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Water Security using Internet of Things (IoT) for Campus Community

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ABSTRACT

This study addresses the critical need for an integrated approach to monitor the quality of spring water in NDUM campus, combining the precision of conventional in-situ instruments with the real-time systems based on Internet of Things (IoT) technology. The study assesses the spring water quality parameters including temperature, turbidity, pH, TDS, and electrical conductivity. The datasets were analyzed using statistical methods, to identify patterns and relationships. The findings demonstrate a strong correlation between real-time and conventional procedures, confirming the effectiveness of both approaches in accurately assessing the quality of spring water. The outcome from this study may contribute to the propose of a new way of monitoring water quality on campus by using a real-time system. In addition, the outcome also provides baseline information about water quality for the welfare of society and supports the green campus campaign, which may also help in future water security, research, and sustainable water management strategies for NDUM campus area.

1. Introduction

Water, being an essential resource, plays a crucial role in ensuring the sustainability of life and ecosystems. In the environment of a university campus, complex issues surrounding water quality assume a crucial role, influence not only on the well-being of the campus community but also contributing to the broad interaction on the sustainable management of resources.

Many educational institutions are leading the way in implementing sustainability initiatives, thereby emphasizing the significance of water quality monitoring as an essential component of environmental management. The interaction of academic, residential, and recreational activity within campus creates a unique environment that requires a comprehensive monitoring of water quality fluctuation. Managing water quality involves unique problems for campuses due to the wide range of activities taking place within their facilities.

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Springs, which frequently become overlooked preserves within the landscapes of campuses, function as natural reservoirs that contribute to the water supply. Nevertheless, the susceptibility of such organisms to human-induced activities, modifications in land utilization, and variations in the environment highlights the need for a comprehensive monitoring system.

Spring water is often of good quality because it filters naturally as it percolates through the ground [3]. Water can pass through geological formations acting as natural filters, eliminating impurities and providing water that is often free of man-made contaminants. The evaluation of spring water quality criteria is crucial in determining the viability of natural spring water for a range of purposes, such as drinking, agricultural, and environmental conservation [4]. The quality of spring water can be influenced by a variety of factors, including both natural and human-induced influences. The extent to which these factors impact water quality is dependent on the specific site and existing environmental conditions [5]. The quality of spring water discharges can be influenced by various factors, including the characteristics of the aquifer and rock strata through which the water has traversed, the temperature experienced along its course, and the historical and current volume of flowing water [6]. The significance of pH levels in the quality of spring water has been highlighted in several research studies. The chemical composition, encompassing minerals and contaminants, influences the usability and safety of the water. The significance of microbiological analysis in assessing the quality of spring water is highlighted in scientific studies, which emphasize the importance of continuous monitoring to detect microbial contaminants promptly.

The potential of IoT-based real-time systems in delivering immediate information into water quality trends is widely acknowledged. The capacity to record changes in real-time is very significant in dynamic campus environments. Research highlights the need of precise sensor calibration in ensuring the precision and reliability of real-time data, addressing concerns regarding possible variation and inaccuracy. An assessment of spring water quality can be determined by evaluating its con-centration levels across numerous physical, chemical, and biological factors, which collectively influence the suitability for specific applications. Therefore, spring water quality monitoring programs should consider local guidelines and requirements to ensure the protection of human health and the environment [7]. Regular and comprehensive monitoring of these parameters enables the early detection of water quality issues and supports informed decision-making to safe-guard spring water resources. Water quality research is a priority topic that re-quires increasing attention from policymakers because it directly affects people's lives. Several studies have focused on monitoring spring water quality internationally [8][9] and in Malaysia [10-14]. These parameters are adequate for identifying the spring water's changes in environmental in real time and will allow the local government authorities to maintain and monitor the water ecosystem. For effective monitoring and management of water resources, it is important to measure the quality of water parameters.

This study implements a combination of techniques to obtain comprehensive information. Real-time monitoring systems, facilitated by IoT technology, provide the benefit of continuous and instantaneous information data collection. Meanwhile, conventional in-situ instrumentation contributes an aspect of consistency and verification to the data collection of spring water. Through an integration of these various methodologies, the present study is designed to clarify the detailed changes in time associated with the quality of spring water in NDUM campus. The outcome from this study will provides a comprehensive approach to water quality monitoring in a campus environment, integrating the technological capabilities of real-time systems with the reliability associated with conventional instrumentation. This approach aims to be adaptable, responsive, and sustainable to support green campus campaign.

2. Methodology

2.1 Water Sampling Method

Water samples were obtained from spring water resources in National Defence University Malaysia campus. The study area is in the NDUM campus area, which is 10 kilometres from the city of Kuala Lumpur, Malaysia and close to Sg. Besi. There are roughly 3000 residents in the campus neighbourhood including staff and students. The map of NDUM campus is shown in Figure 1 and the location of the investigated springs in NDUM campus is presented in Figure 2, Figure 3 and Figure 4. Sg. Besi is a town and suburb area, and the climate is considered humid throughout the year. The town is easily accessible from the main highway. The campus is situated in the Malaysia Army forces camp at Sg Besi Kuala Lumpur. The average daily temperature is between 21oC and 32oC. The area receives an annual rainfall of 750-900 mm. The major water sources are streams, lake, and groundwater. There is a lake and some of the small watershed under the hilly area in the campus. There are still many unexplored areas within the UPNM campus.

The two parallel assessments were carried out: real-time monitoring using Internet of Things (IoT) sensors and conventional in-situ instrumentation techniques. The main parameters investigated including pH levels, electrical conductivity (EC), turbidity, total dissolved solids (TDS), and temperature of the samples. The data obtained from the sensors was gathered, converted, and analysed by the microcontroller before being transferred to cloud storage for the purpose of monitoring. Selection of appropriate instruments is essential for accurate parameter measurement. In this study, digital thermometer, turbidity meter, pH meter, TDS meter and electrical conductivity meter are used to measure spring water on site. All instruments are calibrated according to the manufacturer's guidelines before data collection to ensure measurement accuracy.

2.2 System Design

The design and development of real-time water quality monitoring for a spring water system utilising an Internet of Things (IoT)-based approach includes five (5) components. These components include a power supply, a process controller, a sensor network system, an IoT dashboard, and a notification system for early warning systems. Figure 1 illustrates the detailed block diagram architecture of the system used to perform real-time monitoring of spring water quality within the NDUM campus. ThingSpeak is an open-source IoT platform that enables users to collect, analyse, and visualize sensor data in real-time. The platform is compatible with a wide range of IoT sensors, including water quality monitors and receives a notification when water quality parameters exceed specified criteria.

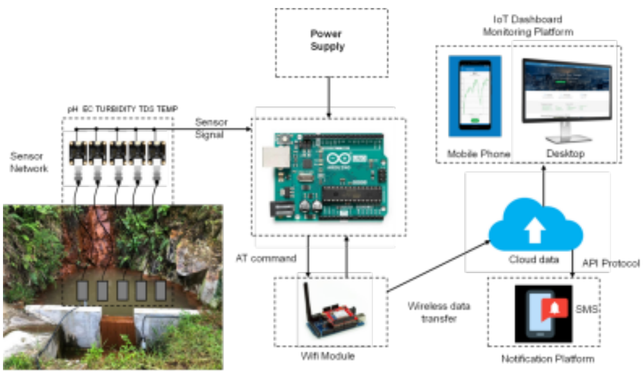

Fig. 1. Architecture diagram of real-time water quality monitoring of spring water in NDUM campus

3. Results

3.1 The Performance of the IoT System

The evaluation of spring water quality is crucial in ensuring both the security and sustainability of water resources. This study presents a comparison of the results produced from a real-time monitoring system utilising IoT technology and conventional in-situ testing tools in assessing the parameters of spring water quality. The water quality results were classified based on National Water Quality Standard [14] and World Health Organization (WHO) parameters [15].

pH is a measure of the water's acidity or alkalinity and is expressed on a scale from 0 to 14. A pH of 7 is considered neutral, values below 7 indicate acidity, and values above 7 indicate alkalinity. The pH of spring water is essential because it affects chemical reactions and the solubility of minerals. Some aquatic organisms are sensitive to pH changes, so maintaining a relatively stable pH range is crucial for supporting diverse aquatic life. Electrical conductivity is a measurement of water's ability to conduct an electrical current, which is influenced by the quantity of dissolved ions. EC is often used as an indirect indicator of TDS levels, indicating a higher mineral content or salinity. Monitoring EC is crucial for assessing water quality and can help detect the presence of dissolved salts or other contaminants. Turbidity is a measurement of water cloudiness or haziness induced by suspended particles. It is commonly measured in Nephelometric Turbidity Units (NTU). High turbidity levels in water might indicate sediment discharge, organic debris, or other pollutants. Excessive turbidity can restrict light penetration, affecting aquatic plant development and disrupting aquatic species' habitat. TDS represents the total concentration of inorganic and organic substances dissolved in the water. It is usually measured in parts per million (ppm) or milligrams per litre (mg/L). TDS can include minerals, salts, metals, and other dissolved substances. High TDS levels may affect the taste of the water and can be an indicator of water quality, especially if certain substances exceed recommended limits. Water temperature monitoring is critical because it may influence a various of physical, chemical, and biological activities in the water ecosystem. Temperature affects the solubility of gases, such as oxygen, which is essential for aquatic life. Drastic changes in temperature can also impact the growth and survival of aquatic organisms.

The results of a spring water quality monitoring using IoT system and instrumentation based on five water quality parameters is presented and analysed in this section: pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), and temperature. The water quality monitoring was undertaken from January to December 2022 between wet (Northeast Monsoon from October to March) and dry (Southwest Monsoon from April to September). The data obtained from the sensors was gathered, converted, and analysed by the microcontroller before being transferred to cloud storage for the purpose of monitoring.

The result showed the variations in temperature, turbidity, pH, TDS, and electrical conductivity of spring water over the year. Figure 2 shows temperature values for spring water. Real-time and instrument data for temperature tracking revealed fluctuations corresponding to diurnal and environmental variations. The results show that spring water has the lowest temperature with the range from 20 °C to 28 °C. The intermittent temperature readings used to confirm the real-time and instrument data, capturing similar trends. The temperature of spring water is influenced by factors such as the depth of the spring source, the surrounding geology, and the local climate. These temperature fluctuations were observed consistently throughout the monitoring period.

Figure 3 show the turbidity variations for all samples. The monthly readings consistently indicated consistent value, which closely aligned with the observations performed in real-time system except on May 22 The results show immediate detection of turbidity changes, reflecting dynamic environmental influences. The periodic measurements consistently confirmed variations in turbidity, which appeared to be consistent with ongoing real-time and instrument observations. Overall, turbidity remained within an acceptable range for drinking water throughout the day. The turbidity of spring water can be affected by the presence of suspended and colloidal particles, including clay, sediment, finely divided organic and inorganic matter, plankton, and other microbes [29]. These values are acceptable based on recommended values by WHO [15] which is within 1000 mg/L and 500 mg/L for NDWQS [14].

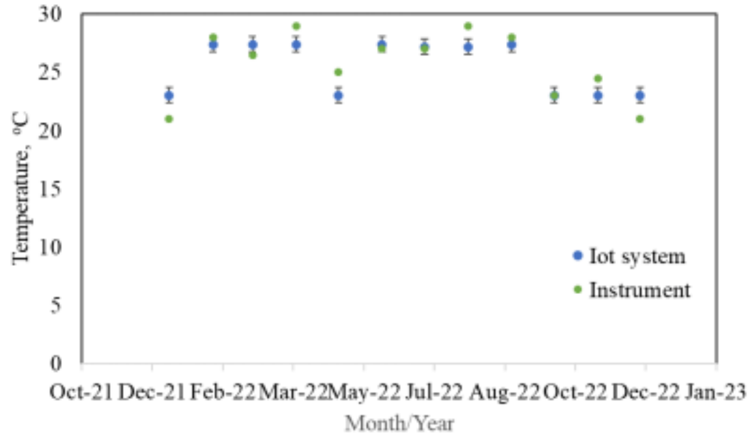

Fig. 2. Temperature values for spring water using Iot system and instrumentation

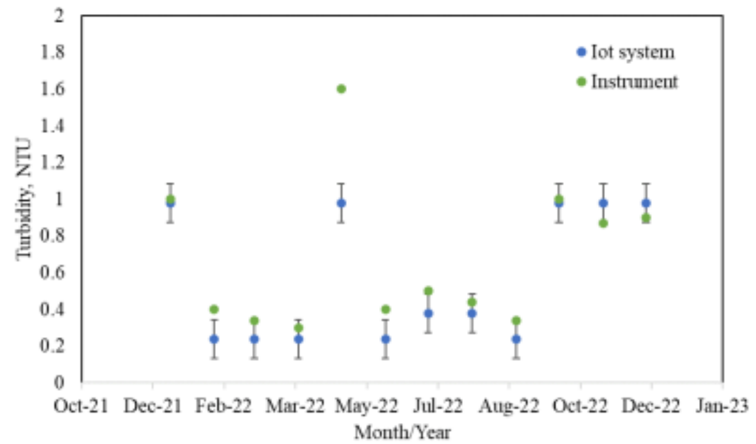

Fig. 3. Turbidity values for spring water using Iot system and instrumentation

Figure 4 show the pH of spring water reading in NDUM campus. Periodic readings on instrument demonstrated stable pH levels, aligning well with real-time observations. The results show that spring water has the pH value within the range of pH 6 to pH 7 which is acceptable based on recommended values by WHO [15] and NDWQS [14]. The pH value of spring water may be influenced by the presence of carbonated-rich soils, such as limestone. Continuous monitoring revealed consistent pH levels with occasional minor fluctuations.

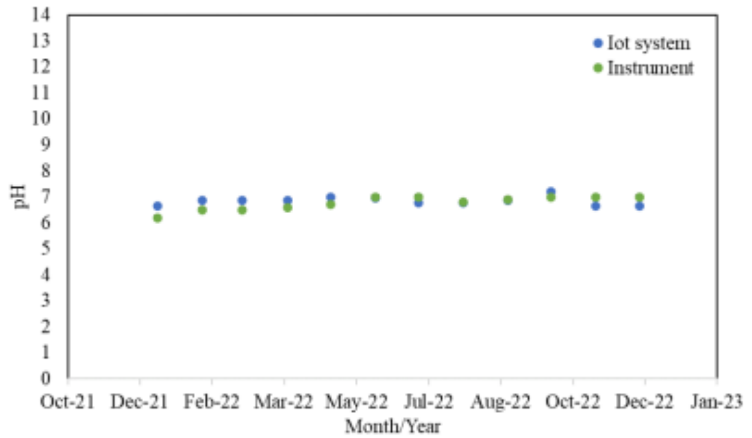

Fig. 4. pH values for spring water using Iot system and instrumentation

Figure 5 shows EC values for spring water monitored in NDUM campus. Based on results from instrument and real-time system, the EC values ranged from 0.01 µS/cm to 0.10 µS/cm. Based on IoT system reading, constant tracking displayed steady EC values, with subtle variations over time. The intermittent measurements provided further support for both instrument and real-time findings, demonstrating a concurrence in the estimates of electrical conductivity (EC). The observed EC variations were coherent with the fluctuations in TDS levels. Charged ions in spring water originate from dissolved minerals, such as clay soils and limestone (Huron River Watershed Council, 2013). According to WHO [15] and NDWQS [14] the reading of EC for spring water is acceptable [31].

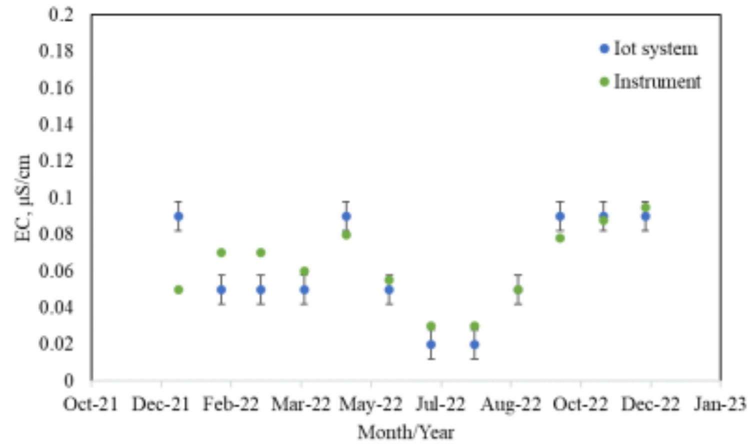

Fig. 5. EC values for spring water using Iot system and instrumentation

Figure 6 shows the TDS of spring water reading in NDUM campus. The monthly readings using instrument consistently indicated consistent value, which closely aligned with the observations performed in real-time system. TDS values in July, August and September shows higher compared to another month. The variations might be influenced by seasonal changes including natural processes of flora and fauna surrounding. These variations suggested a relatively stable TDS values over the course of the day. The TDS value of spring water may be influenced by the geological composition of the land through which the water flows [32,33]. Different rocks and soils contain varying minerals that dissolve in water. The composition of the groundwater is also influenced by geological features that contribute to the TDS of the spring water. Increased rainfall and runoff can influence the TDS values by introducing contamination into the water. The decay of organic matter in the water or surrounding ecosystems can also contribute to the value of TDS for spring [32][33].

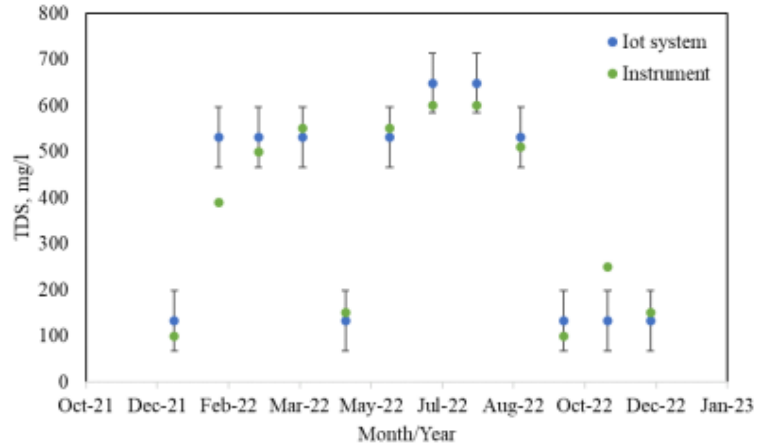

Fig. 6. EC values for spring water using Iot system and instrumentation

Generally, as indicated in Table 1, the one-way ANOVA test results and revealed that there was a statistically significant difference in the means of temperature, turbidity, and pH between at least two groups with (F (2, 33) = [1.5293], p = 0.02168), (F (2, 33) = [2.1489], p = 0.01167) and (F (2, 33) = [1.6353], p = 0.01949). From the results, the p-value of three parameters is less than 0.05. Thus, null hypothesis is rejected. For all water parameters tested, at least one group of water samples has a significant difference from the overall mean of the water samples. The statistical significance shows that the data collected is probably true and is due to factors of interest. Thus, we strongly suppose that temperature, turbidity, and pH potential can affect the analysis of water quality. The mean of TDS and EC readings for the three different time taken were not significantly different from each other at the significance level of 5%, F (2, 33 =0.4481, p = 0.06389) and F (2, 33 =0.2202, p = 0.08023). Thus, this implied that the TDS and EC readings at morning, noon and evening of a spring water using real-time system were equal.

Table 1
One-way ANOVA test for different water quality parameters

Parameters	F	p-value
Temperature	1.5293	0.02168
Turbidity	2.1489	0.01167
pH	1.6353	0.01949
TDS	0.4481	0.06389
EC	0.2202	0.08023
Parameters	F	p-value

4. Conclusions

This comprehensive study investigates the monitoring of spring water quality using both real-time systems and conventional in-situ instrumentation, resulting in an in-depth knowledge of the fluctuating nature of spring water parameters. The integration of Internet of Things (IoT) technologies for continuous, real-time monitoring, high-precision assessments conducted using conventional instruments, has provided valuable insights that are essential for effective water resource management. The results highlight the potential benefits of combining real-time monitoring systems with conventional instrumentation. Real-time systems have outstanding abilities in directly capturing and monitoring immediate fluctuations and variations in water quality indicators, hence offering an exceptional capability to instantly identify and detect unusual events. This capacity holds significant value in situations where immediate actions are crucial for ensuring the protection of water security. On the other hand, conventional tools provide an important quality of precision and calibration assurance, which is essential for establishing fundamental measurements and ensuring the accuracy of datasets over extended periods of time. The periodic nature of conventional assessments complements the continuous monitoring process, offering a regulated and calibrated reference for validating real-time data. As we conclude this study, there are significant implications for future research and the development of water resource management strategies. The integration of real-time monitoring into established water quality frameworks has the potential to improve the effectiveness of management practises by facilitating rapid action in response to unexpected events. Future research initiatives should prioritise the improvement of calibration techniques for real-time systems and developing standardized protocols for ensuring the accuracy of continuous monitoring.

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