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The Utilization of Date (*Phoenix dactylifera*) Pits and Raspberry Pi Pico in Making a Water Quality Management Device

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Abstract: Water quality remains a critical global issue, affecting health, ecosystems, and economies. The challenge of ensuring clean and safe water has intensified in the 21st century, aligning with Sustainable Development Goal (SDG) 6, which advocates for universal access to clean water and sanitation. SDG 12 further emphasizes responsible consumption and production, urging the development of sustainable, affordable solutions for environmental protection. In response, this study developed an affordable Water Quality Management Device utilizing date pits for filtration and a Raspberry Pi Pico for real-time monitoring. Using an experimental, quantitative approach, the device accurately measured pH, turbidity, and TDS, facilitating timely detection of contamination. Results demonstrated a significant reduction in contaminants, from 40.47 g/L to 23.87 g/L, and high accuracy with average discrepancies of 0.04 for pH, 0.03 NTU for turbidity, and 0.04 g/L for TDS. These findings support the device's effectiveness and potential for application in low-resource settings. Future improvements include enhancing the filter design, using better absorbents, and integrating disinfection features.

Keywords: *Date Pits, Raspberry Pi Pico, Water Quality Management Device, Water Quality, Water Quality Issues*

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I. INTRODUCTION

Water quality issues persist as a critical global concern, impacting communities, ecosystems, and economies worldwide. In the 21st century, the challenges of maintaining clean and safe water sources have intensified, as Sustainable Development Goal (SDG) 6 emphasizes universal access to clean water and sanitation (Evaristo et al., 2023). Rapid population growth, industrialization, and increased agricultural activity have put immense pressure on water resources, leading to contamination from pollutants such as chemicals, pathogens, and nutrients (Jahan & Singh, 2023). Deteriorating water quality threatens human health and endangers ecosystems and biodiversity.

Qatar faces water quality and scarcity issues driven by urbanization, population growth, and environmental stress. The country depends on energy-intensive desalination, which generates harmful brine waste (Sezer et al., 2018). Meanwhile, date palm farming produces large amounts of waste, including date pits which is an environmental concern but also a potential resource due to their adsorption properties (Real et al., 2021). These challenges highlight the need for a sustainable, cost-effective water management system that improves water monitoring and filtration while repurposing agricultural byproducts.

Costly water management systems have become vital in ensuring water quality. However, traditional methods of estimating water quality through laboratory and statistical analyses are expensive and time-consuming, making real-time monitoring impractical (Marques & Pitarma, 2020). In response to these challenges, an increasing focus has been on developing and implementing advanced technological solutions for real-time water quality monitoring. Integrating sensor networks, remote sensing technologies, and Internet of Things (IoT) devices has transformed the tracking and monitoring of water quality (Miller et al., 2023).

Several advancements have been made to enhance water quality management systems. One of these is the water monitoring system which was developed with Raspberry Pi as the central controller (Jamlos et al., 2023). Various sensors were employed, including turbidity, total dissolved solids (TDS), and pH sensors. Sensor readings were transmitted to the Raspberry Pi, which then relayed the data to other devices

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via the built-in Wi-Fi capability of the Raspberry Pi. A study found date pits to be an effective, low-cost adsorbent for water treatment, with date fiber showing potential as an alternative to activated carbon (Surkatti et al., 2021). Another study used date pits to remove pollutants from dye wastewater, achieving up to 90% removal efficiency and significant reductions in electrical conductivity and salinity (Ahsan et al., 2023).

Date pits, derived from the fruit of date palms, are an abundant and valuable natural resource, particularly in regions like Qatar, where date cultivation is widespread. Their high surface area, pore volume, and pore radius make them highly effective in water filtration, efficiently removing heavy metals such as lead (Rambabu et al., 2019). Additionally, date pit extracts exhibit antimicrobial properties against bacteria like E. coli and Salmonella, further enhancing their potential for water treatment by inhibiting bacterial growth (Hussain et al., 2019).

Raspberry Pi Pico is a tiny, fast microcontroller board that can control electronic devices and read sensors, making it ideal for projects involving lights and motors (Ojha & Sikka, 2021). It has a dual-core Arm Cortex MO+ processor, a flexible clock capable of running at high speeds, significant Static Random Access Memory (SRAM), and onboard flash memory. As part of the Raspberry Pi ecosystem, the Pico excels in managing electronic components, processing sensor inputs, operating motors, and enabling real-time monitoring applications (Real et al., 2023).

Key water quality indicators include pH, turbidity, and total dissolved solids (TDS). pH reflects water's acidity or alkalinity, with imbalances signaling possible contamination (Ezugwu & Akhimien, 2022). Turbidity measures water clarity; high levels can indicate pathogens and affect treatment (Leziart et al., 2019). TDS reflects dissolved substances like salts and metals, impacting taste, odor, and safety (Hidayana et al., 2024). Monitoring these parameters is crucial for early contamination detection and protecting public health and water sustainability.

II. RESEARCH QUESTIONS

The objective of this study is to create a Water Quality Management Device out of Date Pits and Raspberry Pi Pico. Specifically, this research aims to answer the following questions:

- How effective is the Water Quality Management Device in terms of contaminant removal?
- What is the accuracy of the Water Quality Management Device in assessing the water quality in terms of pH level?
- What is the accuracy of the Water Quality Management Device in assessing the water quality in terms of turbidity?
- What is the accuracy of the Water Quality Management Device in assessing the water quality in terms of total dissolved solids?

III. METHODOLOGY

This study used the experimental design of research. Experimental research design is defined as being applied when the study seeks to determine the cause-and-effect relationships between the dependent and independent variables (Bialowas et al., 2021). In this study, the Date Pits and Raspberry Pi Pico are the independent variables, and the Water Quality Management Device is the dependent variable. Moreover, the quantitative method was used to organize the experiment correctly and ensure that the correct data type was available to answer the research questions as clearly and efficiently as possible (Rana et al., 2021). It is necessary to use this method because it provides a high level of control over the variables that demonstrates an outcome and has an advantage in finding accurate results.

A. Research Locale

This research was conducted in the researchers' school in Mesaimeer Area, State of Qatar. Conducting the study on campus allowed them to utilize essential resources such as laboratories, specialized equipment, and technical support for prototyping and testing the Water Quality Management Device.

B. Data Gathering Procedure

The procedure shows the step-by-step process of making a Water Quality Management Device out of Date Pits and Raspberry Pi Pico and how its effectiveness is tested.

To ensure safety, personal protective equipment, including goggles, gloves, shoes, and a lab coat were worn. The process began by constructing the device housing and control box using foam board, and cutting holes for the filter and LCD. Then, the Raspberry Pi Pico was mounted on a breadboard with an ADC, and secured inside the box. Next, the Pico was connected to the sensors, power module, and ESP8266 for wireless capability, while the LCD was attached with a glue gun and wired to the Pico. For the water filter, date pits were rinsed, soaked, dried, and crushed, then placed in a mesh bag inside a suitable filter housing with secure connections. Finally, the researchers downloaded Thonny, a Python IDE compatible with the Raspberry Pi Pico, and installed the necessary MicroPython libraries, including machine, time, utime, and sensor-specific libraries to facilitate communication between the microcontroller and the connected sensors. They then wrote and calibrated the sensor code on the Pico to enable accurate data readings from the pH, turbidity, and TDS sensors.

To evaluate the effectiveness of the Water Quality Management Device in removing contaminants, the unfiltered water samples were tested to determine their initial quality, focusing on TDS levels. After filtration through the device, the TDS levels were measured again. Comparing the TDS values before and after filtration indicated how well the device reduced contaminants. Three trials were conducted to ensure data reliability, with average TDS levels calculated.

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To determine the device's accuracy in assessing water quality, its readings for pH, turbidity, and TDS were compared with those from commercially available water testing meters. Each parameter was measured using both methods to check for consistency and reliability. Three trials were conducted for credibility, and the average was taken by dividing the summation of all values by three.

IV. RESULTS

This section presents the results and interpretations of the data collected during the testing procedure aligned to the research questions. The objective of this study was to create a Water Quality Management Device with Date Pits and Raspberry Pi Pico as its main components, explicitly investigating its effectiveness in terms of contaminant removal and accuracy in assessing the water quality in terms of pH level, turbidity, and total dissolved solids.

A. Effectiveness of the Water Quality Management Device in Filtering the Water in Terms of Contaminant Removal:

Table 1: Contaminant Removal of the Water Quality Management Device

Trial	1st	2nd	3rd	Average
Before Filtration (g/L)	40.7	40.6	40.1	40.47
After Filtration (g/L)	23.2	23.3	25.1	23.87

Table 1 presents the effectiveness of the Water Quality Management Device in reducing contaminants by comparing TDS levels before and after filtration. Three trials were conducted for accuracy, with average TDS levels calculated. In the first trial, TDS was 40.7 g/L before and 23.2 g/L after filtration. In the second trial, TDS was 40.6 g/L before and 23.3 g/L after. In the third trial, TDS was 40.1 g/L before and 25.1 g/L after. On average, TDS levels were 40.47 g/L before and 23.87 g/L after filtration.

These results demonstrate the device's ability to significantly reduce TDS levels, improving water quality. The reduction is largely attributed to the date pit filter, known for its porous structure and strong adsorption properties, which allow it to effectively trap various contaminants (Hossain et al., 2014).

The TDS level reflects the concentration of dissolved substances, such as inorganic salts and impurities, in water. A study using date palm leaf fibers as a filter material found that they significantly reduced physical pollutants in contaminated water (Rosima et al., 2024). This highlights the feasibility of using dates as an effective filtration material to lower TDS levels.

B. Accuracy of the Water Quality Management Device in Assessing the Water Quality in Terms of pH Level:

Table 2: pH Level Detection of the Water Quality Management Device

Trial	1st	2nd	3rd	Average
Observed Value (pH)	4.50	4.45	4.40	4.45
True Value (pH)	4.45	4.44	4.38	4.41

Table 2 displays the accuracy of the Water Quality Management Device in measuring the water's pH level compared to a commercially available pH meter. Three trials were conducted for credibility, and the average was taken by dividing the summation of all values by three. In the first trial, the device recorded a pH of 4.50, whereas the actual value was 4.45. In the second trial, the reading was 4.45, with the actual value being 4.44. Finally, the device measured 4.40 in the third trial, while the actual value was 4.38. Overall, the device's average reading for the unfiltered water pH was 4.45, compared to the actual average of 4.41.

The device exhibits an average discrepancy of only 0.04 between its readings and actual values, indicating a high level of accuracy and showcasing its effectiveness in measuring pH levels in line with commercially calibrated meters. A study developed a Smart Water Quality Monitoring System using a gravity pH sensor. The pH sensor in the study successfully achieved similar precision, producing highly reliable results across various water samples (Srivastava et al., 2021).

The pH level is a key indicator for measuring water quality because it affects water bodies' chemical and biological processes (Dewangan et al., 2021). Assessing the pH level of water helps reveal the availability of metals and other contaminants in water which influences their toxicity and solubility. Considering the difficulties in managing the quality of water and the fact that it is one of the necessities for life, it is necessary to monitor and evaluate the sources of contamination.

Maintaining a balanced pH level in water is crucial for chemical stability and suitability for various applications. Water with a pH around seven is considered neutral, indicating neither acidic nor alkaline (Yehia & Said, 2021). A high pH level, which indicates alkaline water, may significantly hinder the absorption of nutrients, resulting in malnutrition and indigestion (Arhin et al., 2023). Conversely, a low pH can enhance the solubility of heavy metals, making them more readily absorbed and posing health risks (Saalidong et al., 2022). Therefore, ensuring a neutral pH is vital for keeping water safe and effective for multiple uses.

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C. Accuracy of the Water Quality Management Device in Assessing the water Quality in Terms of Turbidity:

Table 3: Turbidity (in Nephelometric Turbidity Units) Detection of the Water Quality Management Device

Trial	1st	2nd	3rd	Average
Observed Value (NTU)	12.0	10.0	11.5	11.17
True Value (NTU)	11.8	10.2	11.6	11.2

Table 3 illustrates the accuracy of the Water Quality Management Device in assessing the water's turbidity in comparison with a turbidity meter sold commercially. Three trials were conducted for data credibility, and the average was taken by dividing the summation of all values by three. In the first trial, the device measured turbidity at 12.0 NTU, while the actual value recorded was 11.8 NTU. In the second trial, the device displayed a measurement of 10.0 NTU against an actual value of 10.2 NTU. In the third trial, the observed turbidity was 11.5 NTU, compared to an actual value of 11.6 NTU. The device recorded an average turbidity measurement of 11.17 NTU, whereas the actual average was 11.20 NTU.

The average discrepancy of 0.03 NTU between the device readings and the actual values shows the accuracy of the Water Quality Management Device in assessing turbidity levels. Similarly, a related study focused on developing a Water Quality Monitoring System using wireless sensor networks. The study validated the accuracy of the gravity turbidity sensor by comparing its data with manual measurements conducted by treatment plant professionals (Obiri et al., 2021). Furthermore, the improvised monitoring system outperformed three established algorithms in effectively measuring water quality, proving its effectiveness and reliability.

Maintaining proper turbidity levels is essential because high turbidity can significantly impact water quality, affecting aquatic ecosystems and human health. Turbidity is a key factor used to assess water quality since it can influence various ecohydrological processes, both directly and indirectly (Sahoo & Anandhi, 2023). High turbidity reduces light penetration in water, disrupting photosynthesis in aquatic plants and decreasing oxygen production essential for marine life. Suspended particles may also carry harmful substances like pathogens and heavy metals, posing health risks to humans and animals. Turbidity is a key indicator of water quality because it reflects the concentration of suspended particles affecting light transmission in water (Boyd, 2017). Monitoring the NTU of water is essential because high turbidity, indicated by high NTU values, reduces light penetration in water, disrupting photosynthesis in aquatic plants and harming marine ecosystems.

D. Accuracy of the Water Quality Management Device in Assessing the Water Quality in Terms of Total Dissolved Solids:

Table 4: Total Dissolved Solids (in g/L) Detection of the Water Quality Management Device

Trial	1st	2nd	3rd	Average
Observed Value (NTU)	23.0	23.5	25	23.83
True Value (NTU)	23.2	23.3	25.1	23.87

Table 4 exhibits the accuracy of the Water Quality Management Device in assessing the water's total dissolved solids (TDS) in comparison with a TDS meter sold commercially. Three trials were conducted for data credibility, and the average was taken by dividing the summation of all values by three. In the first trial, the device recorded a TDS level of 23.0 g/L, while the actual value was 23.2 g/L. The second trial yielded measurements of 23.5 g/L for the device and 23.3 g/L for the actual value. In the final trial, the device indicated a TDS level of 25 g/L, in contrast to an actual value of 25.1 g/L. The average TDS observed across the three trials was 23.83 g/L, whereas the actual average measured was 23.87 g/L.

The average discrepancy of 0.04 g/L between observed and actual values highlights the device's accuracy in measuring TDS levels. Similarly, a study on TDS sensors found that they reliably distinguished between clean and contaminated water, with an average error of just 0.008894% (Zukhruf et al., 2024). The study also emphasized the sensor's ability to provide real-time, cost-effective water quality monitoring in various conditions.

TDS levels significantly impact water safety for consumption. Water with TDS levels above 500 ppm can cause gastrointestinal issues such as nausea and diarrhea (Pushpalatha et al., 2022). Elevated TDS often indicates contamination, leading to health risks like dehydration and poor nutrient absorption (Tariq & Sharma, 2017). By utilizing the Water Quality Management Device, individuals can check TDS levels before consumption, reducing potential health risks.

V. DISCUSSION

Analyzing the results based on the HHQ14D Digital Conductivity Meter, a clear improvement in the TDS levels was observed in the laboratory tests of filtered water using the Water Quality Management Device, made from date pits and the Raspberry Pi Pico. This study's findings demonstrate that the Water Quality Management Device consistently reduces TDS levels in the sampled water. This outcome aligns with similar research highlighting date pits as an adsorption medium for removing pollutants from dye wastewater (Ahsan et al., 2023). The study indicates that

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applying date pits in water treatment can significantly decrease parameters such as electrical conductivity and salinity, achieving up to 90% removal efficiencies.

In addition, the Water Quality Management Device has demonstrated exceptional precision in its Water Quality Indicator, consistently maintaining a minimal margin of error across all three evaluated parameters. The Water Quality Indicator's dependable performance affirms its effectiveness and showcases its versatility for various water monitoring applications. By accurately measuring pH, turbidity, and TDS levels, the device facilitates early detection of water quality issues, enabling timely interventions to mitigate health risks. However, the study has limitations, including the need for controlled testing conditions and the device's reliance on laboratory settings for calibration. Additionally, while date pits have proven effective for adsorption, their long-term efficiency in diverse environmental conditions requires further investigation. Future research should focus on optimizing the device for field applications and exploring ways to enhance its adaptability across different water sources.

In conclusion, this study highlights the effectiveness of the Water Quality Management Device, which uses date pits and a Raspberry Pi Pico, in accurately evaluating and improving water quality. By measuring critical parameters such as pH, turbidity, and TDS, the device consistently delivered reliable results with minimal discrepancies compared to commercial meters. These results underscore the innovative potential of this approach to water quality management, especially in areas with limited resources. The significant decrease in TDS levels observed in the filtered water samples further validates using date pits as a sustainable filtration medium. Moreover, the precision of the Water Quality Indicator across all measured parameters reinforces its role as an effective real-time water quality monitoring tool.

It is recommended that ongoing research and development focus on refining the filter's design to target dissolved solids, such as salts and heavy metals, specifically. Incorporating adsorbent materials, such as activated carbon or ion exchange resins, which exhibit a high affinity for dissolved ions, could notably enhance filtration by selectively eliminating these substances. Furthermore, integrating coagulation and disinfection into the filtration process could result in a more thorough water purification. Coagulation uses chemicals to aggregate small particles for easier removal, while disinfection methods like chlorination or UV treatment effectively eliminate pathogens, ensuring the water is safe for consumption.

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