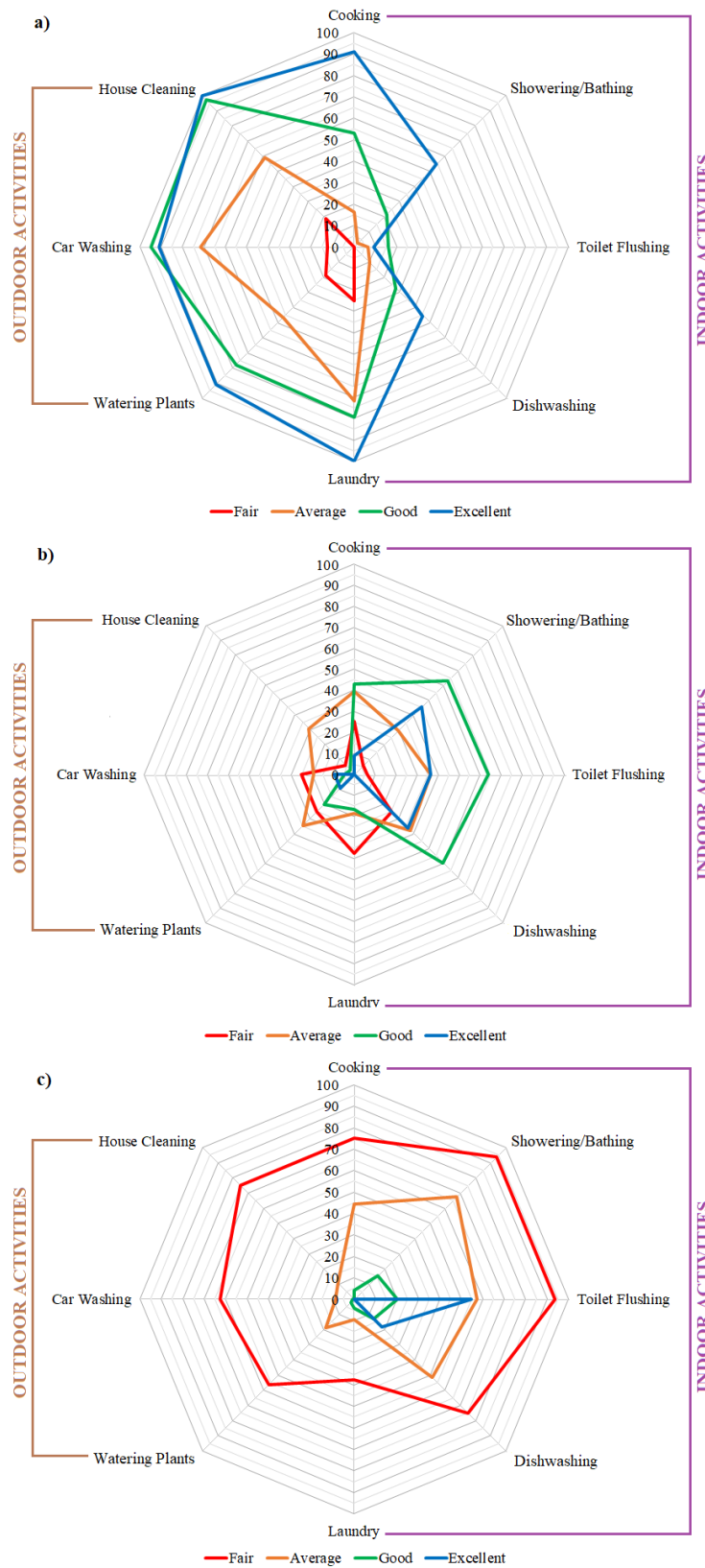


Figure 2. Percentage of ratings based on each frequency category for indoor and outdoor activities: a) 1–2 times per day or week; b) 3–4 times per day or week; c) more than 4 times per day or week.

Respondents with an Excellent rating minimise the frequency of indoor and outdoor activities, such as cooking, house cleaning, car washing, laundry, and watering plants, as shown in figure 2(a). This trend is also seen with respondents who received Good and Average ratings. In these groups, indoor and outdoor activities are often done more than 1–2 times per day or per week, especially for households consisting of young families or couples who are both working, working during the day, or rarely spend their weekdays at home.

Higher frequencies (3–4 or more than 4 times per day or week) of activities are plotted in figures 2(b) and 2(c), respectively. Recall that people who live in tropical countries often bathe at least twice a day because high humidity causes perspiration and usually requires one to take a bath in the morning and evening. Other indoor activities, such as cooking and dishwashing, are also normally done twice a day. Therefore, it is interesting to observe the ratings of respondents who perform these activities with high frequency. As shown in figure 2(b), a more than 50% of respondents receiving a Good rating engage in bathing/showering, toilet flushing and dishwashing 3–4 times per day. Notably, less than 50% of respondents with other ratings (Fair, Average, and Excellent) engage in each of the outdoor and indoor activities.

On the other hand, figure 2(c) illustrates that domestic water consumption for respondents receiving a Fair rating is high for all outdoor and indoor activities. Respondents with an Average rating exhibit a high frequency for the indoor activities: bathing/showering, toilet usage, and dishwashing. Respondents receiving Good and Excellent ratings use water wisely by reducing the frequency of their outdoor and indoor water consumption activities.

4. Conclusion

In this study, the development of an innovative and straightforward scoring method to rate the water usage behaviour of a domestic household was presented. The proposed scoring system uses 5 ratings: Poor, Fair, Average, Good, and Excellent. Important conclusions from this study are as follows:

- a) A simple self-assessment scoring system is established for residents of a suburban community to evaluate their domestic water consumption.
- b) A high percentage of respondents received an Average (124 respondents, 41.3%) or a Good rating (149 respondents, 49.7%). A lower percentage of respondents received a Fair (16 respondents, 5.3%) or an Excellent (11 respondents, 3.7%) rating. No respondent received a Poor rating. This result indicates that there are intrinsic behaviours of good water usage and conservation efforts in the community.
- c) Respondents with an Excellent rating minimise the frequency of indoor and outdoor activities to reduce water usage at home. They also practice good water habits by taking shorter baths and showers and using rainwater harvesting systems.
- d) An individual can improve a rating (e.g., from Average to Good or from Good to Excellent) by not only minimising the frequency of indoor and outdoor activities but also using equipment that reduces water consumption, such as buckets, dual-pump cisterns, and rainwater harvesting systems. Rainwater harvesting systems reduce treated water usage for non-potable uses such as general cleaning and watering plants.
- e) Consumers are likely to become more aware and motivated to avoid excessive water consumption when they can quantitatively assess their domestic water usage with the rating and scoring system developed in this study.

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