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OPENING THE BLACK BOX OF WATER CONSERVATION BEHAVIOR: HOLISTIC PERSPECTIVE OF A DEVELOPING COUNTRY

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ABSTRACT
Water is becoming increasingly scarce due to physiochemical changes in the environment brought on by human activities. This scarcity of water resources if not managed properly can lead to disastrous situations. It is therefore imperative to introduce an effective water conservative system that could handle this very deadly important resource. Thus, considering the above factors, this research aims to provide empirical and physical information from Pakistan's less developed areas, depicting people's attitudes and activities about water conservation at home (WC). For that purpose, demand management" measures were used to collect data as it jointly includes engineering practices/regulatory measures and behavioral practices which include attitudinal and market-oriented measures. Survey results indicate that people show positive attitudes towards WC but mixed responses were observed to water saving appliances. However, it was experienced through water audit that these positive attitudes are poorly deciphered into practicing the behavior. Only 20% of people are using a few water efficient appliances and they do not bother minor to moderate leaks in water supply pipes. The major obstacles to the application of water conservation habits are the high costs of appliances and a lack of awareness about water scarcity. So, it is proposed that repairing tiny breaches might save a household 1000 liters each day. Moreover, this study contributes to the existing body of knowledge by addressing the difficulty related to water conservation and increasing the exposure for decision-makers to support this process in the Pakistani context.
Keywords: Water Conservation; Demand Management; Water Efficient Appliances.

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INTRODUCTION

Water scarcity is one of the major problems, facing most developing countries these days. The primary reasons for rising water consumption include exponential population growth, a rise in the number of dwellings, a low number of people per residence, improved levels of standard of living, and subsequent changing lifestyles. Pakistan is currently experiencing a severe water scarcity that is expected to devastate the country by 2025. The Indus River System Authority (IRSA) recently announced a severe water scarcity in the irrigation water of the Indus Basin (IBIS). For the summer farming period, IBIS is considered one of the world's biggest contiguous irrigation systems. It is a concern for both the community and the authorities to save water not just for agribusiness but also for human utilization to fulfill the growing water requirements caused by the increasing population. Pakistan's overall population increased from 132.35 million in 1998 to 189.87 million in 2016, with the yearly availability of water per capita (m3/capita/annum) dropping to 1014 per person. According to a UNDP report from 2016, the water quality has deteriorated to a dangerous level as a result of improper storage and management in dwellings.

Due to poor management, land degradation, over-extraction, and global warming, even drinking water is rare in some parts of the country, and these limited resources are swiftly depleting. The importance of conserving water has grown to the point where the LEED grading system has lately lowered the water efficiency list's marks from five to 10. Green building is already being designed in several nations throughout the world. The study's major goal is to examine individuals' behavioral patterns on the relevance of water management and the usage of energy-efficient equipment in the home. One of the goals of the research is to reduce water wastage and to highlight the best methodologies for saving water at the grassroots level. Although the major purpose of water conservation is a decrease in building operational costs, greater demand for housing, some energy efficiency, and improved interactions with inhabitants are additional benefits of conserving water. Water-saving adaptation of current dwellings can help not only to alleviate the nation's water constraint but also to ensure the construction sector's long-term viability.

MATERIALS AND METHODS

For water efficiency goals, Manouseli et al. (2018) established physical proof drought scenarios designs. This academic evidence focuses on home water consumption during both 'regular' and 'drought' situations (Manouseli, 2018). The paper emphasizes the necessity of inter- and intra-household reasons, and water use procedures, to be included in future growth modeling techniques considering the limited provision of facts upon many various and developing variables impacting housing demand including both "normal" and "drought" circumstances. The research then introduces 'Water Cultures' as a holistic modeling approach for combining the scant evidence on how social standards, behaviors, and material civilizations connect. This allows the researcher to record both the ambiguity and diversity of individual and/or micro-level variance, as well as the areas for further research which need to be filled. Claire Hoolo-han and Alison L investigate the social, technological, and ecological relationships that determine the collective pattern of home water consumption (Hoolohan and Browne, 2015).

Water use as a collaboratively ordered activity must be rethought to attain continuous residential water usage. The findings of this study highlighted the significance of responsible household water consumption in future data and opportunities for people to develop a more democratic and transparent connection with water supplies. This study also detects and analyzes broader technological and social issues that influence behavioral intention (Hoolohan and Browne, 2015). Many researchers have discovered that the economic impact of population rise, number of dependents, individual behavior, and education have a critical impact on water usage. It's worth noting that it can be divided into two types: price and non-pricing systems. Residential water usage is influenced by a variety of factors, including age, money, occupation, and the size of one's home. Many researchers believe that education is among the most important aspects that affect water use (Nunes et al., 2019; Benninghaus et al., 2017). It was discovered that the greater one's educational level, the less water one consumes (Saur, 2013). Although age has an impact on water usage, the study found no apparent link between water use as well as user age. Although it's been suggested that older individuals drink plenty of water (Bich-Ngoc and Teller, 2018; Picetti et al., 2017) because they choose to spend more time at home due to variables such as retirement. Geller et al. also discovered that a higher educational level was linked to the use of water-saving technology (Geller et al., 1983).

METHODOLOGY

The research was conducted in Multan a city in south Punjab due to the rapid increase in population with a growth rate is 2.23 from 1998 to 2017. According to a survey conducted by the government of Pakistan in 2017, the total number of residents of District Multan are 4745109 out of which males are 2437412, female is 2307504 and Shemale / Transgender are 193. A set of 400 questionnaires were distributed based on stratified proportional sampling among faculty, staff, and their family members (residing inside and outside the university) across different departments. Out of these 30% of people live inside the university and the other 70% are living outside of the university in different areas of Multan. From these 70% of respondents, 20% live in posh housing colonies 40% are in middle-class areas, and 40% live in less developed areas. However, 350 surveys were received. A total of 310 replies were utilized for data processing, with the remaining comments being rejected owing to missing or similar responses, yielding 82 percent of respondents. However, one responder is believed to represent one household and 310 participants are assumed to depict 310 families. The responders were promised that their participation would be kept completely confidential. Males made up 40% of our overall sample (500 cases), while females made up 60%. Regarding education, 22% had only a matriculation certificate, 20% had a bachelor’s degree, 38% had a master’s degree, and 28.8% had a doctorate. Concerning their current university designations, 30% were authorized employees, 28% were Instructors, 30% were Assistant Professors, 5% were Associate Professors, and 7% were Professors.

Water supply strategy is characterized as "any socially beneficial measures undertaken by a person or a group of individuals that is beneficial in preventing or adjusting average or maximum water deduction or utilization, be it from surface water or groundwater while maintaining or improving water quality" (Qdais, 2003; Brooks, 2007). Water demand management is a key and helpful way for observing societal attitudes toward conserving water (Russell and Fielding, 2010). Many researchers and observers have emphasized its significance, and surprisingly, several scientists have called demand management systems for freshwater resources (Jorgea et al., 2015; Willis et al., 2011; Jorgea et al., 2015; Corazon et al., 2018). Researchers have utilized several ways to monitor water requirements, but because Pakistan's infrastructure is lacking, the current study has established various strategies to manage water needs, that have been implemented for household use, such as equipment and prices. Water saving equipment has been in the foreground while establishing surface and groundwater management policies since engineering is a non-price factor (Koutiva and Makropoulos, 2019). Using technology to calculate the total loss of Water, leakage monitoring, and locating the management of pipe pressure are the main components of a water Audit (Adedeji *et al.*, 2017b). A household water audit is used to assess the water usage behavior of respondents and how much water they are saving at home (Addo *et al.*, 2018). By conducting a water audit (Master and Gandhi, 2017; Khedikar, 2011); (Gagnon, 1984), researchers estimate the water used in dishwashing, cloth washing, bathing (Kulkarni *et al.*, 2014), showering (Simpson *et al.*, 2019), car washing, flushing (Kubade *et al.*, 2017), and in yards.

Leaks were observed by the pressure gauge method (Yoo *et al.*, 2018; A. Kulkarni *et al.*, 2014b) and by visual inspection of all pipes as well as by looking for telltale watermarks on walls or ceilings. The water pressure gauge was connected to different outdoor hose bibs as shown in Fig 1. Turn off all the taps and showers and other appliances. After properly installing the pressure gauge start to see the gauge move, if the value of pressure is 100% it means there are no leaks in pipes; (Rottländer *et al.*, 2016), shower heads and toilets, etc. Low pressure value indicates the leaks in the respective pipe (Ferrante *et al.*, 2014; Zyl and Malde, 2017). The pressure gauge used in the research is shown in Fig 2. The land just above the water's surface in the backyard may stay moist all the time or water may run on the ground. Following the discovery of breaches, fast and effective methods for conserving water in the property were advised. Various scholars have also used such methods and techniques to compute the water requirements in residential areas (Adedeji et al., 2017; Brunone et al., 2004).

RESULTS AND DISCUSSIONS

Water Audit, Operation, and maintenance

Clean water is very precious in the world and especially in Punjab due to environmental changes and poor handling (Briscoe *et al.*, 2005). Unfortunately, In Pakistan piping system installed is very old and water is lost through this aging infrastructure (Siegmann and Shezad, 2006; Bank, 2013). And due to these losses revenue to the water service supplier is also lost (Perera *et al.*, 2018). Leakage and breaches in pipework allow water to escape. Because most construction is below (Daud et al., 2017), visualizing the site of these breaches is nearly impossible except if the water level reaches the ground (creating French drains and sink openings, structural failure, collapsing sidewalks, and so on), and the actual position may be unknown. Special technologies are required to detect leak type and severity by allowing inspectors to precisely determine its location in pipeline. An indoor water audit survey was conducted by the researchers to physically observe water usage practices of respondents.

Flow rate of Fixtures

The volume of water that goes across the ground per unit of time is known as the volumetric flow rate (Pourmehrana et al., 2015). Or, to put it another way, the rate at which water runs through a channel. The flowing effect is affected by water speed, pipe size, and friction factor (Koop et al., 2019). Because of their size, the diameter of pipework restricts the movement of water. It was observed that in 15% of houses, Oversized water plumbing pipes were installed in houses which increase the flow rate. It is anticipated that the larger the diameter of the pipe, the greater the water flow.

Table 1: Typical flow rate of Fixtures Used

Fixture Type	Fixtures Flow Rates Low flow fixture max (flow rate)	Fixture used in Multan (flow rate)
Showerheads	1.8 GPM	2.71 GPM
Lavatory faucets	1.2 GPM	6.12 GPM
Kitchen faucets	1.8 GPM	3.78 GPM
water closets	1.28 GPM	2.5 GPM

Leakage of Water

For water supply systems and private users, leaks from pipework, sanitary fittings, and valves are a significant source of water loss. According to studies, a usual residence leaks 2,000 to 20,000 gallons (7.6 m3 to 76 m3) of freshwater each year. Some breaches are obvious, such as dripping faucets and dripping heating systems. Since the cause of the incident is not obvious, hidden breaches might linger for years. A pressure gauge was used to detect the leakage that was not visible. Toilet flapper valves and damaged water system lines were the most common sources of hidden leakage. It was also discovered that only hidden leaks, either separately or jointly, were consuming thousands of gallons of water per year in a private residence. Table 4.1 shows the water loss per year due to a few drops of water leak per minute.

Fig.1 *Leak detection device used in research*

In the water audit survey, many leaks were observed in different areas of houses. On the bases of the literature, the author categorized the leaks as minor, major, and severe leaks. one or two drops of dripping leaks in pipes or fixtures were considered minor leaks. It was recorded that with just one minor leak 35 liters of water was wasted on daily bases.

Fig.2 *Measurement of leaks at various places*

The amount of water was calculated with a bucket test. Steady dripping fixtures were considered major leaks. It was recorded that due to one major leak 170 liters of water was wasted per fixture per day. In the case of a single severe leak (continuously flowing water), 525 liters of water was wasted per fixture per day. Fig.no. 2 and 4 show the measurement process of different leaks.

Table 2: Standard Water Loss per Year through Different Drops

Estimated Water Loss Through Leaks		
Drips per minute	Water Waste/Month/gallon	Water Wasted /Year/gallon
10	43 gallons	526
30	130 gallons	1,577
60	259 gallons	3,153
120	518 gallons	6,307
300	1,296 gallons	15,768

<u>Reuse of Grey Water:</u>

Grey water is the water collected from rain. The reuse of greywater reduces freshwater requirements as well as sewage generation**.** Due to changing weather conditions, grey water has a strong capability for use in garden irrigation, washing cars, and flushing toilets. But it was observed that only 3% of people from the sample are using grey water at a small scale. Fig no 3 shows the average rainfall in the Multan region.

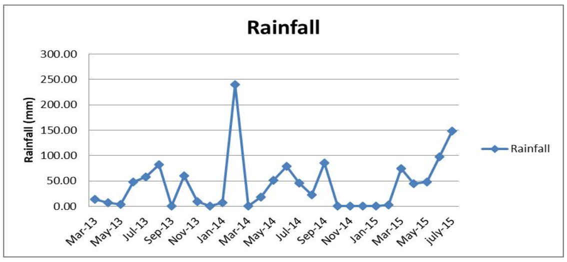

Fig.3 Average rainfall in Multan.

<u>Water Efficient Appliances</u>

According to the survey results, water-saving appliances have a higher level of support. Almost 60% of respondents agreed that water-saving equipment is a fine decision. People that do not know anything about efficient water appliances account for 42% of the population. When purchasing appliances, around 40% of individuals examine the water supply rating. Price is the main obstacle to introducing water-saving equipment, according to 80% of participants. Water efficient equipment isn't thought to save some water being worth the money by 42% of individuals. Overall the survey indicates that the use of energy efficient appliances has a direct relation with education. Mostly graduated people know about water efficient appliances.

Ownership of Water Efficient Appliances

A very small number of houses had water efficient fixtures. Mostly traditional toilets with a capacity of 15 to 201 liters of water per flush were installed. Only 20% of houses had the two or three energy efficient fixtures

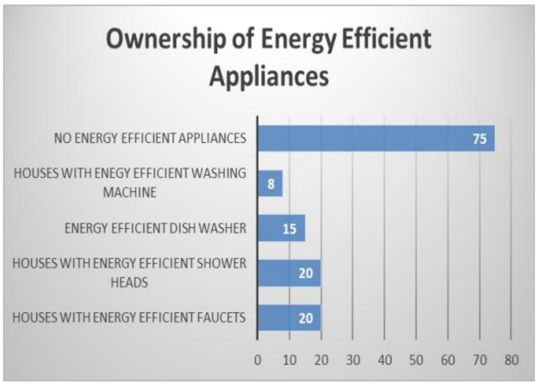

Fig.4 *houses with energy efficient appliances* ures.

However, most homes do not have a single water-saving device, and low-flush toilets utilize just 61 liters or even less water. Low-flush toilets lower the quantity of wastewater generated by using less water. Replacement of regular flushes with low-flush toilets is a viable and cost-effective water-saving alternative even in existing homes. Money has a direct correlation with the possession of water-saving appliances; educated wealthy individuals have a plethora of water-saving equipment. The high price of these devices is a major hindrance to their acquisition, as it is extremely difficult for poor and low-middle-class individuals to buy them.

Table no.4 shows the frequency distribution among the respondents and for graphical representation see Fig 5. Results for the descriptive stats for the model are given in Table 4.

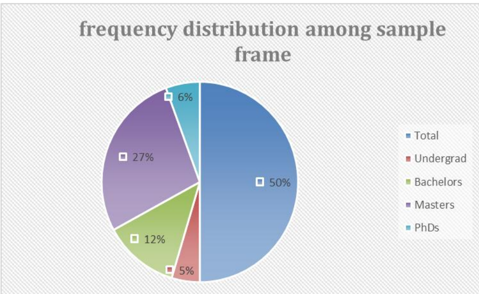

Fig 5: frequency distribution of respondents

Table 4: Variance Inflated Factor and Descriptive Statistics

Variables	VIF	Means	Std	TE	WCB
TE	1.00	3.96	.35	1.00	.43
WCB	--	3.98	.41	.43	1.00

The results depict that on average, the respondents showed a positive attitude toward water conservation behavior, with a mean of 3.98 and a standard deviation of 0.41. Similarly, the attitude of the respondents towards technological efficiency was also positive, which shows that people value the need for water conservation.

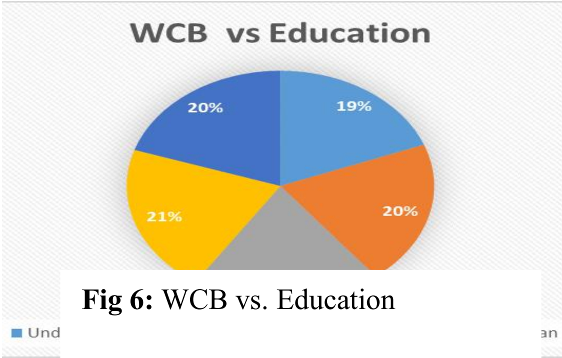

Fig 6: WCB vs. Education

The ANOVA results are shown in Table 5 of the results. The level of significance of the key variables, namely gender and knowledge, as well as the potential interactions between gender and ethnicity, are included in the results.

Table 5: Summary Results for the Test of Variance (ANOVA)

		Effects	
	Gender (main)	Education (main)	Two-way interaction
Variable	F-value	F-value	F-value
WCB	0.30	.04	.09

Notes: **p⩽ 0.01; ***p⩽0.001

The non-significant value of F for gender shows that the perception of people of water conservation does not differ. However, the significant value of F for education shows that people's perception regarding water conservation issues varies across the different levels of education.

Table 6: Summary Results for the Test of Variance (ANOVA)

Notes: **p⩽ 0.01; ***p⩽0.001

		Effects	
Variable	Gender (main)	Age (main)	Two-way interaction
	F-value	F-value	F-value
WCB	0.30	.78	.91

Moreover, the results for the relationship between gender and WCB are given in Table 6. However, the non-significant value of the F-test depicts that the people's behavior regarding water conservation is not different from each other. A summary of the mean and grand mean is shown in Table 6.

Table 7: Summary of the means and grand means score (Education)

		Categories by Education				
Variables	Gender	Undergrad	Bachelors	Masters	PhDs	Grand mean
WCB	F	3.78	3.98	3.94	4.09	3.93

Furthermore, a review of the average results table revealed that the mean ranking for males is 3.98 and for females is 3.964, while the average result of respondents with an undergraduate program is 3.74, 3.98 for bachelor's university graduates, 3.94 for master's university graduates, and 4.09 for PhDs, indicating substantial differences in people's perceptions of water management attitude. So, the mean score of respondents for the perception of "Water conservation behavior" is not across the levels of education. A graphical representation of Water Conservation Behavior vs Education is shown in Fig 6. Age also has very little effect on the WCB of respondents.

The age average score (see Table 8) reveals there is very little variation in individuals ' behavior based on their age, indicating that people's perceptions do vary with age.

Table 8: Summary of the means and grand means score (Age)

		Categories by Education			
Variables	Gender	25-29	30-34	35 and above	Grand mean
WCB	F	3.96	3.93	4.00	3.96

The results show that WCB and Efficient Technology have a positive relationship. Likewise, the results for the association between water conservation behavior (WCB) and efficient technology are given in Table 8. The findings demonstrate a good and substantial association (ET) between advanced technologies and water management attitude, implying that the more efficient energy appliances one uses, the more water is saved.

CONCLUSION

The research adds to the corpus of information in Pakistan about people's perceptions and practices about conserving water. The study's goal is to figure out what drives consumers' water consumption habits and how attitudes, opinions, and motives affect the implementation of innovative water management. The research also aims at identifying the obstacles that impede homes from implementing water saving technologies and techniques. The results obtained through the analysis highlight that lack of knowledge about water conservation and costly appliances is the main reason for not adopting water conservation technology. This study also found a positive attitude of households towards the perception of conservation practices. However, it was observed by the water audit survey that people do not bother with minor to major cracks. And almost 200 leaks were observed at different places in sample houses; wasting gallons of water per month. It was illustrated that by repairing a leaky faucet, showerhead, or toilet a household can contribute a lot to managing the country's freshwater resources. The least prevalent conserving measure taken by Multan inhabitants was the reuse of treated wastewater or the use of a rain bucket. No metering device was installed in different housing societies of Multan. Instead in some areas fixed water supply and sewerage tariffs were collected from users.

This is one of the causes that discourage the consumers' water conservation behavior. So based on this, the study recommends that water usage should be measured with the meter providing the necessary data to charge, based on the actual consumption of the customer. Sub-metering can be installed in multiple units, such as in apartment buildings and suits. Installing water-saving appliances, low-flow valves, and fittings is a vital issue around the world, especially in Pakistan. This will give an adequate analysis of the ongoing involvement of people so that water conservation can be implemented in nearby communities as well. Recycled gray water and stormwater can be used for domestic activities, lawn mowing, landscaping, washing cars, and other purposes that do not need treated water to protect the nation's groundwater aquifers. As it was the significant perception of respondents that the cost of efficient appliances was too high to adopt. It is the responsibility of the Government to motivate this process by promoting research on efficient technology at national and international levels and identifying the problems associated with water conservation and efficient technology adoption. It is suggested that government should immediately start public information and education programs to enlighten the people about the situation of fresh water in Pakistan and the basics of water conservation. So considering this, advertisement or education reform campaigns can be used to target the initiatives for water conservation in Pakistan.

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