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Accurate Estimation of Water Demand and Diurnal Water Consumption Pattern in Hostels in Peshawar

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***Abstract:** This study looks into water demand and daily water consumption patterns in hostels, which is important for long-term water supply systems. It produces exact estimates by combining IoT-based algorithms with ultrasonic sensors. In Pakistan, there was no precise study on hostel water usage. Ultrasonic sensors in hostel water tanks monitor real-time water levels and pump status, allowing hourly water consumption to be calculated. The average daily water consumption per person in hostels is 168.5 Liter Per Capita per Day (LPCD), with a standard deviation of 29.3 LPCD ranging from 112.25 LPCD to 218.5 LPCD. Demand peaks around 10:00 a.m. and gradually declines throughout the day. Weekdays average 172.5 LPCD, whereas weekends average 157.7 LPCD. This information assists in effective water management techniques such as consumption reduction, awareness promotion, optimizing usage, and leak repair, hence improving sustainable water supply system planning and management.*
***Keywords:** Water demand, Water Consumption Pattern, Hostels, IoT Data Logger, Ultrasonic Sensor*

I. INTRODUCTION

Water is one of the most important resources for the earth's environment and human survival [1]. Water demand and consumption patterns are critical components for water management, particularly in countries where population growth and diverse lifestyles are putting increasing strain on restricted water supplies. Water demand forecasting is critical for the many water-related entities in the planning, evaluation, operation, and construction of water delivery systems [2], [3]. A precise assessment of water demand for customers should be made to provide proper hydraulic control of the water supply network [4], [5]. Given Pakistan's water scarcity challenges, it is critical to precisely assess water demand and use trends. In this country, 96% of water is utilized for agricultural purposes, with the remainder used for domestic, industrial, and other reasons. This country's daily water usage ranges from 30 to 350 LPCD. Water use in Pakistan is influenced by variables such as fast urbanization and population growth. This country's principal source of drinking water is groundwater [1]. Furthermore, different organizations in Peshawar use varied water demands while constructing, operating, and maintaining water supply systems and networks. PHED uses 15 GPCD (gallons per capita per day) to design water delivery systems, but PDA uses the figures below (based on living standards).

1) High living standard =300 LPCD or above
2) Normal living standard = 200-250 LPCD
3) Basic low standard = 70-120 LPCD

Then what will be the daily water consumption in hostels (which might be part of the water supply system)? Which 24-hour diurnal pattern should be employed for a hostel's continuous water supply network? This suggests that there is no realistic value for water demand and consumption patterns that all agencies might use when constructing water supply systems for hostels. Water demand and consumption trends for hostels must be properly estimated.

The following goals and objectives will be addressed by this research:

a) To estimate the amount of water required by students in engineering hostels.
b) To evaluate the average diurnal pattern and peaking factors for water usage in an engineering hostel.

IoT devices were used in this project to monitor water use in Peshawar dormitories, giving vital data for tackling water-related concerns. We detected significant patterns and trends in this data using statistical analysis, indicating the promise of IoT devices in capturing high-resolution, real-time data on water consumption. The consequences of this research are critical for water supply management and planning organizations. Water demand and consumption patterns that are precisely estimated can lead to sustainable and equitable access to water resources while potentially lowering delivery costs.

Our research, which makes use of IoT data loggers and sensors, provides exact, accurate, and high-resolution data on water consumption in Peshawar, Pakistan. This adds to the expanding body of information about water demand and consumption trends in cities, as well as demonstrating the usefulness of IoT data loggers in obtaining such data. We anticipate that our findings would be of interest to many stakeholders in the water sector, supporting informed water management policies and practices to improve water resource sustainability.

II. LITERATURE REVIEW

Accurate assessment of water demand and consumption patterns is critical for successful water management in tackling the worldwide water scarcity challenge. Numerous studies have been conducted across the world to investigate these issues utilizing various approaches such as surveys, water metering, Smart Pulse metering, interviews, observation, and IoT-based systems. Notably, IoT-based devices have emerged as a trustworthy choice, providing real-time and exact data for determining water demand and consumption patterns.

This review of the literature gives a complete overview of these research activities, emphasizing the potential of IoT-based solutions to improve accuracy and reduce biases in data collecting.

In Toowoomba, Australia, a study was undertaken. In this study, 10 homes were chosen as a sample and fitted for 138 days with expensive high-resolution data collectors (water meters and data loggers). They discovered that the average water consumption was 112 LPCD. According to this study, water demand may be impacted by water restrictions, rebate schemes, and water-wise education [6]. In 2012. research was carried out in South East Queensland, Australia. They gathered information using a Smart Pulse meter. The effect of the rainwater tank on water demand and consumption patterns was discovered. The water demand was determined to be 133 LPCD on average [7].

The research was done to evaluate the amount of water used inside a university in the United Arab Emirates. Monthly data were gathered via water meter readings for three years (2016, 2017, and 2018), and in addition, a survey of 412 students was also carried out. The university (hostels) utilized the most water, according to the findings (47.5%). 81.7 liters of water per person per day was the average [8].

The end-use of household water was the subject of research in 5 different KP areas. Water pumps and above-water tanks were present in the homes. The water pump's discharge rate and the time it took for the water storage to fill up were used to calculate the daily water volume. They discovered that the average consumption in Kohat (urban) was 100 LPCD, Mardan (urban) was 105.99, Charsadda (urban) was 102.84, Charsadda (rural) was 61.81, and Kohat (urban) was 100 LPCD [9].

In summary, earlier research employing Arduino flow meter-based devices in Peshawar hostels has shed light on patterns of water demand and usage, although with certain limitations, [10] observed that on January 8, 2018, there was a per-person demand of 74.5 LPCD, with consumption peaking at 8.2 LPCD at 2:00 PM and a peak factor of 2.64.

However, this study's constraints, such as its one-day duration, the instrumentation of only one of four water tanks, and its destructive methodology, may have resulted in errors. Further research conducted in the same area by [11] produced a different conclusion, with a per capita demand of 99.6521.79 LPCD, an hourly peak factor of 2.4 between 13:00 and 15:00 hours, peaking at 1.15 on Saturdays.

The same restrictions were found. There is still a need to do more studies using more reliable and ongoing IoT-based technologies to get accurate and complete information on water demand and consumption patterns in Peshawar hostels. This is because the existing studies are inconsistent and have limitations.

In conclusion, this literature review demonstrates the potential of IoT-based solutions and emphasizes the significance of precise water demand and consumption pattern estimates for optimal water management. Given the shortcomings of earlier studies conducted in Peshawar, additional research utilizing IoT technologies is needed. By creating an IoT-based monitoring system for Peshawar hostels to precisely estimate water demand and use trends, our effort intends to close this gap.

III.METHODOLOGY

The goal of this study is to evaluate how much water is used in the hostels at the University of Engineering and Technology Peshawar. A thorough comprehension of water use is promised by the suggested real-time monitoring approach, which covers important elements from the research area through data processing.

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A. Study Area

The study focuses on six dormitories in Peshawar which host 1,862 students and have constant access to water from a common tank.

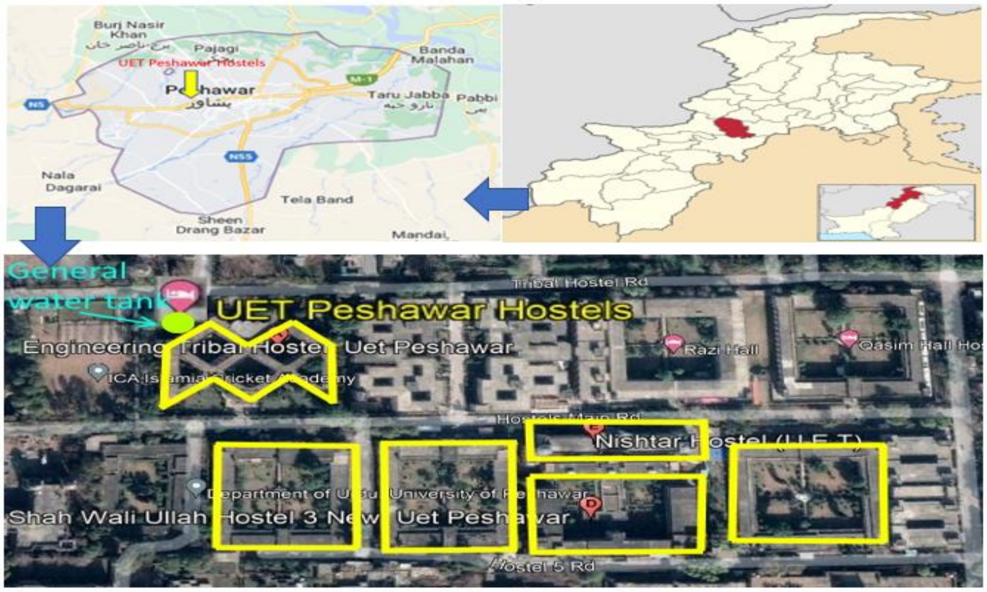

Figure 1. The Study Area for The Study

B. Equipment

In order to precisely evaluate water levels and pump status, this study used an IoT data logger with ultrasonic sensors. The technology measured pump activity and used ultrasonic waves to determine distances of water level from mounted ultrasonic sensor parallel to the water surface. IoT Data Loggers for Sensors were used to capture the data, and MS Excel was then used to analyze it.

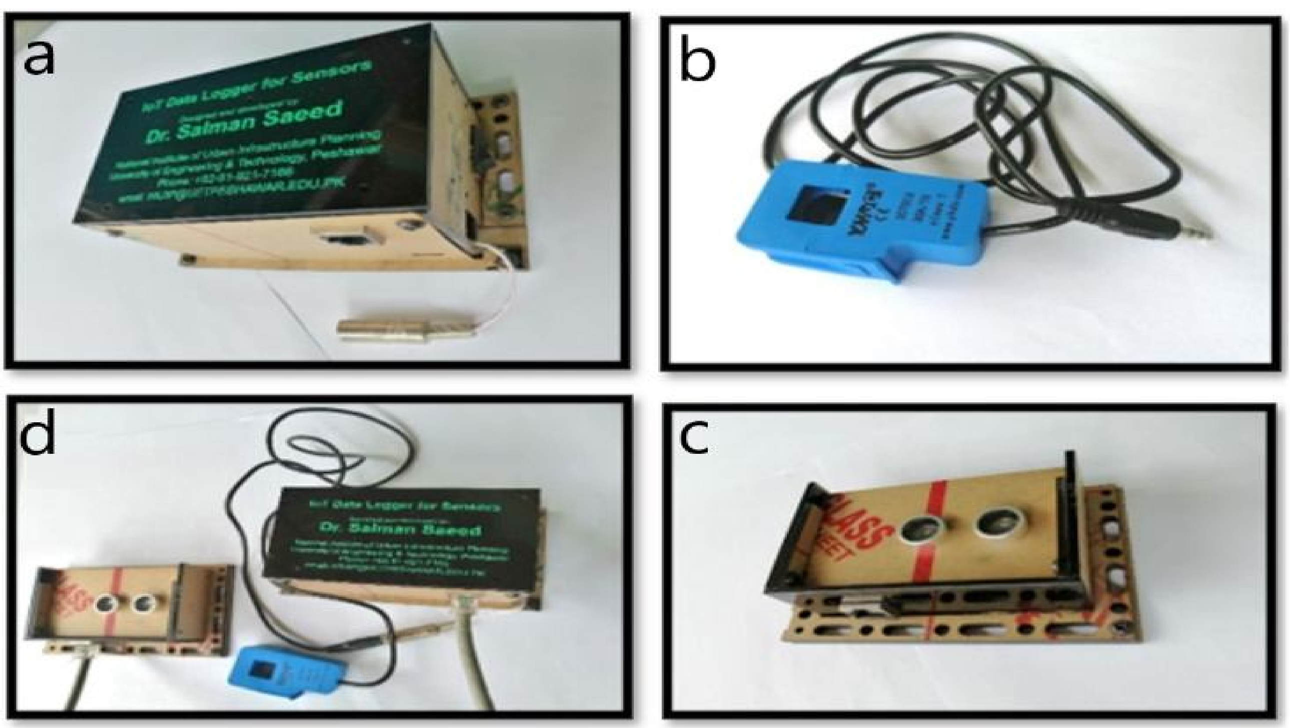

Figure 2. Equipment Used; a. IoT Data Logger for Sensors, b. Split-core Current Transformer, c. Ultrasonic Sensor, d. The Combination of Parts

C. Device Calibration

Before being installed, the equipment was thoroughly tested and calibrated, and manual readings verified the perfect alignment and were almost error-free.

D. Device Installation

The water surface monitoring device was meticulously installed, and the IoT data logger was connected by a wire with an ultrasonic sensor measuring water levels in the water tank. A Split-core current transformer was used to monitor the water pump's status. Regular site visits ensured device functionality.

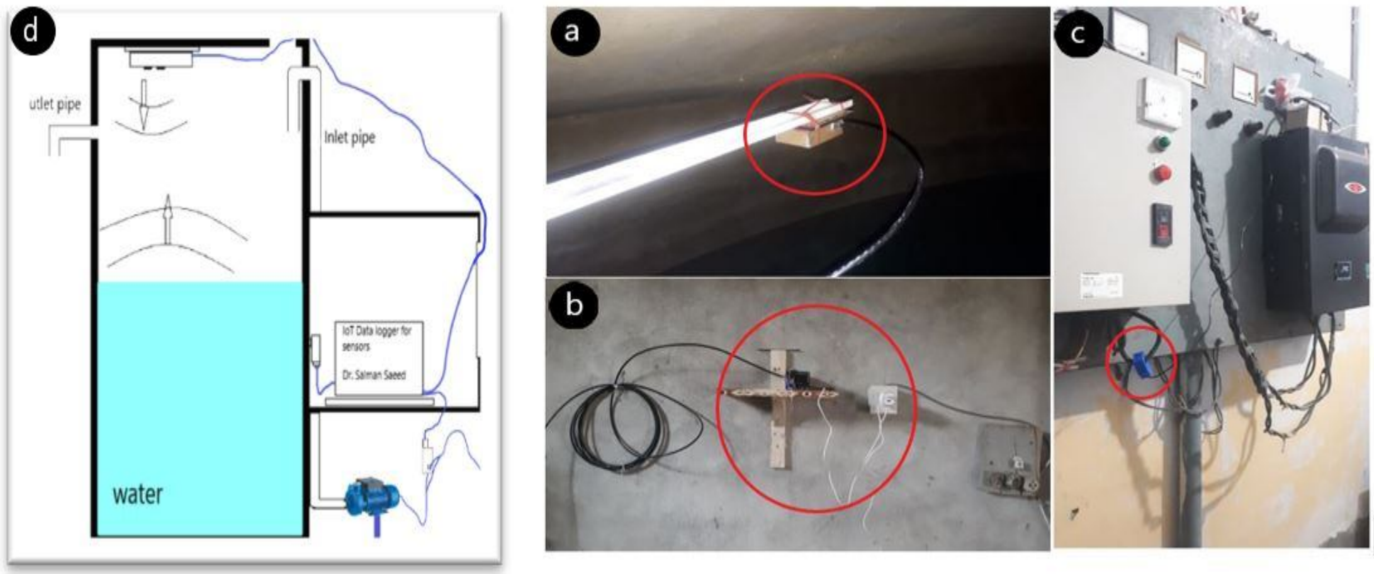

Figure 3. (a) Ultra-sonic Sensor Installed Parallel to The Water Surface, (b) IoT Data Logger for Sensor, (c) Installation of Split-core Current transformer for Water Pump Off/On, (d) Combined Skitch

The data collection spanned two months (from 2022-Dec-15 to 2023-Feb-15) in Peshawar hostels, capturing water surface variations as CSV files from IoT devices, and registered student numbers from hostel records. These datasets were exported and organized in MS Excel for statistical analysis, with a focus on both hourly and daily water demand. Hourly demand was calculated by subtracting water levels between each hour, multiplied by the tank area, while the diurnal consumption pattern involved hourly water consumption calculations and plotting against time. Daily demand was derived from hourly data aggregation. A constant water pump flow rate and a constant water tank area are two crucial considerations for estimating the water demand at the commencement of pump operation.

Actual and Expected Water Levels: This computation takes into account two different water levels. Sensor readings taken at the beginning (Ab) and end (Ae) of the hour are used to calculate the "actual water level" (A). In contrast, the "expected water level" (E) is calculated by subtraction of water pump's flow rate (R, expressed in cm/hour) from the actual water level at the beginning of the hour (Ab). And expected water level must be greater than the actual water level (E > Ae) at the beginning of the hour, because of consumption at the moment of pump operation.

Calculation of Water Consumption: The actual water level at the end of the hour (Ae) is deducted from the expected water level (E) to determine the amount of water consumption during pump operation. Water consumption during pump operation is calculated using the formula: water consumption = E - Ae. This technique guarantees an accurate water demand estimate when the pump turns on. For example, from Figure 4, for 04:00 PM water pump is on, for this hour Ab = 262.49cm, Ae = 175.38cm, R = 104 cm/h constant, first we calculate E, E = Ab-R= 262.49-104=158.49, now we calculate water consumption at 04:00 PM as water consumption = Ae-E= 175.38-158.49= 16.89 cm, it means that at 04:00 PM the water level drops 16.89 cm. In litters, 16.89*water tank area = 0.1689m * 89.58 m^2 *1000= 15130 Litters per 04:00PM.

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	pump status	A	E	Water cons (cm)	Water cons (cm)	Water cons (Lit)	
15:00:00	Off	270.87	249.01	21.86	21.86	19582	2:00 PM
15:44:29	Off/On	286.33	270.87	15.46 +			
16:00:00	On	262.49	260.38	2.11 =	17.57	15739	3:00 PM
17:00:00	On	175.38	158.49	16.89	16.89	15130	4:00 PM
18:00:00	On	93.54	71.38	22.16	22.16	19851	5:00 PM
18:25:35	On/Off	57.07	50.29	6.78 +			
19:00:00	Off	64.01	57.07	6.94 =	19.6	17558	6:00 PM

Figure 4. Water Consumption Calculation for The Hours in Which Water Pump is on.

After that, some statistical analyses were carried out such as descriptive statistics, Mean, Median, Standard division, etc.

In conclusion, the water consumption calculated throughout the study period for each hour was then divided by the number of students (1862) for specific water demand (LPCD). This study offers an accurate and reasonable method for determining water use and daily trends in the hostels at UET Peshawar utilizing IoT data loggers and sensors. The method is demonstrated to be workable and appropriate for the research region by putting these loggers in the overhead water tanks.

IV.RESULTS

The purpose of this study was to use IoT devices to evaluate water demand and daily consumption patterns in Peshawar hostels. According to the study, each person needs 168.5 liters of water each day on average with a standard deviation of 29.3 LPCD. There was no mode value found; daily per capita water use ranged, from 112.25 LPCD to a peak of 218.5 LPCD. Findings showed that the weekdays have higher water demand than weekends.

The investigation of the daily water consumption pattern, as displayed in Figure 5, reveals that it peaks at 10:00 AM and steadily decreases throughout the day.

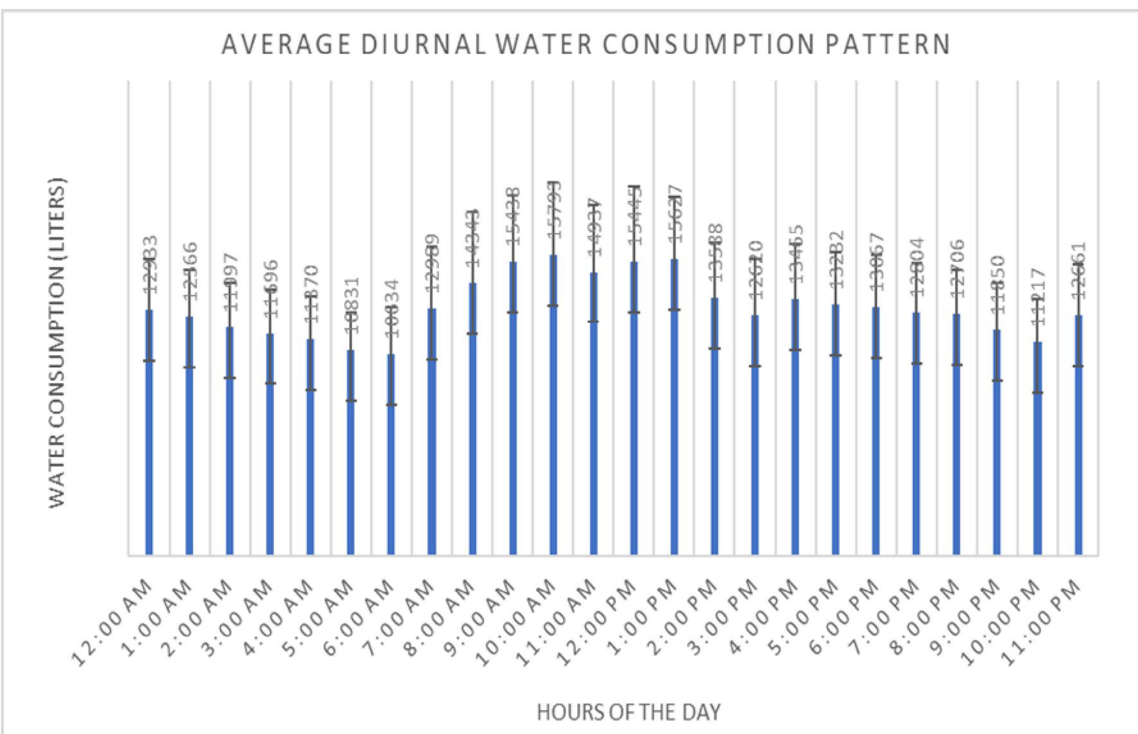

Figure 5. Diurnal Water Consumption Pattern

Additionally, Figure 6 shows the Peaking Factors recorded during various times of the day. These elements are crucial for improving the effectiveness of a water distribution system and offer useful information for forecasting peak water demand.

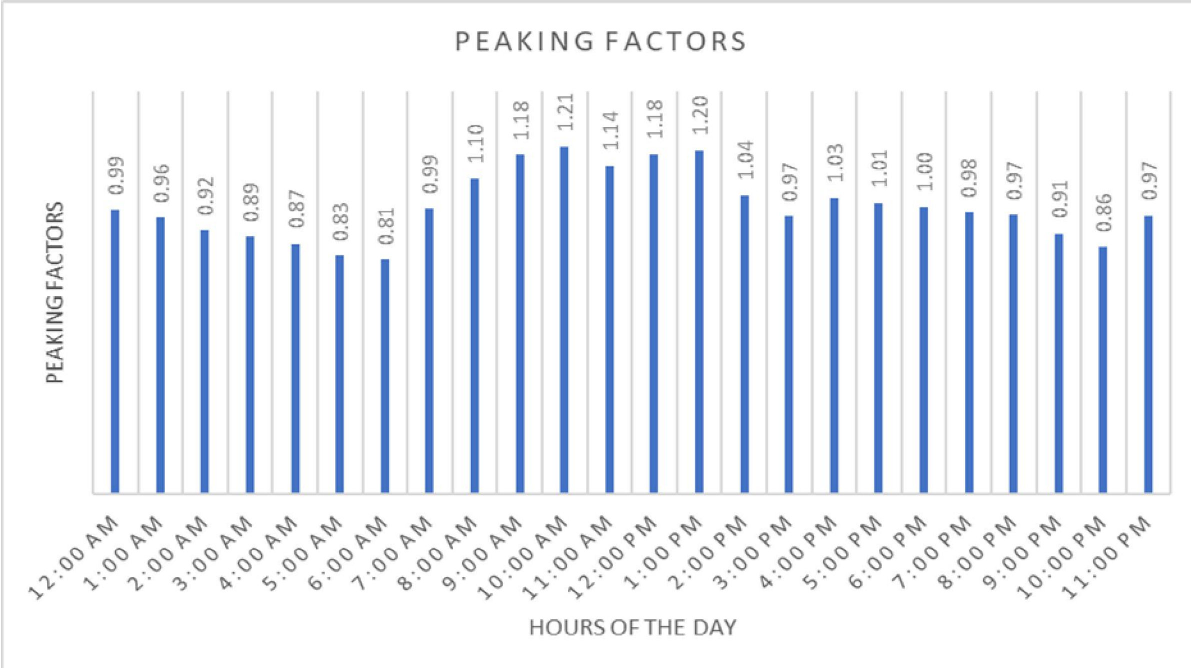

Figure 6. Peaking Factors for UET Peshawar Hostels

The study's findings are highly relevant for planning an efficient water supply during periods of high demand. In conclusion, this study provides important information on water demand as well as useful insights into the patterns of water usage in hostels. An effective water delivery system may be created using this information and customized to the daily needs of the hostels.

V. DISCUSSION

For effective water management in Peshawar hostels, precise forecasting of water demand and daily consumption patterns is essential. An average daily consumption of 168.5 liters per person per day, with a range of 112.25 to 218.5 LPCD was found from this study, using IoT devices for accurate and real-time data.

The study conducted by [10] reported a lower water consumption value of 74 LPCD for Hostel 8 in UET Peshawar. However, it's important to note that this value has been specific to the day of their investigation, as daily variations in consumption are common. [11] also reported a different value of 99.65 ± 21.79 LPCD for the same hostel. Our study, spanning two months and encompassing daily variations, provided a more comprehensive overview. The similarity between our findings and those of [11] may be attributed to the extended study period. The study identified a daily water consumption pattern with peak demand at 10:00 AM possibly for various activities such as watering trees and washing bathrooms etc., gradually decreasing throughout the day, with a secondary peak at 01:00 PM, possibly reflecting student routines. This pattern contrasts with other investigations in Peshawar hostels, where [11] reported peak consumption at 06:00 PM, and [10] found a peak at 02:00 PM. These variations can be attributed to diverse factors, including student habits and study durations.

However, this study is aware of its shortcomings, which include assuming constant student enrolment and not to account for seasonal differences because of a short study period. The results encourage the creation of cost-effective water delivery systems.

VI. CONCLUSION

In this study, Pakistan's Peshawar engineering hostels were examined for their water demand and consumption patterns. The study found that every person needs 171.5 liters of water daily. A notable pattern emerged in the daily water usage, with the peak demand happening at 10:00 AM and then gradually declining throughout the day. The study also identified peaking variables at distinct periods throughout the day. These findings have important ramifications for the organization, administration, and design of water delivery systems.

They can provide a solid starting point for developing more efficient water management plans, such as those that encourage water conservation, put water-saving devices into use, and deal with leaks. However, it's crucial to recognize some of this study's shortcomings, including its brief length and dependence on a constant student population. Future studies could examine creative methods for reducing water use and broaden the scope of the analysis over a longer period to account for any seasonal variations. In summary, this study offers insightful information about water consumption and patterns, providing a solid framework for the creation of long-term water management strategies.

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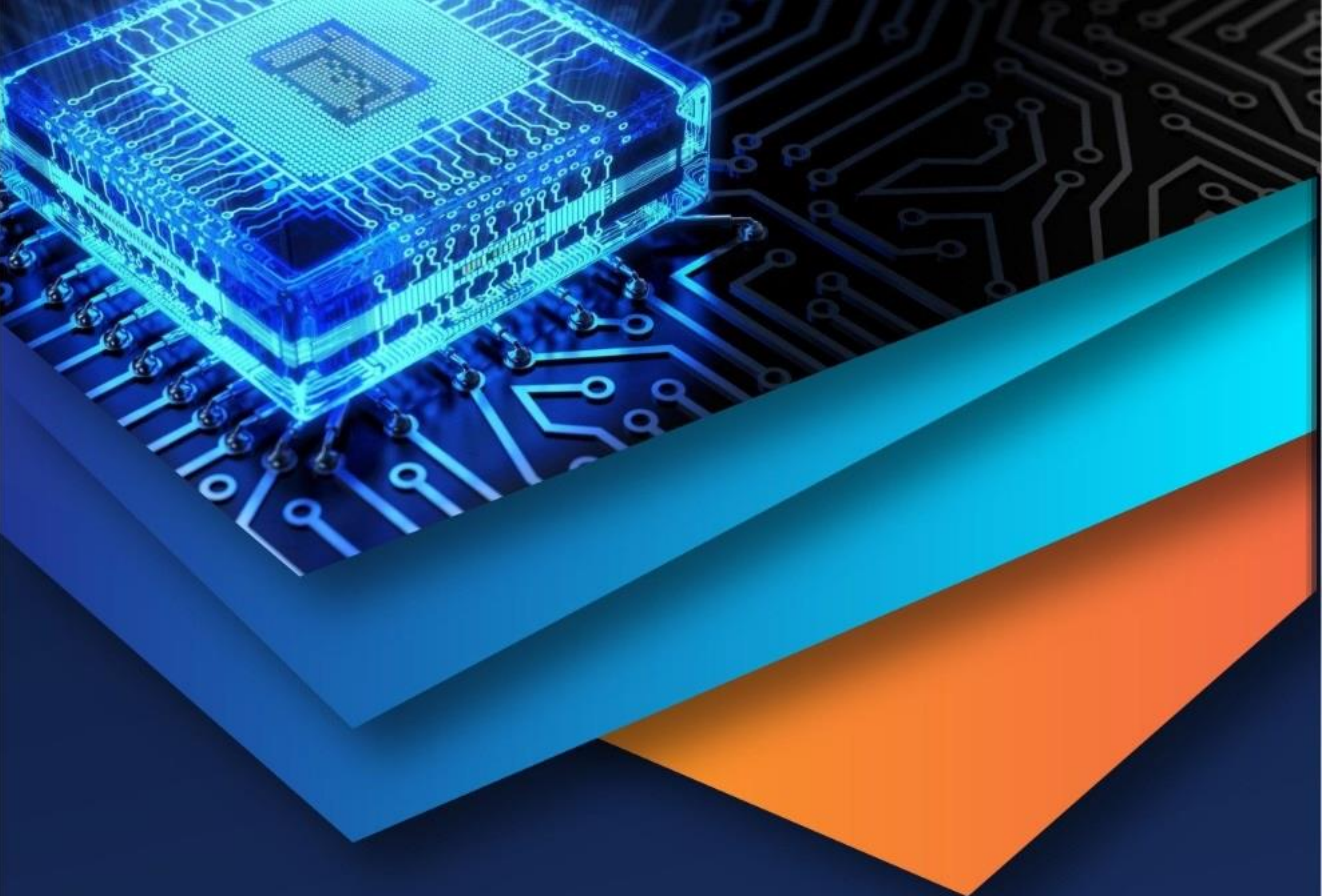

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