EcoSmart Irrigation: Harnessing Treated Wastewater for IoT Integrated Agriculture

Yagnesh Dawankar, Ansh Kumar, Sayam Chavan and Manoj S. Kavedia
Department of Electronics and Telecommunication Engineering (EXTC),
Thadomal Shahani Engineering College Mumbai, India

Keywords: Treated Wastewater, IoT, Sustainable Irrigation, Precision Agriculture, Water-Use Efficiency, Smart Irrigation, Real-Time Monitoring, Water Conservation, Soil Moisture, Food Security, Climate Resilience.

Abstract: With the increasing demand for water globally and complications caused by climate change, advanced technologies need to be integrated into the agricultural sector for sustainable management of water. EcoSmart Irrigation applies treated wastewater in conjunction with IoT technologies, providing an innovative way of optimizing the efficiency of water usage in agriculture. The current research aims to study the feasibility and benefits of treated water as a source of irrigating water while integrating IoT-based systems that will enable real-time monitoring and automation of water distribution systems. Integration of IoT enables precise control of soil moisture, crop health, and environmental conditions and thus optimizes irrigation processes to conserve water while maintaining or improving crop yields. Additionally, the research study considers the environmental and economic impacts of IoT-enabled water recycling irrigation systems, assessing how these systems can support a decrease in freshwater consumption, improve water-use effectiveness, and improve food security. EcoSmart Irrigation solves the needs of modern agriculture through a scalable and sustainable model, allowing for the advancement of initiatives toward climate resilience and environmental stewardship.

1 INTRODUCTION

Water scarcity, exacerbated by rapid urbanization, population growth, and climate change, has become one of the most pressing global challenges. With agriculture accounting for nearly 70% of global freshwater consumption, there is an urgent need to rethink water usage and implement sustainable practices. One promising solution is the reuse of treated wastewater for irrigation. This approach not only reduces dependence on freshwater resources but also promotes water recycling within a circular economic model. By combining treated wastewater with cutting-edge IoT technologies, EcoSmart Irrigation presents a transformative, sustainable method to meet agricultural demands while addressing environmental challenges.

The cornerstone of this system is wastewater treatment, which transforms municipal, industrial, and agricultural discharge into a resource fit for irrigation. Through primary filtration, biological processing, and disinfection, harmful pollutants, pathogens, and chemicals are removed, ensuring the safety of treated water for crops and the environment. This process provides a reliable and sustainable water source, particularly in regions facing frequent droughts or limited freshwater availability. However, to maximize the potential of treated wastewater, precise monitoring and control of its quality and distribution are essential.

This is where IoT technologies play a pivotal role. IoT-enabled systems can monitor key parameters such as soil moisture, water salinity, nutrient content, and weather conditions in real time. These insights allow farmers to make data-driven decisions, adjusting irrigation schedules and water application rates based on crop and soil requirements. Automated systems further enhance efficiency by remotely controlling irrigation, optimizing water distribution across vast agricultural fields, and minimizing wastage. Real-time alerts ensure that only high-quality treated wastewater is used, safeguarding both crop health and environmental standards.

The integration of IoT with treated wastewater not only improves water use efficiency but also enhances crop yields by creating uniform growth conditions. This synergy reduces the ecological footprint of agriculture by minimizing freshwater abstraction and

Dawankar, Y., Kumar, A., Chavan, S. and S. Kavedia, M.
EcoSmart Irrigation: Harnessing Treated Wastewater for IoT Integrated Agriculture.
DOI: 10.5220/0013607100004664
Paper published under CC license (CC BY-NC-ND 4.0)
In *Proceedings of the 3rd International Conference on Futuristic Technology (INCOFT 2025) - Volume 2*, pages 910-916
ISBN: 978-989-758-763-4
Proceedings Copyright © 2025 by SCITEPRESS – Science and Technology Publications, Lda.

preventing untreated wastewater from entering natural ecosystems. Additionally, the energy and resources required for water pumping and treatment are significantly reduced, contributing to lower carbon emissions.

EcoSmart Irrigation also enables the collection and utilization of historical data for predictive analysis, allowing farmers to anticipate crop and environmental conditions. This data-driven approach empowers better long-term planning and resource management, aligning with broader goals of sustainability and resilience.

In summary, the union of treated wastewater with IoT technologies represents a revolutionary leap toward sustainable agriculture. By turning wastewater into a valuable resource and employing IoT for precision irrigation, EcoSmart Irrigation addresses critical challenges of water conservation and food security. This integrated system not only optimizes water use but also promotes environmental sustainability, offering a scalable and resilient solution to the growing pressures of climate change and resource scarcity. EcoSmart Irrigation is a forward-looking model for a healthier and more sustainable global food system.

2 LITERATURE REVIEW

Karpagam et al. (Karpagam, Merlin, et al. , 2020) proposed an IoT-based smart irrigation system that leverages sensors to monitor soil moisture and automate water supply, thereby improving water efficiency in agriculture. Obaideen et al. (Obaideen, Yousef, et al. , 2022) provided a comprehensive overview of IoT-based smart irrigation systems, emphasizing their energy-saving capabilities and cost efficiency. Alomar and Alazzam (Alomar and Alazzam, 2018) introduced a smart irrigation framework utilizing fuzzy logic controllers, highlighting their ability to optimize water usage under varying environmental conditions.

Srivastava et al. (Srivastava, Bajaj, et al. , 2018) demonstrated the use of an ESP8266 Wi-Fi module in a smart irrigation system, showcasing the module's reliability in real-time data transmission for effective decision-making. Meanwhile, J. G et al. (J. G M. N S. S and A. S, 2020) designed an IoT-based system for water filtration monitoring, focusing on real-time quality control to ensure safe water consumption. Similarly, Hong et al. (Hong, Kim, et al. , 2022) developed a novel Arduino-based monitoring method for water filters, enabling direct observation of filter status via IoT integration.

Vaishali et al. (Vaishali, Suraj, et al. , 2017) explored a mobile-integrated smart irrigation system that combines IoT and GSM technology for remote monitoring and control, emphasizing its practical applications in areas with limited connectivity. Kumar et al. (Kumar, Gouthem, et al. , 2021) proposed a water quality control and filtration system that utilizes IoT to maintain consistent water standards for industrial applications. AlMetwally et al. (AlMetwally, Hassan, et al. , 2020) introduced a real-time IoT-based water quality management system, which incorporates sensors to monitor key parameters such as pH and turbidity.

Ragab et al. (Ragab, Badreldeen, et al. , 2022) designed an IoT-based smart irrigation system that uses cloud computing for data storage and predictive analytics, demonstrating improved agricultural yields. Varsha et al. (Varsha, et al. , 2021) presented an IoT-enabled water quality monitoring solution capable of identifying contaminants in real-time. Similarly, Jha et al. (Jha, et al. , 2018) proposed a smart water monitoring system for real-time water quality and usage tracking, emphasizing its ability to promote sustainable water consumption.

Ajith et al. (Ajith, Manimegalai, et al. , 2020) developed a cloud-integrated IoT system for water quality monitoring, allowing users to access data remotely and make informed decisions. Gultom et al. (Gultom, et al. , 2017) designed a smart water sprinkle and monitoring system for chili plants, incorporating IoT technology to automate water delivery based on soil conditions. Singh and Ahmed (Singh and Ahmed, 2021) conducted a systematic review of IoT-based smart water management systems, highlighting recent technological advancements and identifying future research directions.

Lim et al. (Lim, Tan, et al. , 2020) introduced an IoT solution for point-of-use water filtration management in residential and commercial settings, which optimizes filtration processes based on water demand. Velasco-Muñoz et al. (Muñoz, et al. , 2018) provided a review of global research on sustainable water use in agriculture, identifying key strategies for improving water-use efficiency. Martínez et al. (Martínez, Vela, et al. , 2020)explored the application of IoT in wastewater treatment plants, demonstrating its potential to enhance water quality monitoring and management.

Razman et al. (Razman, Ismail, et al. , 2023) proposed a water quality monitoring and filtration system designed specifically for different water types in Malaysia, addressing local challenges in water resource management. Another study by Velasco-Muñoz et al. (Muñoz, et al. , 2018) performed a bibliometric analysis on advances in water-use efficiency in agriculture, identifying trends and research gaps.

3 METHODS

3.1 System Overview

The Wastewater Filtration System can be said to be doing a multi-tank sequential treatment for wastewater to serve agriculture. The system has four tanks: a pre-filtration tank, an aeration and chlorination tank, a sedimentation tank and an UV filtration tank, and a final water quality assessment tank which automated the whole process with an ESP32 microcontroller managing pumps, motors, and sensors for this efficient operation. The system not only provides the purifying ability to the water, but also provides real-time feedback on the quality of water using sensors for pH, turbidity, and total dissolved solids (TDS).

3.2 Pre-Filtration (Tank 1)

The wastewater treatment system starts with Tank 1, which is the pre-filtration unit. The pre-treatment target of this tank is to remove larger solid particles from the effluent. The pre-filtration tank construction consists of three-layer materials performing each of its different activities in the following ways:

1) *Sand (Top Layer):* The sand layer is the first filtration medium removing suspended particles from the water in finer sizes. This will guarantee that when the water goes out of Tank 1, the larger part of the solids and suspended particles shall be stopped.
2) *Charcoal (Middle Layer):* The second layer is made up of activated charcoal, which does a very important work of adsorbing dissolved organic impurities, odors, and some chemicals from the water. Mainly, charcoal is used to remove such contaminants that cause bad odors and colors within the water.
3) *Gravel and Pebbles (Bottom Layer):* At the bottom-most layer, the part is gravel and pebbles affecting the final trapping of the bigger debris and particles usually found in waste. These typically include organic matter, soil, and other solid contaminants sized more than 1 mm.

After passing through these layers, water gets filtered. The solid wastes are left behind which cannot proceed to the next process. The filtered water is carried to the aeration and chlorination tank termed as Tank 2 with means of a pipe connecting both.

Figure 1: The Pre-filtration Tank

3.3 Aeration and Chlorination (Tank 2)

The water in Tank 2 is aerated and chlorinated through two basic processes that effectively further lessen biological contaminants and improve clarity in water. Its parts include the following equipment:

1) *Aeration Pump (A1):* It is the process by which oxygen is introduced into the water, which is necessary in the aerobic decomposition of organic matter. Aeration serves to reduce the BOD of the water so that this water becomes less destructive to crops when used for irrigation purposes.
2) *Chlorination Mechanism (Servo Motor SM1):* A servo motor helps in the rotation of a container with chlorine for chlorination. This is done where the motor rotates to an angle of 45 degrees, hence controlling the release of chlorine into the water. Chlorine then kills the pathogens, bacteria, and other

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

microorganisms that could be present in the wastewater.

In a scenario where the float switch-L1 will monitor the water level in Tank 2, this will trigger the operation of the aeration pump (A1) for 90 seconds following the threshold detection of water level by the float switch. This will also trigger a movement of the servo motor (SM1) of 45 degrees to release chlorine into the water. The aerated and chlorinated water will then be moved to tank 3 from where turning off the aeration pump at 90 seconds will activate Water Pump P1.

3.4 Sedimentation and UV Filtration (Tank 3)

Tank number three involves sedimentation coupled very interestingly with ultraviolet (UV) filtration, further access in the purification of an already pure water sample. Here are some processes that take place in that tank:

1) Sedimentation: It is a natural settling process where suspended particles in water may be carried by gravity down to the bottom of the tank as suspended solids. It removes those contaminants as solids that escape extraction in the previous stages already mentioned.
2) UV Filtration (UV Strip U1): This is an ultraviolet filter, which has a strip that emits UV (U1). This always exposes water to UV light, which interacts with microbes' DNA. This interaction with DNA prevents the microorganisms from reproducing and thus effectively disinfects pathogens causing disease from the water.

The level of water in Tank 3 is controlled by the float switch L2. When activated, it will automatically turn on the UV strip to ensure that it plays at least 90 seconds for disinfecting action with a UV light over water. So, after this time, water pump P2 will carry the water into a final reservoir, i.e., tank 4.

3.5 Final Collection and Monitoring (Tank 4)

This tank is the final collection point for the treated water. After going through prefiltration followed by aeration, chlorination, sedimentation, and UV filtration, water is stored in Tank 4, where it will be held for agricultural purposes. For this tank has been installed continuous quality monitoring sensors that measure and convey the information on state water quality parameters:

1) pH Sensor: Measures the acidity or alkalinity of the water, ensuring it falls within a range suitable for irrigation purposes.
2) Turbidity Sensor: Indicates how cloudy or hazy the water is, telling whether there are any remaining suspended solids.
3) TDS (Total Dissolved Solids) Sensor: Indicates the presence of total dissolved solids concentration in the water, which is a useful indication of the purity with respect to the intended application in agriculture.

Here, a float switch (L3) is used to measure water level in Tank 4. If L3 is triggered, indicating the tank is full, Water Pump P2 shall shut down. At this moment, the ESP32 microcontroller reads from pH, turbidity, and TDS sensors. Thus, the values can constantly be monitored through an LCD display system positioned as stationed within the immediate vicinity. It makes sure that the user frequently receives updated information about the quality of filtered water and makes corrective actions if necessary.

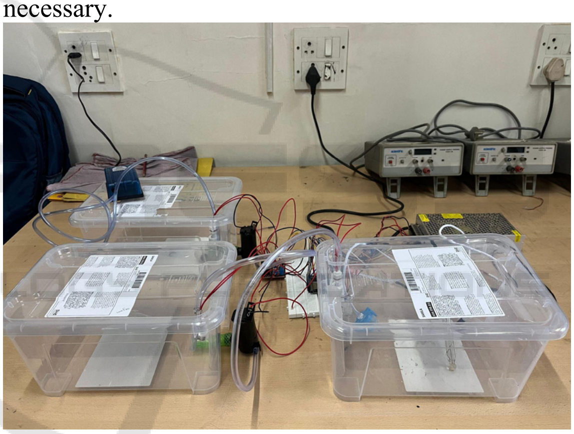

Figure 2: Prototype with Tank 2,3 and 4 where aeration, chlorination, sedimentation, and UV treatment take place.

3.6 Control Mechanism with ESP32 Microcontroller

The entire filtration system is managed through the ESP32 microcontroller that controls pumps, motors and sensors used in the system. The ESP32 is programmed to carry out the following tasks:

1) Pump and Motor Control: A1 is the aeration pump, P1 and P2 are the water pumps and SM1 is the chlorination servo motor, which are operated by microcontroller to turn on and off these devices. All these components are activated depending on the state of float switches (L1, L2, L3) so that each process follows the other.

2) Timing and Sequencing: The ESP32 ensures that the pumps and motors operate for certain time durations including aeration and UV filtration at 90 seconds. This timing is quite important if one has to get the right functioning of the system to the level of purification that is required.
3) Sensor Data Acquisition: Finally, after going through the filtration process, the ESP32 queries the pH, turbidity, TDS sensors of water quality. The microcontroller reads the details captured by the sensors and relays them onto the LCD where the end user can make reference.

The possibility of using an ESP32 microcontroller ensures that the filtration process is fully automated so that the process is efficient, and one does not need to over-insert their hands in the process. In addition, the real time display of the water quality adds value to the system since the users are in a position to see the truth of the efficacy of the filter. As shown in the flowchart of our system designed for water purification for reuse in Fig. 3. The wastewaters first flow through a layer of rocks, sand and charcoal to remove large particles from the liquid. The system t

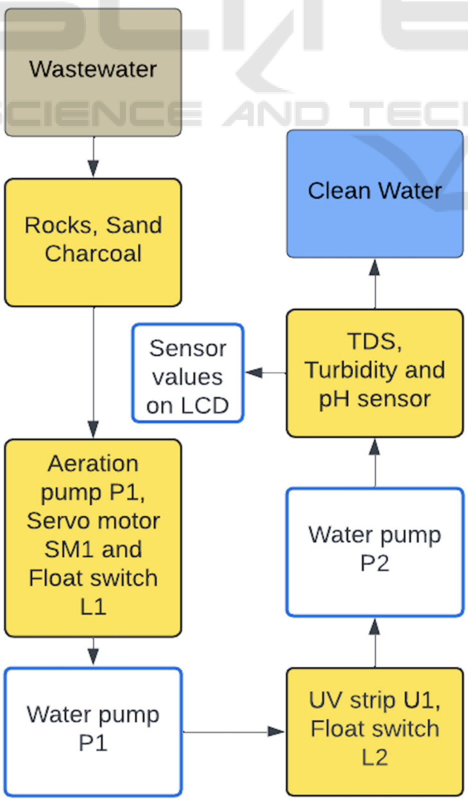

Figure 3: Flowchart of Stage 1

hen flows through an aeration chamber that has a pump, servo motor and a float switch which help to add air into the water so as to facilitate breaking down of contaminants. Subsequently, the water is disinfected under UV sterilization stage further and is tested for TDS, turbidity and pH level is indicated in an LCD panel. The water that passes through the above conditions is channeled as clean water which is going to be used next.

4 RESULTS

In this experiment, muddy water was used as input and the efficiency of the performed wastewater filtration system was analyzed. The water quality was measured before and after treatment using three key parameters: They include pH levels, turbidity and the total dissolved solids (TDS). The findings with regards to the input and output water are as follows:

The input water samples showed high turbidity and high TDS, which suggest that the water quality in the study area is not fit for irrigation. The pH level, though slightly on the acidic scale, was also not ideal for most crop production, which ranged between 6-7. In the following study, the water passing through the filtration system showed enhanced overall quality with regard to the three aspects. It was brought to an average pH of 6.8 which is considered appropriate in the irrigational practice concerning most crops. Turbidity was lowered from 120 NTU to 2 NTU proving the effectiveness of the system in settling particulate matter. Same way TDS also came down from 867 ppm to 448 ppm which is suitable for irrigation purposes as it should not exceed 500 ppm in general.

Table 1: Comparison of water quality

Parameters	Input water (Muddy)	Output water (Treated)	Acceptable range for irrigation
pH	5.2	6.8	6.0-7.5
Turbidity	120 NTU	2 NTU	< 5 NTU
TDS	867 ppm	448 ppm	< 500 ppm

4.1 Calculations

4.1.1 Calculation of pH:

$$\boldsymbol{Voltage = Value * \left(\frac{3.3}{4095.0}\right)}$$

$$\boldsymbol{pH = (3.3 * Voltage)}$$

4.1.2 Calculation of Turbidity:

$$Voltage = Value * \left(\frac{3.3}{4095.0}\right)$$
$$Turbidity\ Value\ (NTU) = Voltage * 100$$

4.1.3 Calculation of TDS:

$$TDS = \Sigma\ cations + \Sigma\ anions$$
$$TDS\left(\frac{mg}{L}\right) = conversion\ factor \times EC\left(\mu\frac{S}{cm}\right)$$

1 mg/L = 1ppm

Table 2: Voltage to TDS, pH, and Turbidity

Voltage(V)	TDS(ppm)	pH	Turbidity (NTU)
0.0	0 ppm	0.0	0 NTU
0.5	50 ppm	2.0	10 NTU
1.0	100 ppm	3.5	20 NTU
1.5	200 ppm	5.0	40 NTU
2.0	400 ppm	6.5	60 NTU
2.5	600 ppm	7.0	80 NTU
3.0	800 ppm	8.0	100 NTU
3.5	900 ppm	9.0	120 NTU
4.0	1000 ppm	10.0	150 NTU
4.5	1200 ppm	11.0	200 NTU
5.0	1500 ppm	14.0	300 NTU

The findings suggest that the system was able to treat high-turbidity, high-TDS and slightly acidic water for irrigation purposes. The treated water pH, turbidity level and TDS were identified to be in the permissible limit for agricultural use indicating that wastewater can safely be reused for irrigation after the present treatment. The system shows strengths to filter the polluted water and describe the water quality in an instant by sensors' feedback.

5 CONCLUSIONS

The wastewater filtration system that is earmarked for application in agricultural application processes has been seen to display a sound and efficient way of addressing the issue of wastewater treatment using a series of steps. Yes a whole sequence of aeration and chlorination, sedimentation and UV filtration before filtration will guarantee that no contaminants will exist in the water for instance to guarantee water quality for irrigation usage.

Upon integrating the ESP32 microcontroller, the system acquires higher reliance and reduced dependency on human input to gain high reliability in the filtration process. Reminders like pH, turbidity and TDS make it easier to monitor the quality of water, this is important in Agricultural usage. The feature of flexibility in design, with the elements and stages of filtration help in easy scalability, depending on the water treatment demand. The system also demonstrates the effectiveness of recycling water by employing water from a water treatment plant for irrigation purposes on the environment thus making it sustainable.

According to this regard, this system results in being economically and readily suitable for agriculture application for wastewater treatment, but it offers quality standards of pure water through automated processes and using real-time monitoring.

REFERENCES

J. Karpagam, I. I. Merlin, P. Bavithra, and J. Kousalya, "Smart Irrigation System Using IoT," 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2020, pp. 1292–1295, doi: 10.1109/ICACCS48705.2020.9074201.

K. Obaideen, B. A. A. Yousef, M. N. AlMallahi, Y. C. Tan, M. Mahmoud, H. Jaber, and M. Ramadan, "An overview of smart irrigation systems using IoT," Energy Nexus, vol. 7, 2022, Art. no. 00124, doi: 10.1016/j.nexus.2022.100124.

B. Alomar and A. Alazzam, "A Smart Irrigation System Using IoT and Fuzzy Logic Controller," 2018 Fifth

SCITEPRESS SCIENCE AND TECHNOLOGY PUBLICATIONS

HCT Information Technology Trends (ITT), Dubai, United Arab Emirates, 2018, pp. 175–179, doi: 10.1109/CTIT.2018.8649531.

P. Srivastava, M. Bajaj, and A. S. Rana, "Overview of ESP8266 Wi-Fi module based Smart Irrigation System using IoT," 2018 Fourth International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), Chennai, India, 2018, pp. 1–5, doi: 10.1109/AEEICB.2018.8480949.

J. G, M. N, S. S, and A. S, "Smart Monitoring and Control of Water Filtration System Using IoT," 2020 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), Chennai, India, 2020, pp. 1–5, doi: 10.1109/ICPECTS49113.2020.9336991.

M. Hong, K. Kim, and Y. Hwang, "Arduino and IoT-based direct filter observation method monitoring the color change of water filter for safe drinking water," Journal of Water Process Engineering, vol. 49, 2022, Art. no. 103158, doi: 10.1016/j.jwpe.2022.103158.

S. Vaishali, S. Suraj, G. Vignesh, S. Dhivya, and S. Udhayakumar, "Mobile integrated smart irrigation management and monitoring system using IoT," 2017 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2017, pp. 2164–2167, doi: 10.1109/ICCSP.2017.8286792.

M. Kumar, S. E. Gouthem, A. Srithar, and V. S. Prakash, "IoT based water quality control and filtration system," Materials Today: Proceedings, vol. 46, no. 9, pp. 3557–3560, 2021, doi: 10.1016/j.matpr.2020.12.978.

S. A. H. AlMetwally, M. K. Hassan, and M. H. Mourad, "Real Time Internet of Things (IoT) Based Water Quality Management System," Procedia CIRP, vol. 91, pp. 478–485, 2020, doi: 10.1016/j.procir.2020.03.107.

M. A. Ragab, M. M. Badreldeen, A. Sedhom, and W. M. Mamdouh, "IoT-based Smart Irrigation System," International Journal of Industry and Sustainable Development, vol. 3, no. 1, pp. 76–86, 2022, doi: 10.21608/ijisd.2022.148007.1021.

L. Varsha, et al., "IoT based smart water quality monitoring system," Global Transitions Proceedings, vol. 2, no. 2, pp. 181–186, 2021.

M. K. Jha, et al., "Smart water monitoring system for real-time water quality and usage monitoring," 2018 International Conference on Inventive Research in Computing Applications (ICIRCA), 2018, doi: 10.1109/ICIRCA.2018.8597263.

J. B. Ajith, R. Manimegalai, and V. Ilayaraja, "An IoT based smart water quality monitoring system using cloud," 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE), 2020, doi: 10.1109/ic-ETITE47903.2020.224145.

J. H. Gultom, et al., "Smart IoT water sprinkle and monitoring system for chili plant," 2017 International Conference on Electrical Engineering and Computer Science (ICECOS), 2017, doi: 10.1109/ICECOS.2017.8167083.

M. Singh and S. Ahmed, "IoT based smart water management systems: A systematic review," Materials Today: Proceedings, vol. 46, pp. 5211–5218, 2021.

T. Lim, H. P. Tan, C. S. Ong, R. Belani, and S. S. K. Agrawal, "Designing a smart Internet of Things solution for point of use water filtration management system in residential, commercial, and public settings," Test Engineering and Management, vol. 83, pp. 12561–12568, 2020.

J. F. Velasco-Muñoz, et al., "Sustainable water use in agriculture: A review of worldwide research," Sustainability, vol. 10, no. 4, Art. no. 1084, 2018.

R. Martínez, N. Vela, A. el Aatik, E. Murray, P. Roche, and J. M. Navarro, "On the Use of an IoT Integrated System for Water Quality Monitoring and Management in Wastewater Treatment Plants," Water, vol. 12, no. 4, Art. no. 1096, 2020, doi: 10.3390/w12041096.

N. A. Razman, W. Z. Wan Ismail, M. H. Abd Razak, et al., "Design and analysis of water quality monitoring and filtration system for different types of water in Malaysia," International Journal of Environmental Science and Technology, vol. 20, pp. 3789–3800, 2023, doi: 10.1007/s13762-022-04192-.

J. F. Velasco-Muñoz, et al., "Advances in water use efficiency in agriculture: A bibliometric analysis," Water, vol. 10, no. 4, Art. no. 377, 2018.