**Circuit:** Jurnal Ilmiah Pendidikan Teknik Elektro
Volume 9 No. 2 March 2025 - August 2025
ISSN: 2549-3698; E-ISSN: 2549-3701
DOI: 10.22373/crc.v9i2.29894

# IoT-Based Real-Time Monitoring and Control of Well Water Filtration

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Submitted: 23-04-2025 Accepted:05-08-2025 Published:18-08-2025

***Abstract***

*Controlling a well water filtration system via the internet is a modern solution in the industry 4.0 era to ensure optimal filter performance. This study aims to develop an IoT-based system to monitor and control well water filtration by measuring inlet and outlet pressures. The system uses two pressure sensors, one turbidity sensor, and five solenoid valves to regulate the filtration, backwashing, and rinsing processes. All components are integrated with a NodeMCU ESP32 microcontroller. The IoT user interface was developed using the Blynk application on an Android smartphone, which allows real-time monitoring and automatic notification when filter performance decreases. Experimental trials were conducted by gradually injecting turbid water with varying turbidity levels (low, medium, high) into the filter. The results showed that filter clogging caused an increase in inlet pressure and a decrease in outlet pressure. The backwashing and rinsing processes can be activated via a smartphone when the inlet pressure increases by 24%–45% and the outlet pressure decreases by 37%–72%. The turbidity of the filtered water remained within the range of 0.14–0.19 NTU, which is still below environmental health standards. This demonstrates that the developed IoT-based filtration system is effective for real-time monitoring and control of well water quality.*

***Keywords****: IoT Control, Real-time Pressure Monitoring, Water Filtration System.*

**Abstrak**

Pengendalian sistem penyaringan air sumur melalui internet merupakan solusi modern di era Industri 4.0 untuk memastikan kinerja filter yang optimal. Penelitian ini bertujuan untuk mengembangkan sistem berbasis IoT untuk memantau dan mengendalikan penyaringan air sumur dengan mengukur tekanan masuk dan keluar. Sistem ini menggunakan dua sensor tekanan, satu sensor kekeruhan, dan lima katup solenoid untuk mengatur proses penyaringan, pencucian balik, dan pembilasan. Semua komponen terintegrasi dengan mikrokontroler NodeMCU ESP32. Antarmuka IoT untuk pengguna dikembangkan menggunakan aplikasi Blynk pada ponsel pintar Android, yang memungkinkan pemantauan waktu nyata dan notifikasi otomatis ketika kinerja filter menurun. Uji coba eksperimental dilakukan dengan memasukkan air keruh secara bertahap dengan tingkat kekeruhan yang bervariasi (rendah, sedang, tinggi) ke dalam filter. Hasil penelitian menunjukkan bahwa penyumbatan filter menyebabkan peningkatan tekanan masuk dan penurunan tekanan keluar. Proses pencucian balik dan pembilasan dapat diaktifkan melalui ponsel pintar ketika tekanan masuk naik 24%–45% dan tekanan keluar turun 37%–72%. Kekeruhan air hasil penyaringan tetap berada pada kisaran 0,14–0,19 NTU, yang masih di bawah baku mutu kesehatan lingkungan. Hal ini menunjukkan bahwa sistem penyaringan berbasis IoT yang dikembangkan efektif untuk pemantauan dan pengendalian kualitas air sumur secara real-time.

**Kata kunci**: Kontrol IoT, Pemantauan Tekanan Real-time, Sistem Filtrasi Air.

## Introduction

Water is a natural resource that plays a vital role in sustaining life for all living beings on Earth, including humans, animals, and plants. It is essential for various human activities such as drinking, cooking, bathing, washing, and other domestic needs [1]. While rural communities often depend on wells due to limited access to centralized water systems, urban populations also utilize groundwater from wells to meet their water supply needs. However, groundwater extracted from wells is not always safe for consumption due to environmental factors, such as seasonal rainfall fluctuations or chemical contamination.

To ensure sustainable access to clean water, particularly in areas underserved by centralized water distribution systems, maintaining well water quality is critical. Water filtration systems are widely employed to remove contaminants and ensure water safety. For instance, studies by Roni Pasonang Sihombing et al. [2] and Akhmad Adi Sulianto et al. [3] have demonstrated the effectiveness of filtration in producing clean water. Beyond purification, filtration systems have also been adapted for wastewater recycling. For example, Abd Mujahid Hamdan et al. [4] utilized iron sand as a filter medium to treat wastewater from slaughterhouses, while Arjuna Neni Triana and Mega Ariana [5] designed a biosand filter combining silica sand, activated carbon, and zeolite to treat palm oil-contaminated river water.

Conventional filtration systems often suffer from suboptimal performance due to inadequate monitoring and control. Over time, accumulated impurities in filter media reduce efficiency, necessitating regular backwashing to restore optimal functionality, as highlighted by Sania Mirelda Sari and Rinawati [6]. Uncontrolled pressure caused by clogged filter media or irregular maintenance can degrade both the quality and quantity of filtered water. Thus, an efficient solution to monitor and control filtration systems is imperative to ensure consistent water quality and sustainability.

Despite advancements in groundwater filtration automation, extant systems exhibit critical limitations in maintenance triggering mechanisms. Sarifudin et al. activated backwash solely via turbidity measurements without incorporating inlet-outlet pressure differentials which a key indicator of media clogging [7], [8]. Zaenurrohman et al. [9] implemented IoT for turbidity monitoring but omitted automated backwash triggering, while another research integrated pH/turbidity sensors yet disregarded pressure-based maintenance protocols [10]. Hong et al. [11] monitored pressure and water color without implementing backwash; this constitutes a significant oversight given that pressure transients precede turbidity changes during filter degradation. While foundational IoT frameworks for water filtration exist [1], [9], [10], [11], [12], [13], [14], [15], [16], they lack integrated pressure-threshold triggering mechanisms for maintenance cycles, a limitation addressed in this study through real-time pressure and turbidity monitoring with empirically optimized thresholds. These gaps highlight the need for a system that integrates real-time pressure and turbidity monitoring with automated backwash control to maintain filter efficiency. Crucially, no prior work has unified real-time pressure differential thresholds for alarm generation, smartphone-controlled solenoid valves for backwash/rinse cycling [17], and integrated turbidity validation against health standard [18], [19]. This study bridges these gaps via an integrated framework that correlates pressure and turbidity real-time monitoring with remote maintenance activation, outperforming existing IoT water systems in response latency and reliability.

This study aims to design and develop an IoT-based system for monitoring and controlling well water filtration performance using inlet/outlet pressure differentials and post-filtration turbidity levels. Unlike prior works that neglect pressure-triggered maintenance, our approach introduces three key innovations i.e. programmable alarm thresholds for real-time pressure anomalies, remote smartphone activation of backwash/rinse cycles via optimized Blynk IoT protocols, and integrated turbidity validation against health standards. Pressure and turbidity data will trigger remote backwash cycles via an Android smartphone, ensuring continuous filter optimization and sustainable water quality. The system thus addresses critical gaps in existing approaches while enhancing operational reliability through its unified hardware-software architecture.

## Method

The study commenced with problem identification related to common challenges in using well water for daily needs and issues arising from water filter systems in purifying groundwater. To remove solid particles from well water, filter media such as silica sand, manganese zeolite, and activated carbon are typically employed [20]. However, sediment accumulation (e.g., sludge and pollutants) in the filter often leads to increased inlet pressure and decreased outlet pressure, compromising the filter's ability to deliver clean water sustainably, both in terms of quality and quantity [21].

To address this, a filtration system was designed using pressure sensors, a turbidity sensor, and a NodeMCU ESP32 integrated with IoT technology. A pressure gauge was also installed to provide real-time visual pressure monitoring on the filter. Electrically controlled solenoid valves were implemented to automate the filter cleaning mechanism (backwash and rinse). Post-cleaning, the system restores ideal pressure levels, ensuring consistent water output quality and quantity.

The system architecture, illustrated in Figure 1, and its wiring diagram, shown in Figure 2, outline the technical framework.

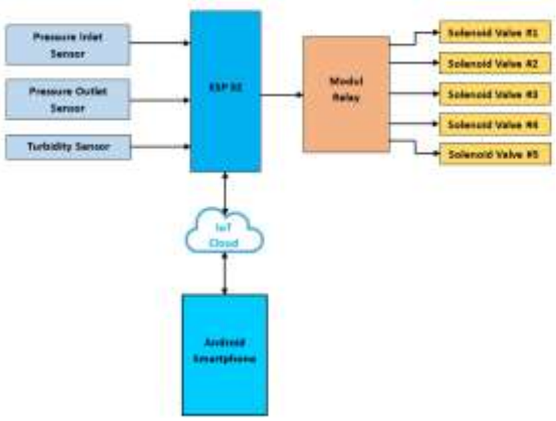



Figure 1. System Block Diagram

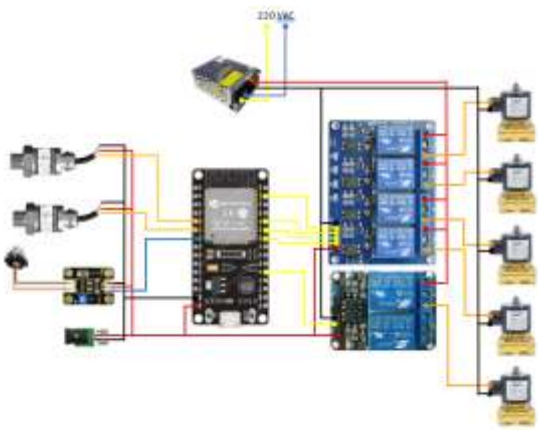


Figure 2. System Wiring Diagram

The pressure sensors and turbidity sensor serve as input devices, measuring the inlet and outlet water pressure and the turbidity of the filtered water, respectively. These measurements guide the control of five solenoid valves, comprising two valves for filtration flow regulation, two for backwash flow management, and one dedicated to rinse process control. Sensor data is displayed on a custom Android application developed using the Blynk IoT platform and transmitted via Wi-Fi. Through this app, users can manually activate backwash and rinse processes upon receiving alarm notifications triggered by a pressure surge on the inlet side and a pressure drop on the outlet side of the filter, as well as increased turbidity in the filtered water. The smartphone interface, shown in Figure 3, provides real-time monitoring and control.


Figure 3. Android Application Interface

## Result

Following the development of a water filtration research prototype utilizing a 4-inch diameter PVC pipe with a height of 60 cm, the system was equipped with layered filter media comprising silica sand, manganese zeolite, and activated carbon. This prototype was designed to investigate the activation of backwash and rinse processes in response to variations in inlet and outlet pressures, as well as changes in the turbidity level of the filtered water. The system was integrated with Internet of Things (IoT) technology to enable real-time monitoring and control. The configuration of the research prototype is depicted in Figure 4.

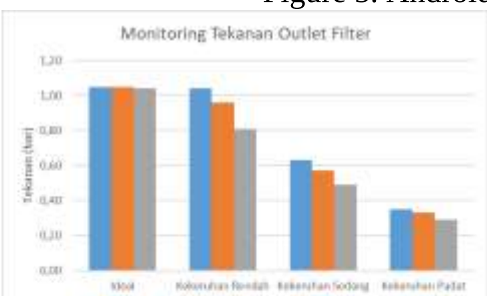
Experimental trials were conducted by contaminating the filter media with low, medium, and high turbidity silt solutions. Each level of contamination resulted in measurable changes in the inlet and outlet pressures compared to ideal operating conditions. During low-level contamination, the filtration process continued uninterrupted, as the increase in inlet pressure and the decrease in outlet pressure remained below the thresholds for triggering backwash and rinse.

Figure 4. Water Filtration System Prototype

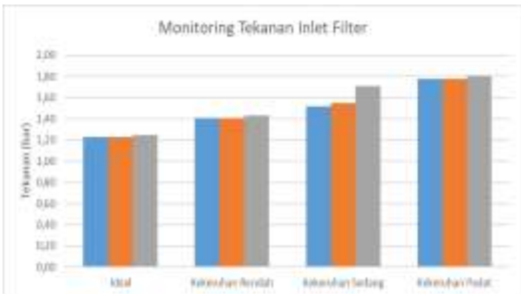
Under medium turbidity conditions, the inlet pressure increased by approximately 24% to 37%, while the outlet pressure decreased by 40% to 53%, relative to the ideal operating range of 1.23–1.25 bar for inlet pressure and 1.04–1.05 bar for outlet pressure during active filtration. When exposed to high turbidity contamination, the inlet pressure rose by up to 45%, and the outlet pressure dropped between 67% and 72%. These pressure differentials were utilized as decision-making parameters to activate the alarm system and initiate the backwash and rinse cycles via the Android-based user interface.

Additionally, the turbidity of the filtered water was found to increase in proportion to the level of contamination in the filter media. Nonetheless, the recorded turbidity values remained below 3 NTU, which is still within the environmental health quality limits established by the Indonesian Ministry of Health Regulation No. 2 of 2023 [18]. The monitoring results displayed on the Android interface, as shown in Figure 5, present sensor data that were also plotted and analysed in Figure 6.

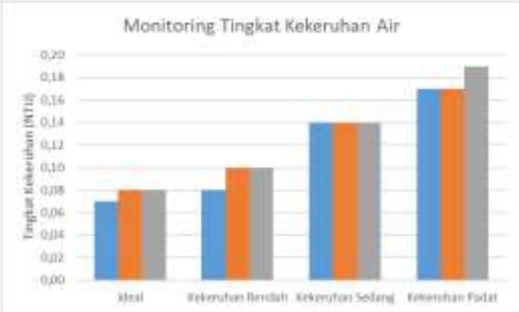

Figure 5. Android User Interface Results




(a) Monitoring of filter outlet pressure




(b) Monitoring of filter inlet pressure




(c) Monitoring of Filtered Water

Figure 6. Graphical Analysis of Sensor Monitoring Data

As observed in the sensor data analysis graph in Figure 6, the inlet pressure increased progressively with the accumulation of pollutants within the filter media (Figure 6(a)), while the outlet pressure decreased due to the reduced flow rate exiting the filter tank (Figure 6(b)). Under ideal conditions, when the filter is first used, the system operates optimally. This is indicated by the inlet pressure remaining well below the pump's cut-off threshold of 1.8 Kgf/cm² (equivalent to 1.76 bar). As the concentration of solid particles within the filter increases, the inlet pressure continues to rise while the outlet pressure declines further. This buildup of particulates in the filter media also leads to a gradual increase in the filtered water turbidity (Figure 6(c)).

The Alarm Indicator allow users to observe when the system requires maintenance and manually initiate the backwash and rinse cycles by toggling Backwash & Rinse Buttons. The filtration, backwash, and rinse processes are executed through the ON/OFF activation of solenoid valves installed along the inlet and outlet water pipelines. The configuration of these control valves is shown in Figure 7, while their operating status during each filtration phase is outlined in Table 1.

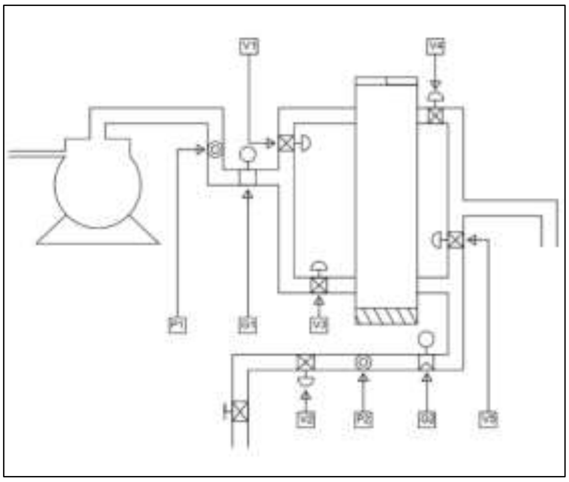



Figure 7. Piping and Instrumentation Diagram

Table 1. Solenoid Valve Configuration Based on Filtration Process

| Valve 1 | Valve 2 | Valve 3 | Valve 4 | Valve 5 | Kondisi Filter |
|---|---|---|---|---|---|
| **ON** | **ON** | OFF | OFF | OFF | Filter |
| OFF | OFF | **ON** | **ON** | OFF | Backwash |
| **ON** | OFF | OFF | OFF | **ON** | Rinse |

## Conclusion

The IoT-based water filtration monitoring and control system demonstrated satisfactory performance in cleaning accumulated pollutants within the filter through automated backwash and rinse processes. These processes were triggered by an alarm notification on the Android interface when the inlet pressure increased by 24%–45% and the outlet pressure decreased by 37%–72%. The turbidity level of the filtered water ranged from 0.14 to 0.19 NTU, indicating that the water quality remained within the acceptable limits defined by environmental health standards. The monitoring of inlet pressure, outlet pressure, and turbidity, as well as the control of the backwash and rinse processes via a smartphone using IoT technology, proved to be effective and reliable. Additionally, the operation of the solenoid valves during the filtration, backwash, and rinse cycles was consistent with the solenoid valve status as provided in Table 1.

This research implies that the integration of real-time pressure-based and turbidity control with IoT-enabled solenoid valve actuation represents a practical innovation for decentralized water treatment systems. The developed system offers a scalable and low-maintenance solution that directly supports solutions suitable for both household and community-scale implementation, especially in rural and semi-urban settings where well water is the primary source of clean water. By enabling autonomous filter maintenance through pressure anomaly detection and turbidity validation, this innovation reduces downtime, ensures water quality consistency, and extends filter lifespan. Furthermore, the system lays the groundwork for future enhancements using AI-driven predictive maintenance and adaptive filtration logic, contributing toward the advancement of smart water purification technologies.

## Acknowledgments

The authors gratefully acknowledge the support and contributions of the Directorate of Academic Affairs for Vocational Higher Education (DAPTV), Directorate General of Vocational Education (DITJEN Vokasi), Ministry of Education, Culture, Research, and Technology (KEMENDIKBUDRISTEK) in this research. This acknowledgement is expressed as a sincere expression of appreciation for the facilitation, financial support, and opportunities provided.

## References

[1] Udin, H. Hamrul, and Muh. F. Mansyur, "Prototype Sistem Monitoring Kekeruhan Sumber Mata Air Berbasis Internet of Things," *Journal of Applied Computer Science and Technology*, vol. 2, no. 2, 2021, doi: 10.52158/jacost.v2i2.219.

[2] R. P. Sihombing, A. Ngatin, J. Suryadi, R. D. Jayanti, Y. T. Sarungu, and R. Sudarman, "Rancang Bangun Sistem Pengolahan Air Jernih di Kampung Wisata

Sablon," *Kumawula: Jurnal Pengabdian Kepada Masyarakat*, vol. 5, no. 1, 2022, doi: 10.24198/kumawula.v5i1.35907.

[3] A. A. Sulianto, A. D. S. Aji, and M. F. Alkahi, "Rancang Bangun Unit Filtrasi Air Tanah untuk Menurunkan Kekeruhan dan Kadar Mangan dengan Aliran Upflow," *Jurnal Sumberdaya Alam dan Lingkungan*, vol. 7, no. 2, pp. 72–80, Aug. 2020, doi: 10.21776/ub.jsal.2020.007.02.4.

[4] A. M. Hamdan, A. M. Ikbar, and B. G. Bhernama, "The use of Iron Sand as Filtration Media for Slaughterhouse Wastewater Treatment," *JRST (Jurnal Riset Sains dan Teknologi)*, vol. 8, no. 1, p. 49, Apr. 2024, doi: 10.30595/jrst.v8i1.17241.

[5] A. N. Triana and M. Ariana, "Perancangan Biosand Filtration untuk Kualitas Air Berdasarkan Tekanan Pompa dari Limbah Industri Kelapa Sawit," *JTL*, vol. 24, no. 2, pp. 242–249, Jul. 2023, doi: https://doi.org/10.55981/jtl.2023.991.

[6] S. Mirelda Sari and R. Rinawati, "Analisis Pengaruh Backwash Terhadap Pengolahan Air Bersih di Water Treatment Plant (WTP) 1 PDAM Way Rilau Bandar Lampung," *ANALIT:Analytical And Environmental Chemistry*, vol. 6, no. 02, 2021, doi: 10.23960/aec.v6.i2.2021.p198-208.

[7] S. Sarifudin, A. Sumardiono, and G. M. Aji, "Control Dan Monitoring Proses Filtrasi Air Menggunakan HMI," *Journal of Energy and Electrical Engineering*, vol. 5, no. 1, 2023, doi: 10.37058/jeee.v5i1.8492.

[8] M. Duran-Ros *et al.*, "Effect of different filter media on emitter clogging using reclaimed effluents," *Agric Water Manag*, vol. 266, 2022, doi: 10.1016/j.agwat.2022.107591.

[9] Z. Zaenurrohman, H. Susanti, F. Hazrina, and S. Rahmat, "Sistem Penjernih Air Otomatis dengan Filtrasi Berulang dan Monitoring Kekeruhan Berbasis IoT," *Infotronik : Jurnal Teknologi Informasi dan Elektronika*, vol. 8, no. 1, p. 1, Jun. 2023, doi: 10.32897/infotronik.2023.8.1.2725.

[10] Moch. D. Septiyan, I. Anshory, A. Ahfas, and J. Jamaaluddin, "Design and Build Integrated Water Filter Automation for Android Smartphones (IoT)," *Indonesian Journal of Innovation Studies*, vol. 14, 2021, doi: 10.21070/ijins.v14i.538.

[11] 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, doi: 10.1016/j.jwpe.2022.103158.

[12] K. L. Tsai, L. W. Chen, L. J. Yang, H. Shiu, and H. W. Chen, "IoT based Smart Aquaculture System with Automatic Aerating and Water Quality Monitoring," *Journal of Internet Technology*, vol. 23, no. 1, 2022, doi: 10.53106/160792642022012301018.

[13] F. Jan, N. Min-Allah, and D. Düştegör, "Iot based smart water quality monitoring: Recent techniques, trends and challenges for domestic applications," 2021. doi: 10.3390/w13131729.

[14] E. E. D. Hemdan, Y. M. Essa, M. Shouman, A. El-Sayed, and A. N. Moustafa, "An efficient IoT based smart water quality monitoring system," *Multimed Tools Appl*, vol. 82, no. 19, 2023, doi: 10.1007/s11042-023-14504-z.

[15] N. Geetha, "IoT based smart water quality monitoring system," *International Journal of Nonlinear Analysis and Applications*, vol. 12, no. Special Issue, 2021, doi: 10.22075/IJNAA.2021.5853.

[16] V. Lakshmikantha, A. Hiriyannagowda, A. Manjunath, A. Patted, J. Basavaiah, and A. A. Anthony, "IoT based smart water quality monitoring system," *Global Transitions Proceedings*, vol. 2, no. 2, 2021, doi: 10.1016/j.gltp.2021.08.062.

[17] S. A. H. Almetwally, M. K. Hassan, and M. H. Mourad, "Real Time Internet of Things (IoT) Based Water Quality Management System," in *Procedia CIRP*, 2020. doi: 10.1016/j.procir.2020.03.107.

[18] Menteri Kesehatan Republik Indonesia, “Peraturan Menteri Kesehatan Republik Indonesia Nomor 2 Tahun 2023 Tentang Peraturan Pelaksanaan Peraturan Pemerintah Nomor 66 Tahun 2014 Tentang Kesehatan Lingkungan,” 2023. [Online]. Available: www.peraturan.go.id
[19] World Health Organization, “Guidelines for drinking-water quality: small water supplies,” 2024.
[20] R. Medi Wilian, L. Fitria, and H. Sutrisno, “Pengaruh Susunan Multimedia Filter dalam Kolom Filtrasi terhadap Penurunan Parameter Zat Organik,” *Jurnal Teknologi Lingkungan Lahan Basah*, vol. 7, no. 2, 2019.
[21] F. A. Yul and D. Denur, “Rancang Bangun Alat Penjernih Air Berbasis Backwash Menggunakan Metode Quality Function Deployment (QFD),” *Jurnal Teknik Industri Terintegrasi*, vol. 4, no. 1, 2021, doi: 10.31004/jutin.v4i1.1671.