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An Analysis of Domestic Water Consumption in Jaipur, India

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Authors' contributions

This work was carried out in collaboration between all authors. Author SMKS designed the study, supervised the data analyses and wrote and revised the manuscript. Author FAM provided suggestions for the study design, model run and statistical analysis and reviewed the manuscript. Authors AJ and SG helped to develop and conducted the survey, and circulated and gathered all information from the participants in India. Author APD reviewed the manuscript and provided some statistical and geographical data. Author WH helped to design, format and file the questionnaires. Authors DAS and DB revised the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To explore the relation between water consumption and water use behaviour and attitudes, and devices applied in households in urban areas in India.
Methodology and Study Site: This paper presents the results of a domestic water consumption survey carried out in Jaipur, India. A questionnaire containing over 60 questions was developed to collect information on households' characteristics (e.g. family size, household type, and number of children), indoor and outdoor water use activities and their respective frequencies and durations. Information was also gathered on the volume of water used in each of these activities. Over 90 households of different types (standalone houses and apartments in a university campus and Jaipur city) participated in the survey. The survey results were analysed using cluster analysis and one-way analysis of variance (ANOVA).
Results: The results show that the per capita consumption varies considerably with household type and size. The average water consumption was 183 and 215 litres/person/day for standalone households and apartments, respectively. Water used in bathing and WC's represent the highest proportion of water consumption in both stand-alone houses and apartments. Over 40% of the households reported no use of showers. The per capita water consumption is inversely related to family size especially in stand-alone houses.

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Conclusion: The information pertaining to water use habits and the qualitative and quantitative analysis can be used as an input to a proposed domestic water efficiency tool (DoWET) which can generate optimal water efficient composite strategies keeping in view a range of sustainability indicators including water saving potential, cost and associated energy consumption of the water saving devices and fixtures available in India.

Keywords: Water-use habits; efficient household micro-component devices; water consumption; water demand management; developing countries.

1. INTRODUCTION

Water crisis referring to scarcity of freshwater resources has become one of the major challenges throughout the world. This has resulted from many interrelated issues such as population explosion, and climate change. The global population has increased from 3 to 7 billion people in five decades [1], placing considerable pressure on water resources. It is estimated that by 2025, 67% of the global population will face moderate to high water stress and half of the population will be suffering constraints in their water supply [2]. India, as one of the largest countries in the world with a population of 1.2 billion, can be classified as a hot tropical country. A large proportion of the Indian population lack access to safe drinking water, and as a result of growing population, this situation has deteriorated. UNICEF [3] reported that the utilisable water for human use (654 billion cubic metres (BCM)) is very close to the current actual water use (634 BCM); these figures indicate an imminent alarming situation in this country. Poor management and overexploitation of groundwater by all sectors in the absence of adequate regulation and effective pricing instruments severely impact water-scarce areas [4]. Domestic water demand accounts for 80 percent of groundwater use, and GR [5] projects the situation to worsen over the coming years. Additionally, an increase in disposable income is projected to change consumption patterns towards more water intensive products which will lead to a significant increase in household water demand [5].

Although the existing urban water systems and technologies provide reliable services at reasonably low costs, over the last decades there has been widespread criticism of their level of environmental sustainability [6,7]. The question of greenhouse gas emissions and the associated global warming, contamination of groundwater, eutrophication, nutrient depletion and other environmental degradations are among the many challenges associated with conventional urban water management approaches [8]. Therefore, innovative water management approaches should be employed to influence demand by augmenting water supply in a way that is both cost-effective and favourable for the water environment whilst still meeting consumer demand [9]. A range of sustainable water management practices and principles can be introduced to ensure the secure supply of urban water. Water demand management (WDM), which can be defined as the practical development and implementation of strategies aimed at influencing demand, are utilised globally to assist in shifting consumers towards sustainable water consumption behaviour.

WDM aims at reducing average water consumption in order to improve sustainable use of water resources [10,11]. WDM measures emphasize reducing end use consumption hence offsetting the need for additional water supply and wastewater treatment measures which are costly and can be environmentally and socially detrimental. The WDM approach relies greatly on consumers to understand how to reduce their water consumption and to apply this understanding to everyday activities to consume sustainably. Reducing demand by improving the efficiency of water use requires an understanding of how water is used and in what ways water savings can be realized [12]. Sofoulis [13] believe an understanding of the cultural domain and the complex world of everyday life experience is crucial for understanding water use and vital to the adoption of more sustainable urban lifestyles. If utilised effectively, WDM can also reduce water and energy cost for households and water operators, so could have a positive impact on wastewater infrastructure by delaying/reducing peak inflow into wastewater systems, reduce pollution loads and thereby increase water supply, and extend the life of ageing water infrastructure [9].

Another approach is micro-component based WDM which has been identified as a way forward to reduce per capita water consumption without necessarily changing user behaviour [8]. The actual volume of water consumption for a given service is believed to be considerably lower than that provided by conventional water-use micro-components. This concept forms the basis for the micro-component oriented water demand management approach, which seeks to meet water efficiency targets without compromising the quality of the services provided [8]. Based on what has been discussed above, two potential solutions for reducing the water stress imposed by population growth and human activities especially at household level can be identified: (1) water efficiency-conservation attitudes and (2) water saving micro-component and devices. Therefore, this research aims to explore the relation between water consumption and water use behaviour and attitudes, and devices applied in households in urban areas in India. A survey conducted to understand some of the behavioural aspects of water consumption in Jaipur is presented as an example of an Indian urban area.

1.1 Factors Influencing Domestic Consumption

In the context of urban areas in India, two types of buildings, where water consumption takes place, can be considered: residential and non-residential. In residential buildings, water is usually used for WC flushing, washing clothes and dishes, showering, bathing and satisfying a variety of other uses (such as cooking and drinking). Since the residential sector represents the largest urban water use sector [14], water saving measures targeting the residential sector could play an important role in reducing the total domestic water consumption. There are significant variations of water consumption in this building type, and level of water consumption varies from building to building depending on type, size, functions, construction age and class of buildings.

The water consumption of a building, which is standardised as “litres/capita/day”, is determined by a number of factors: (1) climate and weather condition; (2) the types and characteristics of water use micro-components installed in a building; and (3) water use habits. The first two have been, to some extent, defined and understood in different parts of the world, while the understanding of water use habits is still incomplete since water use habits vary from region to region, and country to country. Household water use habit itself depends on a number of factors, including household occupancy, household types, household income, and water prices. In England, EA [15] reported a strong and clear relationship between household occupancy and water use, with per capita consumption decreasing as occupancy increases. Additionally, water use habits can significantly differ between households, depending on socio-economic, cultural, and/or religious factors [9]. Since water use devices/ appliances play important roles in water consumption/conservation, here the main appliances will be described.

1.2 Household Water-using Appliances

A clear understanding of household types and household water consumption breakdown leads to better understanding of water consumption trends; subsequently, more efficient use of water and better forecasting of future water demand would be possible [9]. It is therefore necessary to break down domestic water consumption and study the individual water consumption elements within the household which leads to better understanding of household water consumption patterns and trends [16]. Breaking consumption into different micro-components of demand has been considered in a number of studies. Fidar [8], for example, focused on six micro-components (e.g. showers, WCs, baths, internal taps, washing machines, and dishwashers). Shaban and Sharma, [17] mainly focused on five micro-components and assessed per capita household micro-component water use in 7 major Indian cities. They showed that on average cooking and drinking account for only 10 percent of water use, with bathing, WC flushing, clothes washing, and utensil washing accounting for much higher water use in households. Since the focus of the survey is mainly on bathing/ showering, water used in WC, dish-washing and clothes-washing, here a summary of these appliances is presented.

1.2.1 Bath and shower

Bathing currently accounts for about 55 percent of household water use in India [18], with modern plumbing, en-suite bathrooms, and changes in lifestyle all potentially contributing to the increase in water use for bathing and showering [19]. Baths are available in a wide range of shapes and volumes, and the main variables which determine how much water is used to fill a bath are its volume and shape. Water use in bathing can only be reduced through extensive awareness raising campaigns on the need to save water by the use of efficient shower heads. In India, bucket bath practice seems to be rather common with ownership of western style bath tubs mainly evident in upper class (high income group) households. There is considerable difference between old and new properties, in terms of water consumption through showers [8]. Defra [20] and estimated that water consumption through showers in standard new built houses is about 20% of the total household water consumption. MTP [21] estimated the proportion of water used for showering in old and new homes as 8.6% and 23.1%, respectively; the increase being due to the move away from baths towards showers in newer properties. In addition, en-suite bathrooms and changes in lifestyle are contributing to the trend towards use significantly more water for showering [17,22]. There are divergences on shower types and categories; Grant, [23] and Elemental Solution, [24] reported the availability of three types of showers in the international market: low-pressure gravity fed showers, mains-pressure/power showers, and electric showers, whereas, Critchley and Phipps [25] divided the showers into electric showers, mixer showers and pumped showers. The type of shower and the duration for taking a shower directly impact on the amount of water consumption. Water consumption in showers also depends on heating mechanism, type of shower control (fixed/adjustable), the shower spray pattern, and even the pressure of the water droplets on the skin.

1.2.2 WC

WCs have constituted the largest water use in households and could be considered as the first target for household water efficiency. In the context of India, an average Indian household (assuming the average urban Indian occupancy of 5.1 in 2001 and an average per capita consumption of 130 LCD) with a nine litre WC cistern will flush 117.7 litres of treated mains water down the pan [18]. Water consumption attributed to WCs can be reduced using water efficient retrofit devices and fittings such as cistern displacement or variable flush devices that reduce water use to reduce flush volumes of old WCs. Recycling of household treated greywater and/or rainwater can also be used to offset mains water demand. In order to ensure risk free recycling, appropriate safeguards must be put in place.

1.2.3 Dish-washing

Washing utensils accounts for 10 percent of per capita household water use in India [18]. Household occupancy will also have an impact on the per capita demand for dish washing, with a higher occupancy reducing per capita water demand. Similar to washing machine, the uptake of more efficient dishwashers is dependent on the appliance lifetime and affluence. It is reported that the average economic lifetime of dishwashers is between 10 and 12 years. Water consumption of the dishwashers is determined by the machine‘s fill volume and the frequency of use of the dishwasher [8].

1.2.4 Clothes washing

Clothes washing represents 20 percent of per capita household water use in India [18]. In general, higher income households wash clothes more frequently. However, no information has been found on how this water is used (washing machine, hand washing, etc.) or how this demand can be reduced in India. In general, washing machines can be divided into two types: (1) front-loading (horizontal axis) and (2) top-loading (vertical axis washing machines). Front-loaded washing machines are reported to be more efficient, both in terms of energy consumption and water use [26]. Lifetime can be considered as the most important factor in determining efficiency of washing machines. The average lifespan of washing machines found in the literature varies widely ranging from 8 years to 16 years [22,27,28,29]. However, it is reported that the average lifespan of washing machines has recently reduced ranging from 4.5 to 10 years [8,30,31].

2. METHODOLOGY

The environment created by the interaction of society and economy in urban centres is a complex system of social and environmental interactions. Urban water consumption can be also considered as a parameter heavily dependent upon social, environmental and financial aspects. As mentioned earlier, water use habit is one of the most important factors influencing domestic water consumption. Yet acquiring information on water use habits in India and most developing countries is still problematic and no reliable data on water use habits has been found in the literature [32]. Therefore, here in this study we conducted a survey on water use practices in households targeting Indian urban areas.

2.1 Technical Notes on the Survey and Study Site

This survey includes the development and distribution of a questionnaire to about 100 households of different types in the Indian city of Jaipur (Fig. 1). This city, which has a population of 3.44 million (2015), is located near the Thar Desert of India and facing significant problems with drinking water. The survey was administered to the city dwellers with a view to improving our understanding of typical water consumption habits in India and to obtain a more holistic and representative sample of data regarding frequency and duration of use of micro-components for use in a water efficiency technology selection tool.

In the survey, 63 number of stand-alone houses and 27 number of flats/apartments participated. This survey was also carried out in 20 stand-alone houses of the Malaviya National Institute of Technology Jaipur. It was a door-to-door survey and involved direct interactions with the households' occupants. The developed questionnaire consists of two main sections:

2.1.1 Household characteristics

This section includes nine questions, and aims to categorize and filter information based on household characteristics e.g. household location, household type, number of occupants in each household, number of washrooms in a household, time/duration of water supply, monthly water bill, and household income. This information is aimed at helping to categorize the responses for further analysis.

2.1.2 Water use characteristics

This section is composed of 11 subsections and aims at identifying/classifying water consumption habits in a household in urban areas in India. The information on water use patterns focuses on middle to high income households in urban areas of India. Low income groups (e.g. slums and informal settlements) were excluded, since the water consumption for those areas is already very low and do not offer significant water saving potential. This section focuses on different water use devices/appliances (e.g. how many showers/bathrooms in a household, duration and number of showers per day, approximate amount of water used for showering). This information will help in analysing water use habits and finding some patterns of water consumption in urban areas.

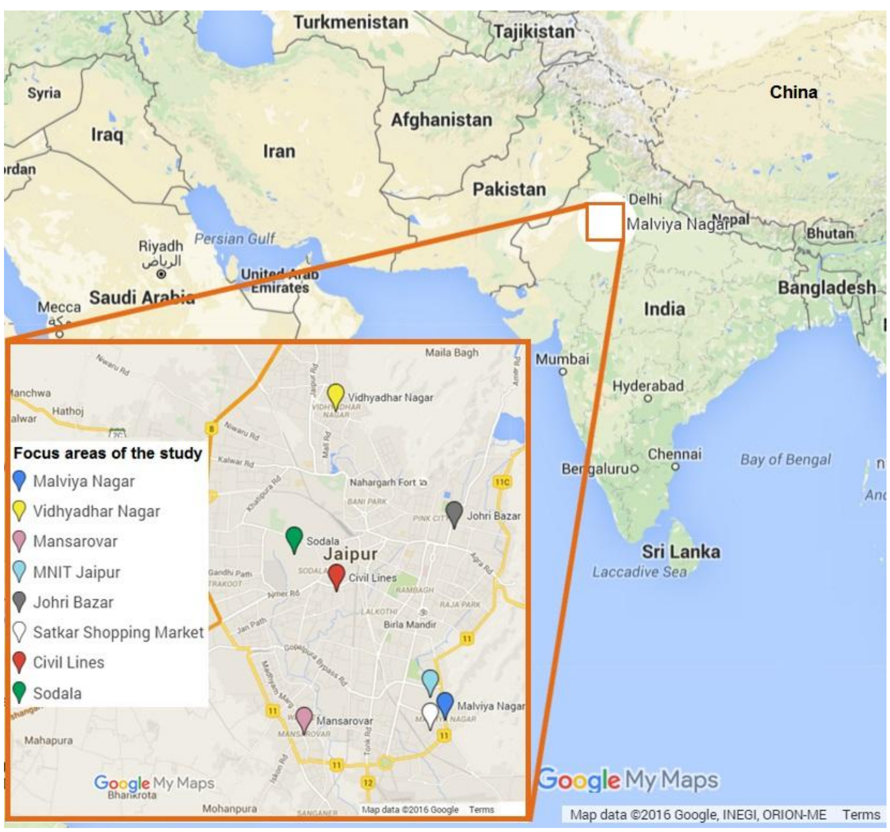


Fig. 1. Jaipur in India and the areas in this city where the survey is conducted [33]

2.2 Analytic Approaches

2.2.1 Clustering approach

Cluster analysis is the art of finding groups in data [34]. The classification of similar objects into distinct groups is an important part of any analysis. A population can be divided into entire unrelated groups pertaining to which variables are selected upon which to define categories [35]. In other words, before engaging in any group classification, a clear theoretical understanding of relevant variables for groupings which represent distinct categories is required. In this research, an attempt to consider recognisable dimensions of water use practices by which a number of clusters can be created has been made. The main focus of analysis is on water consumption for different types of households based on different appliances. In addition, for further analysis (Table 1), three clustering dimensions (frequency / diversity / technological preference) (second column) have been created with focus on four water using practices (left column): showering/bathing; WC and hand-washing; dish washing; and clothes washing. The detailed description of the water use measure employed is given in the third column, whilst the fourth column gives the normalised scale values used for the cluster analysis. It is worth noting that the analysis method used in this study follows that of Browne et al. [35] with some modifications. This analysis method is commonly in use and tries to maximise the chances of identifying real groups in the data where these exist [36]. In addition, scale values are normalized between 0 and 1 for all dimensions of each practice. The focus of analysis is mainly on household type, family size, and water use appliances.

Table 1. Dimensions of bathing/showering and clothes-washing practices used for clustering analysis

Water using practices	Dimension	Description	Normalised scale values
Bath and shower	Frequency	Number of baths and showers per week per household	0 → 1 per week or fewer 1 → 12 per week or more
	Diversity	Duration of each shower or number of buckets (15-20 litres) used for each bath	0 → 1 minutes or fewer / 1 bucket or less 1 → 12 or more / 4 buckets or more
	Technological preference	Bath to shower ratio	0 → always taking showers 0.5 → taking baths and showers equally 1 → always taking baths
WC and hand-washing	Frequency	Number of times flushing toilets are used per person per day – Number of times washbasin/taps are used per person per day	Toilet: 0 → 2 per day or fewer Toilet: 0 → 10 per day or more Hand-wash-washbasin: 0→ 2 per day or fewer Hand-wash-washbasin: 1→12 per day or more
	Diversity [1]	Average duration for each wash (second)	0 → 10 s or less 1 → 60 s or more
	Technological preference	Taps/washbasin in the toilet to taps/washbasin (not in the toilet) ratio	0 → always using taps/washbasin in the toilet 0.5 → equal using taps/washbasin in the toilet and out of the toilet 1 → always using taps/washbasin (not in the toilet)
Dish washing	Frequency	Number of times dishes are washed per day per household	0 → Less than once per day 0.25 → Once per day 0.75 → Twice per day 1 → Three times per day or more

Water using practices	Dimension	Description	Normalised scale values
	Diversity		0 → 4 litres per person per day or less 1 → 32 litres per person per day or more
	Technological preference	Hand washing to dishwasher ratio	0 → always washing manually 0.5 → equal manual washing & using dishwasher 1 → always using dishwasher
Clothes washing	Frequency	Number of times clothes are washed per week per household	0 → 1 per week or fewer 1 → 12 per week or more
	Diversity	Number of buckets per wash or type of washing machine	0 → 1 bucket or less 0.25 → top loading or small-size machines 0.75 → front loading or large-size machines 1 → 12 or more / 4 buckets or more
	Technological preference	Manual washing to washing machine ratio	0 → always washing manually 0.5 → equal manual washing & using washing machine 1 → always using washing machine

[1]Information on the duration of using toilet was not provided by majority of the participants

2.2.2 Analysis of variance

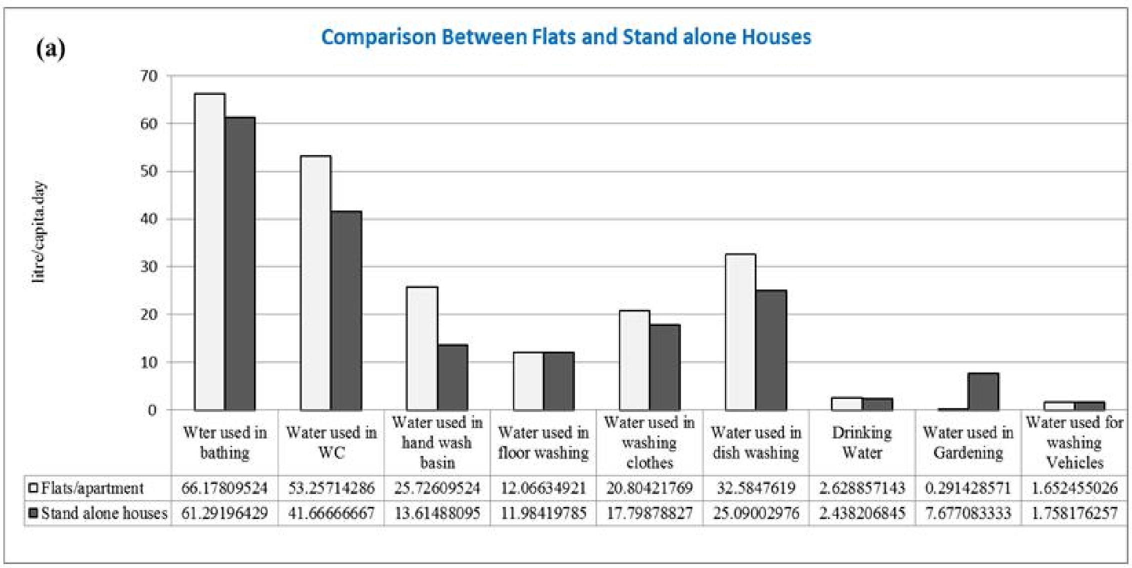
The results obtained are analysed using one-way analysis of variance (ANOVA) for mean differences among the clusters. ANOVA is a data analysis methods of great elegance, utility and flexibility [37]. ANOVA is used to determine whether there are any major differences between a number of independent groups. Although ANOVA is a robust method [38], it cannot determine which specific groups are different from the other groups. Therefore, after conducting the ANOVA test, a post hoc test is used to determine where the differences occurred between groups.

3. RESULTS

Questionnaire and interview responses provide the quantitative and qualitative household water values and cultural/behavioural information. Fig. 2a compares the per capita water consumption of different water use practices in stand-alone houses and flats/apartments. It shows that bathing has the highest water consumption and it is followed by water used in WC, dish washing, and clothes washing. It is interesting that similar trends can be seen for both flats and stand-alone houses. However, generally water consumption in flats/apartments is a slightly higher than that in stand-alone houses, except water used in gardening which is nearly zero in the flats/apartments. This trend can be explained by the fact that the quality of life is higher in the areas where the flats are located. In addition, nearly three quarters of the flat/apartment population have a family size of six or smaller. It is shown in Fig. 2b that per capita consumption is higher in smaller families and vice versa. According to the result of the survey, the majority of households have only one person earning for the whole family; it can be assumed that generally smaller families have higher life quality. Since changes in water use habits in bathing/ showering, WC-handwashing, dishwashing and clothes-washing could considerably change household water consumption, here in this section, the focus will be on these four water use practices.

3.1 Analysis on Bathing and Showering

Showering/bathing has changed substantially for the majority of the population in many places in the last few decades [35]; in many counties, taking showers is becoming the norm representing a transition from bucket bathing and flannel washing [25]. In India, although taking showers is becoming more common, generally bucket bathing is still the preferred way of having a full body wash. It is widely believed that the frequency of taking showers/baths has significantly increased [39]. The results from the questionnaires illustrated in Fig. 3 reflect this change with approximately 70% of the whole population having daily showers/baths. 15% of participants never have a bath, while 43% never have a shower. Fig. 3a shows the distribution of all respondents in the population on the three dimensions by which clusters are defined. The bubble sizes represent the weighted percentages of respondents having value on that particular dimension. Fig. 3 illustrate the distribution of members of seven clusters in turn on different dimensions. It can help in better comparing bathing/showering behaviours in families with 3 members (Cluster 1), families with 4 members (Cluster 2), families with 5 members (Cluster 3), families with 6 members (Cluster 4), families with 7-10 members (Cluster 5), stand-alone houses (Cluster 6) and flats/apartments (Cluster 7) with the overall population. The proportion of baths and showers varies, with a reasonably significant proportion of baths. There is also variety in the duration of the bath/shower and the amount of water used at each time, based on a number of reasons. It was shown in the survey that daily baths/showers, which represent about 70% of the total do not usually take more than 10 minutes. Families with children are shown to have more frequent and longer bath/showers. It has been also observed that families with 1-4 members take longer shower/bath; this can be again explained by the fact that smaller families have higher life quality (Figs. 3b, 3c, 3d, 3e and 3f). Although frequency of bath/showers are generally in the same range in different households, a slightly lower frequency can be seen in larger families. Figs. 3g and 3h show that in stand-alone houses generally taking bucket bath is still the preferred way of washing the whole body, while taking a shower is slightly more common in flats/apartments.



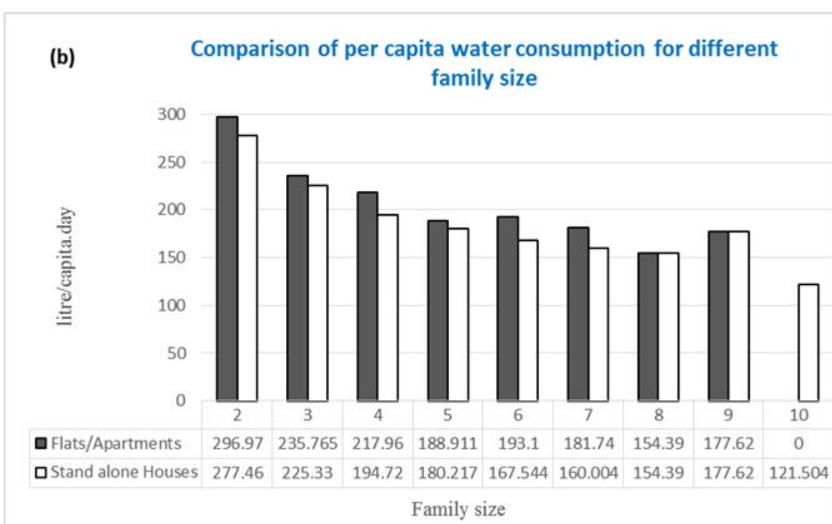


Fig. 2. The average per capita water consumption (a) Versus different household water usage; (b) Versus family sizes

In order to determine whether there are any significant differences and how significant the differences between each cluster are, an ANOVA test and a post hoc test are conducted. The results of ANOVA analysis indicate that there is only one significant difference between clusters for showering/bathing ($p<0.05$). As can be seen in Table 2, the highest difference is in frequency of bath/showering in the household with 4 and 6 members (Cluster 2 and cluster 4, respectively). In the post hoc test, any two cluster means that are higher than the honest significant difference (HSD) value are defined as significantly different. The results of these tests confirms that regardless of family size and household type, the overall habits of bathing/showering is similar.

3.2 Analysis on Water Used in Toilet

As mentioned earlier, an average Indian household with a nine litre WC cistern could flush 117.7 litres of treated mains water down the pan [18]. However, the amount of domestic consumption attributed to WCs is decreasing, since efficiencies of recently designed WC technologies are higher [40]. In addition, water consumption attributed to WCs can be reduced by changing water use habits in households. Similar to the previous section, a cluster analysis directed to the selection of eight different groups. The results show that water used in toilet varies according to both family size and household type (Fig. 4). High frequency of using toilet and handwashing can be seen in families of 4, 5 and 6; these three clusters mainly represent families with children. The frequency of handwashing and using toilet in these families are in relatively similar patterns (Figs. 4c, 4d and 4e); these results coincide with those of the ANOVA test (Table 3); where no significant difference between clusters has been detected ($F_{Frequency\text{-}Family\ size} = 1.581 > F_{Frequency\text{-}Critical}$, $F_{Frequency\text{-}Household\ type} = 0.222 > F_{Critical}$, $p_{Family\ size} = 0.195 > \alpha$, $p_{Household\ type} = 0.639 > \alpha$).

About 40% of the population tend to wash their hands for about 30 seconds, whereas, only 4% have a habit of washing hands for more than 1 minute. Figs. 4g and 4h show that generally both the duration of handwashing are higher in flats/apartments. The results of ANOVA and post hoc tests (Table 3) also shows a significant difference between duration of handwashing in the toilet where F was higher than the critical F, and the subtraction of the mean of Cluster 6 from the mean of Cluster 7 (0.242) was significantly higher than HSD value (0.154). This can be further explained by the fact that a large proportion of the flats/apartments in this study is located in the upper middle class areas of Jaipur, and generally people with a better living standard and conditions are more concerned about sanitation and hygiene.

3.3 Analysis on Dish-washing

Fig. 5 shows a cluster analysis comparing different family sizes and types of households. It is clearly shown that the majority of the population still prefers manual dish-washing. It is also possible that some families cannot afford dishwashers. It was shown in the survey that people tend to wash utensils on a regular basis where dish-washing once, twice, and three times per day accounts for 30%, 40% and 30% of the whole population, respectively. Families with children and more members are shown to have more frequent dishwashing. The highest amount of water used for dish-washing was seen in 7 households with only 2-4 members, (more than 30 litres per day per person on average). On the other hand, the lowest water use for washing utensils, less than 6 litres per person per day, was reported in 2 stand-alone houses with 10 family members. The per capita water use for dish-washing is higher in smaller families and in flats/apartments (Fig. 5). This also can be observed in the ANOVA and post hoc tests; where F value for diversity (17.480) is higher than the critical F (2.578). This means the null hypothesis of having identical clusters is rejected (Table 4). It can now be concluded that there are statistically significant differences between cluster means. The results of post hoc tests shows that the diversity of per capita water consumption in the households with 1-3 occupants is significantly different from those with 5, 6 and 7-10 members (9.266, 12.333 and 12.460, respectively; where HSD equals 4.915).

By contrast, in the households where dishwashers are in use, the water consumption is shown to be lower (Fig. 5). It is evident that, on average, manual dishwashing takes more water and energy than washing the same amount of dishes in a fully loaded dishwasher [41]. Therefore, dishwashers would be an appropriate option in urban areas with water scarcity challenges; although it must be noted that the product cost is still very high for people in India.

Table 2. Results of ANOVAs and post hoc tests for bathing/showering

Comparison categories	Dimension	ANOVA test				Post hoc test	
		Critical F	F	Alpha	P-value	HSD	Significant differences
Family size	Frequency	2.579	2.657	0.050	0.0420	2.210	$\tilde{x}_{C2} - \tilde{x}_{C4}$ = 2.28
	Diversity	2.579	1.270	0.050	0.2900	0.360	-
	Technological preference	2.579	1.520	0.050	0.2100	0.420	-
Type of household	Frequency	4.026	1.720	0.050	0.1950	0.090	-
	Diversity	4.026	0.040	0.050	0.8400	0.200	-
	Technological preference	4.026	0.048	0.050	0.8260	0.130	-

HSD: Honest significant difference; X̃: Cluster mean; C1: Cluster 2 (Households with 4 members); C4: Cluster 4 (Households with 6 members)

Table 3. Results of ANOVAs and post hoc tests for water consumption in the toilet

Comparison categories	Dimension	ANOVA test				Post hoc test	
		Critical F	F	Alpha	P-value	HSD	Significant differences
Family size	Frequency	2.578	1.581	0.050	0.1950	2.020	-
	Diversity	2.578	6.101	0.050	0.0005	0.145	$\tilde{x}_{C1} - \tilde{x}_{C5}$ = 0.150 $\tilde{x}_{C2} - \tilde{x}_{C5}$ = 0.235 $\tilde{x}_{C4} - \tilde{x}_{C5}$ = 0.167
	Technological preference	2.578	6.587	0.050	0.0002	0.055	$\tilde{x}_{C1} - \tilde{x}_{C5}$ = 0.414 $\tilde{x}_{C2} - \tilde{x}_{C5}$ = 0.414 $\tilde{x}_{C1} - \tilde{x}_{C3}$ = 0.166 $\tilde{x}_{C2} - \tilde{x}_{C3}$ = 0.690
Type of household	Frequency	4.026	0.222	0.050	0.6390	1.497	-
	Diversity	4.026	20.060	0.050	0.0001	0.154	$\tilde{x}_{C6} - \tilde{x}_{C7}$ = 0.242
	Technological preference	4.026	53.700	0.050	0.0001	0.033	$\tilde{x}_{C6} - \tilde{x}_{C7}$ = 0.084

HSD: Honest significant difference; X̃: Cluster mean; C1: Cluster 1 (Households with 1-3 members); C2: Cluster 2 (Households with 4 members); C3: Cluster 3 (Households with 5 members); C4: Cluster 4 (Households with 6 members); C5: Cluster 5 (Households with 7-10 members); C6: Cluster 6 (stand-alone houses); C7: Cluster 7 (flats/apartments)

Table 4. Results of ANOVAs and post hoc tests for water consumption for dish-washing

Comparison categories	Dimension	ANOVA test				Post hoc test	
		Critical F	F	Alpha	P-value	HSD	Significant differences
Family size	Frequency	2.578	5.904	0.050	0.0006	0.828	$\tilde{x}_{C1} - \tilde{x}_{C5}$ = 1.200 $\tilde{x}_{C2} - \tilde{x}_{C5}$ = 1.100
	Diversity	2.578	17.480	0.050	0.0001	4.915	$\tilde{x}_{C1} - \tilde{x}_{C5}$ = 12.460 $\tilde{x}_{C1} - \tilde{x}_{C4}$ = 12.333 $\tilde{x}_{C1} - \tilde{x}_{C3}$ = 9.266
	Technological preference	2.578	3.156	0.050	0.0220	0.493	$\tilde{x}_{C3} - \tilde{x}_{C5}$ = 0.500
Type of household	Frequency	4.026	0.032	0.050	0.8580	0.591	-
	Diversity	4.026	18.634	0.050	0.0001	4.203	$\tilde{x}_{C6} - \tilde{x}_{C7}$ = 6.352
	Technological preference	4.026	0.416	0.050	0.5210	0.328	-

HSD: Honest significant difference; X̃: Cluster mean; C1: Cluster 1 (Households with 1-3 members); C2: Cluster 2 (Households with 4 members); C3: Cluster 3 (Households with 5 members); C4: Cluster 4 (Households with 6 members); C5: Cluster 5 (Households with 7-10 members); C6: Cluster 6 (stand-alone houses); C7: Cluster 7 (flats/apartments)

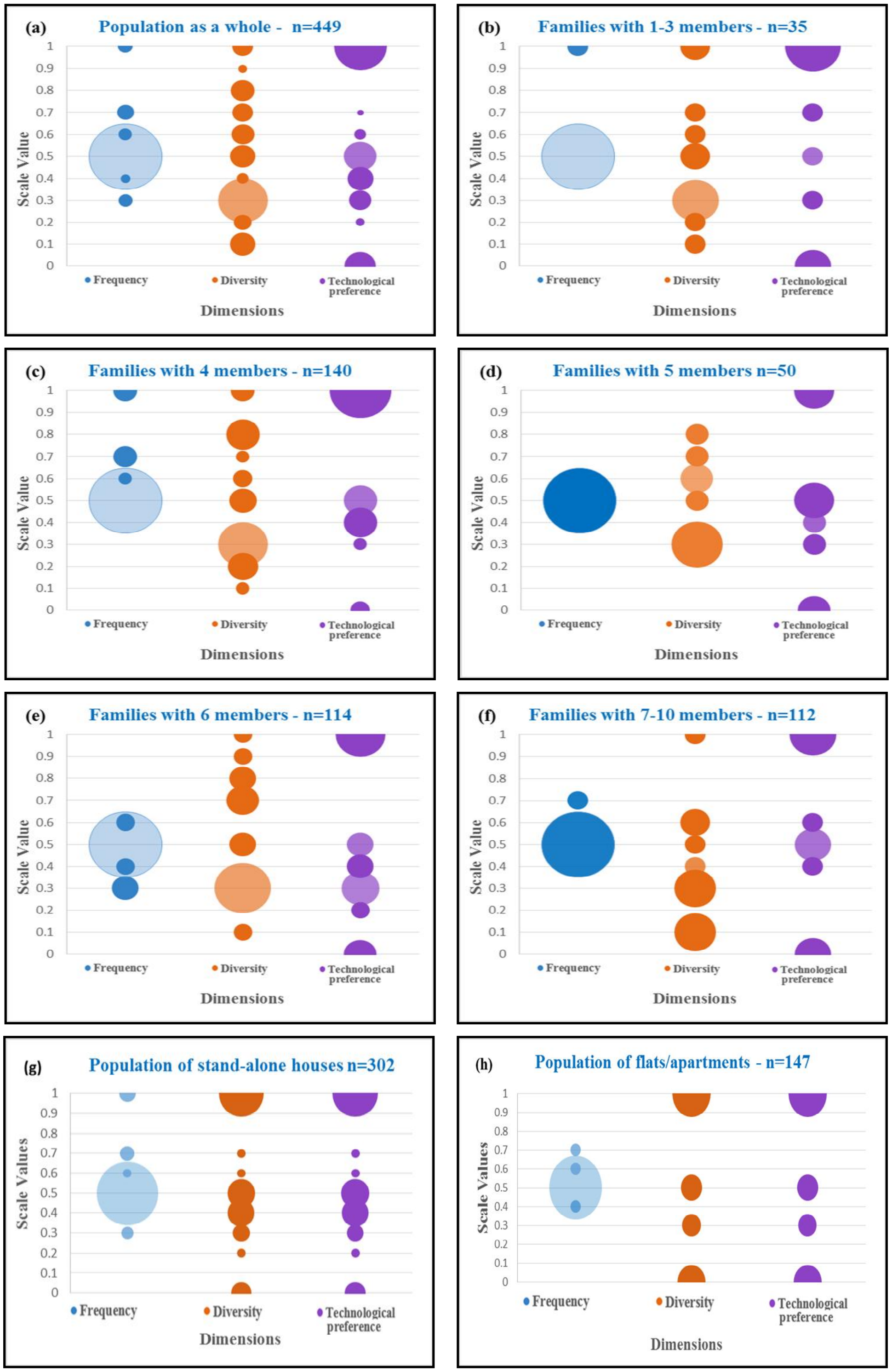


Fig. 3. Population and cluster results for bathing/showering (a) Whole population; (b) Families with 1-3 members; (c) Families with 4 members; (d) Families with 5 members; (e) Families with 6 members; (f) Families with 7-10 members; (g) Population of stand-alone houses; (h) Population of flats/apartments

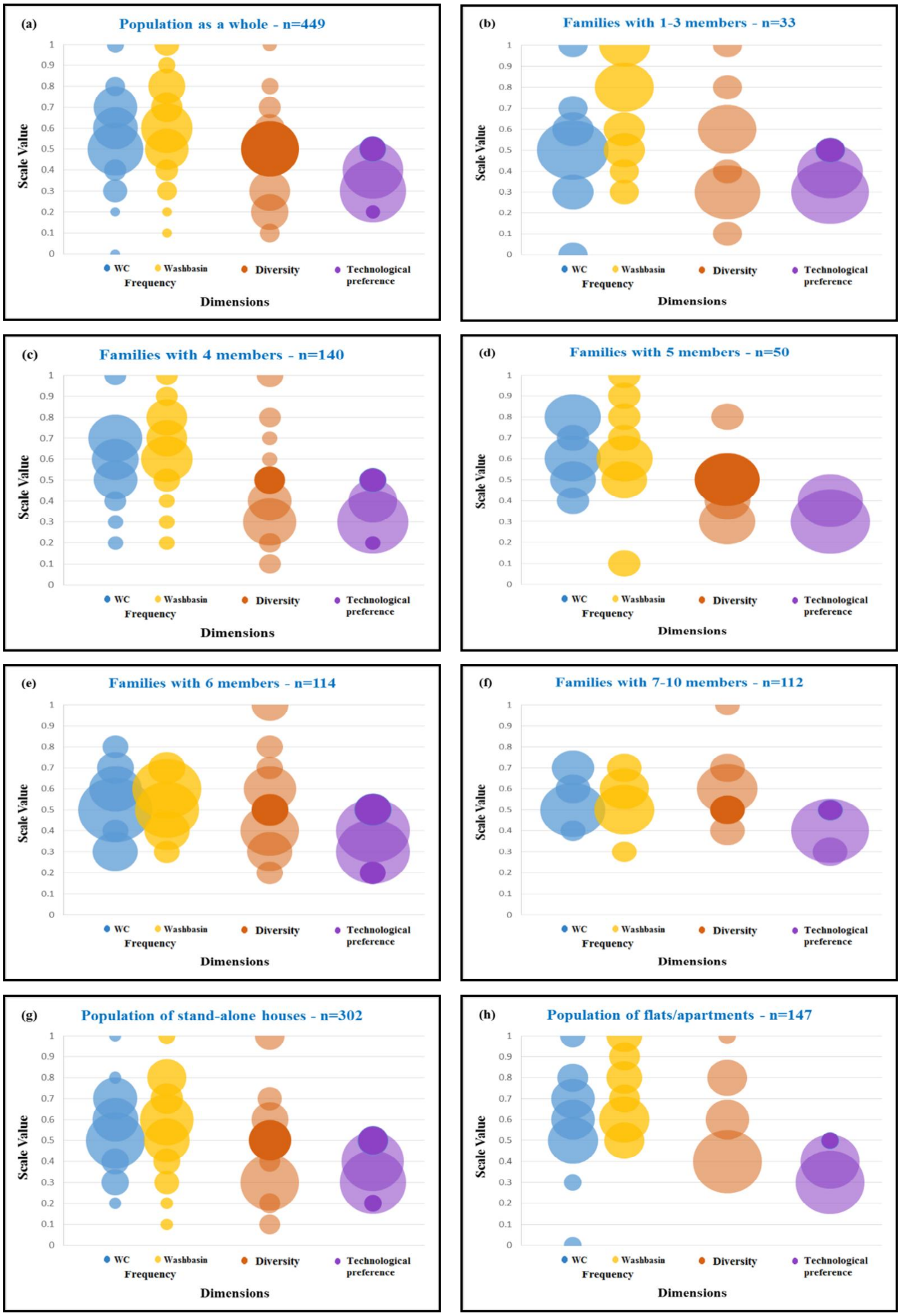


Fig. 4. Population and cluster results for using WC/handwashing (a) Whole population; (b) Families with 1-3 members; (c) Families with 4 members; (d) Families with 5 members; (e) Families with 6 members; (f) Families with 7-10 members; (g) Population of stand-alone houses; (h) Population of flats/apartments

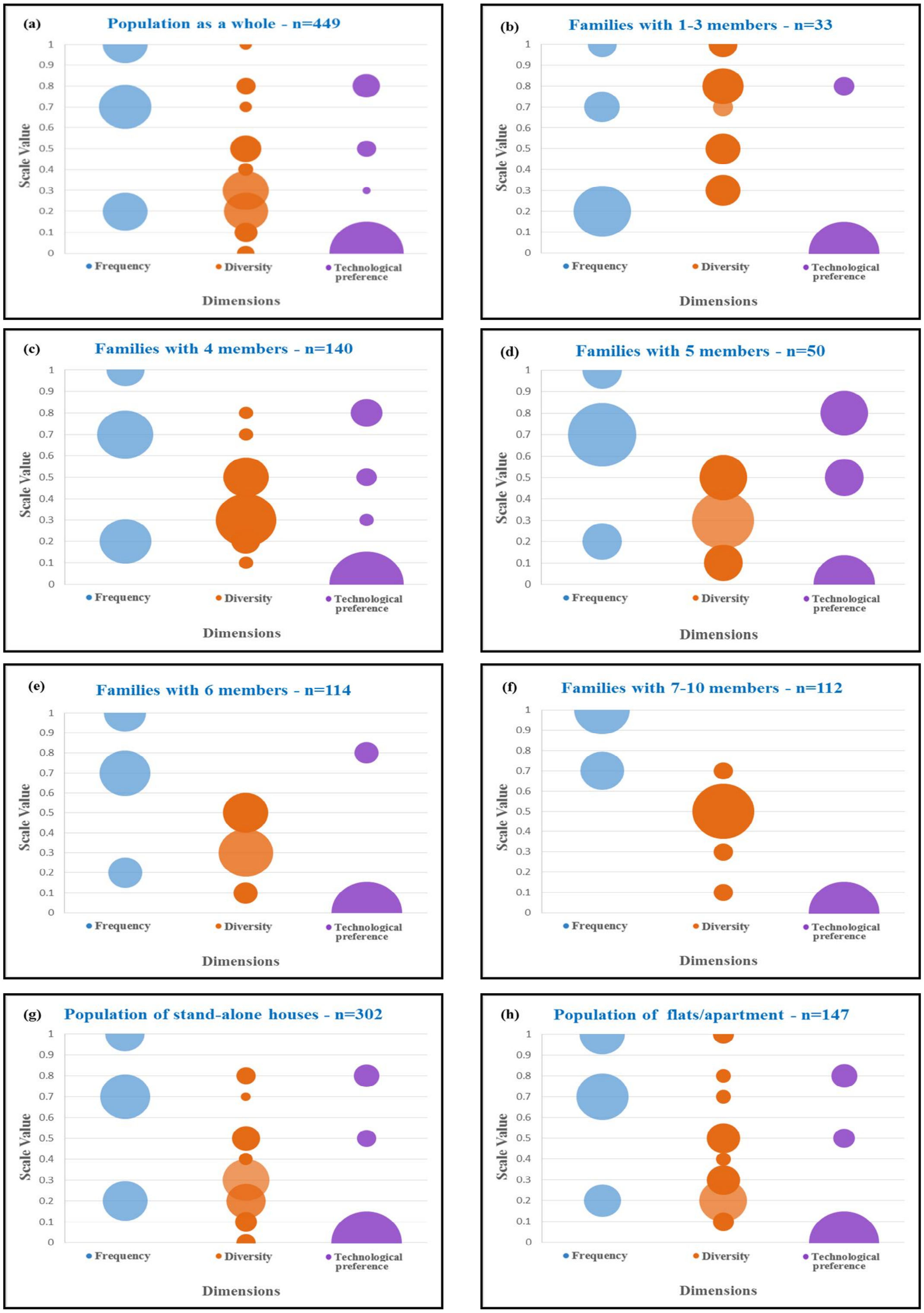


Fig. 5. Population and cluster results for dish-washing (a) Whole population; (b) Families with 1-3 members; (c) Families with 4 members; (d) Families with 5 members; (e) Families with 6 members; (f) Families with 7-10 members; (g) Population of stand-alone houses; (h) Population of flats/apartments

3.4 Analysis on Clothes-washing

In the area of the study, 40% of the households have families with four members, and families of five and six, respectively, account for 11% and 21% of the whole population. Therefore, as mentioned earlier, separate clusters have been considered for these family sizes (Figs. 6b, 6c, 6d, 6e and 6f). Water consumption rates for clothes-washing, 21 l/capita/day in flats/ apartments and 18 l/capita/day in stand-alone houses, indicate that, on average, residents of flats consume more water for clothes-washing than people living in stand-alone houses (Figs. 6g and 6h). This may be due to number of reasons including family size: the majority of the participants living in flats have small families, and as mentioned earlier, water consumption (per capita) is higher in smaller families (Fig. 2b). Another reason would be the family salary class; a large proportion of the flats/apartments in this study are located in the upper middle class areas. Generally people in this class are more concerned about sanitation and hygiene [40]. Conversely, the results of ANOVA tests presented in Table 5 show that the frequency of clothes-washing is similar in all clusters regardless of family size or household type ($F_{\text{Frequency-Family size}} = 1.183 > F_{\text{Frequency-Critical}}$, $F_{\text{Frequency-Household type}} = 0.571 > F_{\text{Critical}}$, $p_{\text{Frequency-Family size}} = 0.330 > \alpha$, $p_{\text{Frequency-Household type}} = 0.0.453 > \alpha$).

Fig. 6a illustrates the water use behaviours for clothes-washing across the whole population. It is shown that 50% of the households wash their clothes on a daily basis (seven times per week), while, less than 1% wash their cloths less than 2 and more than 10 times per week. It is interesting that nearly 30% of the population consume 700 litres per week only for clothes-washing; this high consumption can be decreased by applying water conservation practices and some changes in water use habits. According to the results of the survey, only 23% of the participants never use washing machine; it means that more than 75% have washing machine in their properties. Washing clothes with fully loaded washing machines is more efficient than manual clothes-washing, while, among the families using a washing machine, water consumption is relatively high. One reason is that more than 78% of these households have top-loading washing machines which consume nearly twice as much water than front-loading machines. Fig. 6b shows that smaller families preferred manual clothes washing mainly on a daily basis. The washing preference in families with four members is similar to the previous group (Fig. 6c). However, this group consumes a higher amount of water for clothes-washing compared to the families with one to three members. By comparing different bubble plots in Fig. 6, it can be seen that water consumption for clothes washing is lower in larger families. Larger families preferred using washing machines more than the smaller families; while manual clothes washing is still in practice in all the households. The results shown in Table 5 also show that the most significant water consumption difference can be seen between Cluster 5 and Cluster 2 ($p_{\text{Diversity-Family size}} = 0.0001 > \alpha$, $\tilde{x}_{C2} - \tilde{x}_{C5} = 0.508 > HSD$).

Table 5. Results of ANOVAs and post hoc tests for water consumption for clothes-washing

Comparison categories	Dimension	ANOVA test				Post hoc test	
		Critical F	F	Alpha	P-value	HSD	Significant differences
Family size	Frequency	2.578	1.183	0.050	0.3300	2.027	-
	Diversity	2.578	12.180	0.050	0.0001	0.243	$\tilde{x}_{C1} - \tilde{x}_{C5}$ = 0.325
							$\tilde{x}_{C2} - \tilde{x}_{C5}$ = 0.508
							$\tilde{x}_{C2} - \tilde{x}_{C3}$ = 0.462
	Technological preference	2.578	3.970	0.050	0.0070	0.271	$\tilde{x}_{C1} - \tilde{x}_{C3}$ = 0.327
							$\tilde{x}_{C3} - \tilde{x}_{C4}$ = 0.314
							$\tilde{x}_{C3} - \tilde{x}_{C5}$ = 0.274
Type of household	Frequency	4.026	0.571	0.050	0.4530	0.979	-
	Diversity	4.026	35.455	0.050	0.0001	0.183	$\tilde{x}_{C6} - \tilde{x}_{C7}$ = 0.381
	Technological preference	4.026	38.011	0.050	0.0001	0.175	$\tilde{x}_{C6} - \tilde{x}_{C7}$ = 0.377

HSD: Honest significant difference; $\tilde{X}$: Cluster mean; C1: Cluster 1 (Households with 1-3 members); C2: Cluster 2 (Households with 4 members); C3: Cluster 3 (Households with 5 members); C4: Cluster 4 (Households with 6 members); C5: Cluster 5 (Households with 7-10 members); C6: Cluster 6 (stand-alone houses); C7: Cluster 7 (flats/apartments)

Fig. 6. Population and cluster results for Clothe-washing (a) Whole population; (b) Families with 1-3 members; (c) Families with 4 members; (d) Families with 5 members; (e) Families with 6 members; (f) Families with 7-10 members; (g) Population of stand-alone houses; (h) Population of flats/apartments

4. DISCUSSION: HOW TO IMPROVE WATER USE HABITS AND SWITCH TO A WATER CONSERVATION MODE?

The qualitative and quantitative analysis provided in the previous sections should help in highlighting opportunities and conceptual approaches resulting in improved water use habits. Browne et al. [35] believe that these approaches should be less reliant on changing people's attitudes towards water and the environment and more focused on the different elements that make up practice. On the other hand, Randolph and Troy [42] stated that policies and rules play an important role in reducing household water consumption. They also argued that for acquiring better responses, the complexity of the forces shaping demand needs to be understood in the context of the socio-demographic composition of households in different kinds of dwellings, as well as the cultural, behavioural and institutional aspects of consumption.

Changing human habits is a long process [43] which means that it needs time and resources to build new habits, whereas, water scarcity is a current and existing concern in India. Therefore, both long term and short term plans should be considered in this situation. The best long term plan would be community capacity building (CCB) or educating people. CCB is basically a conceptual approach to development focusing on understanding the obstacles that inhibit people and governments from realizing their development goals while enhancing the abilities that will allow them to achieve measurable and sustainable results [44]. A number of studies suggested that water use habits can be improved by educational campaigns and dissemination of knowledge in changing behaviour together with the effect of consumerism on water consumption through the daily routines and awareness of entitlement [13,45,46]. People can be informed of the water scarcity, its associated issues and any inappropriate water use habits/behaviours; then they can be guided through appropriate direction towards more efficient water consumption. Randolph and Troy [42] proposed 13 actions for reducing household water consumption e.g. taking shorter showers, filling washing machine before using, reducing garden watering, and reducing car washing; it was shown that almost all of these actions are to some extent efficient. In the previous sections it was shown that water consumption for bathing/showering and clothes-washing is relatively high in Jaipur; the average shower time of nearly 25% of the participants is between 15 and 30 minutes. This can be reduced by at least a few minutes which will help to improve the city's water consumption efficiency.

Applying water saving devices and micro-components would be the best short-term plan, as some of these can reduce water usage by 50% or even more [8,30,31,47]. However, most of these water saving appliances/devices are rather expensive for the majority of the population. It means that in order to encourage people to apply water saving devices and thereby effect a general lowering of water use, subsidising these technologies is required. In a survey in Australia, it was shown that 77% of the participants were willing to fit these devices if the price was subsided by 50% [42]. More studies are required to investigate the impact of each water saving device in improving water efficiency in Indian cities. Conducting a longitudinal diary-based study on water use habits would be worthwhile in order to derive even more useful evidence.

5. CONCLUSION

Indian water demand is projected to very soon overtake the availability of water. Household water using habits and water demand in particular is growing as a result of increased water use for personal hygiene and use of water consuming appliances as a result of increasing standards of living. This growing demand will impose additional strains on ageing and deteriorating water and wastewater infrastructure, which could further reduce per capita mains water supply. Climate change and climate variability will also likely challenge the resilience of the water sector by adversely affecting the water resources in this country.

Given the above challenges and the role water efficiency can play in mitigating some of the challenges, this paper presented the findings of a domestic water consumption survey carried out in Jaipur, India. A questionnaire containing over 60 questions was developed to collect information on households' characteristics as well as the volume of water used in different water use practices. To analyse the results of the survey, cluster analysis and ANOVA test were undertaken. The results showed that the per capita consumption varies considerably with household type and size. Water used in bathing/showering represented the highest proportion of water consumption in both stand-alone houses and apartments. Family size and income were also found to be important indicators in estimating household water consumption; it was shown that small families have higher water consumption in general. It was shown that high frequency of using toilet and handwashing are in families with 4, 5 and 6 members. Water consumption rates for dish-washing and clothes-washing indicated that, on average, flat residents consume more water for clothes-washing in than people living in stand-alone houses. Analysing the results of cloth-washing showed that 50% of the households wash their clothes on a daily basis; water used in clothes-washing can be significantly reduced through the use of washing machines.

The findings of this study draw the conclusion that although changing water use habits of any city dwellers seems to be a long and complex process, it would substantially reduce the household water consumption. In addition to that, several water saving devices/micro-components can be adopted in household levels to improve the domestic water efficiency. As a final note, in order to undertake further research, conducting a diary study on water use habits would be worthwhile.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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