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# Implementation of Wastewater Monitoring System using Low-Cost Water Sensor and IoT-based SCADA

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*Keyword :*

*Wastewater monitoring*
*Water sensor*
*IoT*
*SCADA*
*Low-cost*

ABSTRACT

*Wastewater monitoring is crucial for ensuring the wastewater quality is in the allowable range. This paper presents the implementation of a wastewater monitoring system using low-cost water sensors and Internet of Things (IoT)-based Supervisory Control and Data Acquisition (SCADA). The low-cost water sensor comprises the pH, temperature, turbidity, and Dissolved Oxygen (DO) sensors. The sensors are connected to the ESP32 microcontroller that is equipped with the WiFi module for communicating with the master unit, namely the Haiwell CBOX. Since the Haiwell CBOX is an IoT-based device, it is connected to the IoT cloud server. Thus, it can be accessed remotely through the Internet. The experimental results show that the user-friendly graphical interface is easy to develop and provides the user with useful and helpful information for monitoring and analyzing wastewater parameters. Further, the communication time interval of four seconds between the ESP32 and CBOX achieves a stable connection.*

## 1. INTRODUCTION

A Wastewater treatment plant (WWTP) processes wastewater before discharging it into the river. It ensures that the water to be discharged contains no pollutants. The communal WWTP is managed by the communities. The performance of the communal WWTP is usually low due to a lack of maintenance (Hendriarianti, Sudiasa and Karnaningroem, 2015).

The WWTP should be monitored regularly to maintain the wastewater parameters in the allowable range (Soetedjo and Hendriarianti, 2022). A real-time monitoring system provides effective monitoring of the WWTP (Kapula *et al.*, 2016; Martínez *et al.*, 2020; Hendriarianti and Soetedjo, 2021; Rizaluddin and Hardiani, 2021; Roby, Soetedjo and Faradisa, 2022; Soetedjo *et al.*, 2022). The Raspberry Pi was used to monitor the WWTP's chemical and physical properties, where the sensor's data were sent to the Internet of Things (IoT) server every 10 s (Kapula *et al.*, 2016). A low-cost wastewater monitoring system was developed by integrating the wireless sensor network (WSN) and a nitrate and nitrite detection method (Martínez *et al.*, 2020).

A real-time monitoring system based on the IoT was developed to monitor the performance of a phytoremediation process to remove the pollutants in the wastewater using the green plants in the WWTP (Hendriarianti and Soetedjo, 2021). The ThingSpeak was adopted as the IoT platform. The real-time wastewater monitoring system on the communal WWTP was developed to monitor the Dissolved Oxygen (DO), turbidity, pH, and temperature (Soetedjo *et al.*, 2022). The work was extended by adopting long-range communication (LoRa) to provide long communication between the sensors and the master unit (Roby, Soetedjo and Faradisa, 2022).

Another approach to monitoring the wastewater is adopting the Supervisory Control and Data Acquisition (SCADA) (Kamarulzaman and Kamal, 2020; Tokos *et al.*, 2021). The SCADA system was used to monitor the pH effluent of the Sewage Treatment Plant (STP) (Kamarulzaman and Kamal, 2020). It consisted of the pH sensor, the TBox LT2 as the Remote Terminal Unit (RTU), and TWinSoft software for configuring the RTU. To ensure a secure connection, a virtual private network (VPN) was adopted (Tokos *et al.*, 2021).

SCADA is an established industrial monitoring system. Meanwhile, the IoT is a modern technology that extends the usage of the internet to monitor and control things such as sensors and actuators. In this work, the IoT-based SCADA is employed to monitor the wastewater in the communal WWTP. It extends the work previously developed (Soetedjo *et al.*, 2022) by adopting the IoT-based SCADA, namely the Haiwell SCADA system (*Haiwell*, 2022). By combining the IoT and SCADA systems, the user-friendly graphical interface can be developed quickly, and the system can be accessed broadly via the internet.

The rest of paper is organized as follows. Section 2 presents the proposed method. Section 3 presents the experimental results and discussion. Conclusion is covered in Section 4.

## 2. PROPOSED METHOD

### 2.1. System Configuration

Figure 1 depicts the configuration of the proposed SCADA system. It consists of the sensor, microcontroller (ESP32), SCADA master unit (Haiwell CBOX), IoT cloud server, and computer or mobile device. The figure shows that the sensor unit comprises the water, maintenance, power, gas, and solar tracker sensors. These five unit sensors are the components of the complete monitoring system. It is worth noting that since this paper deals with the wastewater monitoring system, it only describes the water sensor.

The water sensor comprises the pH, temperature, turbidity, and DO. The liquid sensor is the same sensor used in our previous work (Soetedjo *et al.*, 2022). The specification of the water sensor is given in Table 1. The sensor units are connected to the ESP32, where the reading sensor data are sent to the Haiwell CBOX wirelessly using WiFi communication. The Haiwell

CBOX is the main component of the IoT-based SCADA. It is the master unit of the SCADA system and is connected to the IoT cloud server. Thus, it can be accessed remotely using a personal computer or smartphone. The specification of the Haiwell CBOX is given in Table 2.

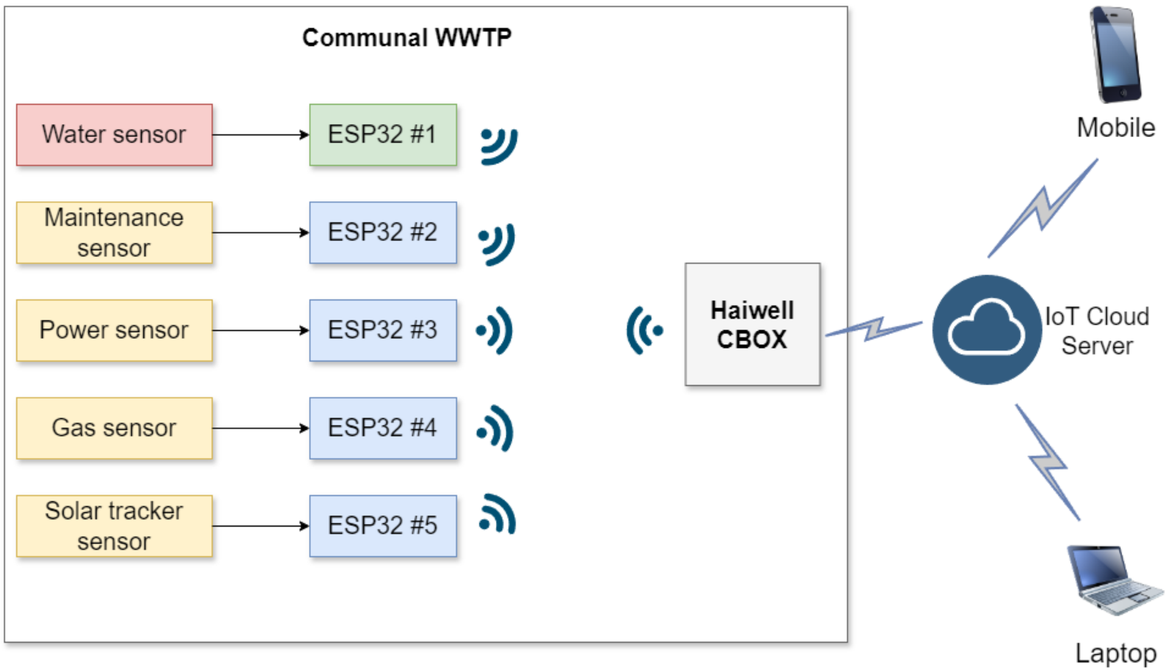


**Figure 1. IoT-based SCADA configuration.**

**Table 1. Specification of water sensor.**

| Parameter | Specification | Sensor device |
|---|---|---|
| pH sensor measurement range | 0 - 14 | Gravity: Analog pH Sensor/Meter Kit V2 |
| pH sensor measurement temperature | 0 - 60 $^0$C | |
| pH sensor measurement accuracy | ± 0.1 | |
| Temperature sensor measurement range | -55 to 125 $^0$C | DS18B20 waterproof temperature sensor |
| Temperature sensor measurement accuracy | ± 0.5 $^0$C | |
| Turbidity sensor measurement range | 0 - 3000 NTU | Gravity: Analog Turbidity Sensor |
| Turbidity sensor measurement temperature | 5 - 90 $^0$C | |
| DO sensor measurement range | 0 - 20 ppm | Gravity: Analog Dissolved Oxygen Sensor |
| DO sensor measurement temperature | 5 - 40 $^0$C | |

**Table 2. Specification of Haiwell CBOX.**

| Parameter | Specification |
|---|---|
| Input power | 24VDC±20% |
| Power consumption | 7W |
| Memory | Flash 4G，RAM 512MB |
| CPU | Processor: Cortex A7, Max Frequency 696MHZ |
| Communication port | COM1 (RS232), COM2 (RS485) |
| Ethernet | 2 x 10/ 100Base-Tx |
| USB interface | 2 x USB 2.0 |
| Extended SD card | 1 x SD Card Slot |
| SIM card | 1 x SIM Card Slot |
| WIFI function | Support |

### 2.2. SCADA Design

The human-machine interface (HMI) layout design of the main menu of the proposed SCADA for wastewater monitoring is illustrated in Figure 2. The figure shows that the upper part displays the title of the monitoring system. Three sub-windows in the middle display the water, power, and gas sensors. The bottom part displays the main menu and the time and date of the CBOX. The HMI layout of the water sensor graphical display is shown in Figure 3. This page is divided into five sub-windows, where each window displays the graphical trend of the sensor value.

The Haiwell CBOX communicates with the ESP32 using the TCP Modbus protocol. This protocol is a popular and open protocol used in the industrial fields. Table 3 shows the device address, variable name, function code, register type, and register address of the wastewater parameters.

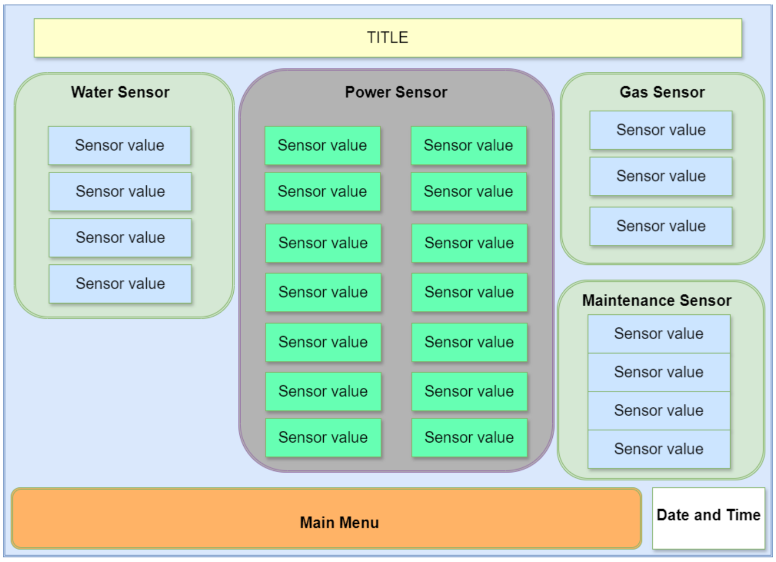


**Figure 2. HMI layout of main display.**

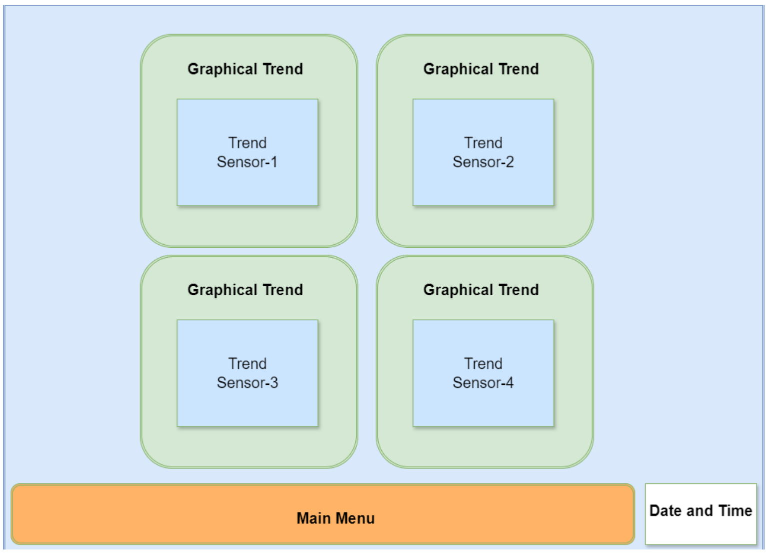


**Figure 3. HMI layout of water sensor graphical display.**

**Table 3. Modbus configuration**

| Modbus device | Station address | Variable name | Function code | Register type | Register address | Remark |
|---|---|---|---|---|---|---|
| Liquid sensor | 1 | TEMP | 04H | Analog input | 1 | Wastewater temperature |
| | | PH | 04H | Analog input | 2 | Wastewater pH |
| | | DO | 04H | Analog input | 3 | Wastewater DO |
| | | TSS | 04H | Analog input | 4 | Wastewater TSS |
| | | TDS | 04H | Analog input | 5 | Wastewater TDS |

## 3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 4 shows the appearance of the HMI main display on the Haiwell CBOX. This menu can be accessed from a computer web browser or a smartphone application. The display in the figure is the complete menu for the system shown in Figure 1. The wastewater monitoring is displayed in the leftmost sub-window, where the water sensor values are displayed. The experiments show that the displayed values are the same as the sensor value sent by the ESP32.

Figure 5 shows the appearance of the HMI water sensor graphical display. The graphics provide a user or operator with an easy interface to monitor the trend of wastewater parameters under monitoring. Further, the data are saved and can be downloaded in comma-separated values (CSV) format for further analysis. It is worth noting that the most beneficial aspect of SCADA is that the user-friendly display shown in Figures 4 and 5 is straightforward to develop without programming skills.

Several experiments are conducted to evaluate the Modbus protocol's connection between ESP32 and Haiwell CBOX. Tables 4, 5, and 6 show the experiment results with different time intervals of 300 ms, 500 ms, and 1000 ms, respectively. The tables show that the Modbus connection is not stable due to timeouts that occur about two or three times every one minute. Further experiments show that the time interval of 4000 ms achieves a stable connection without timeouts.

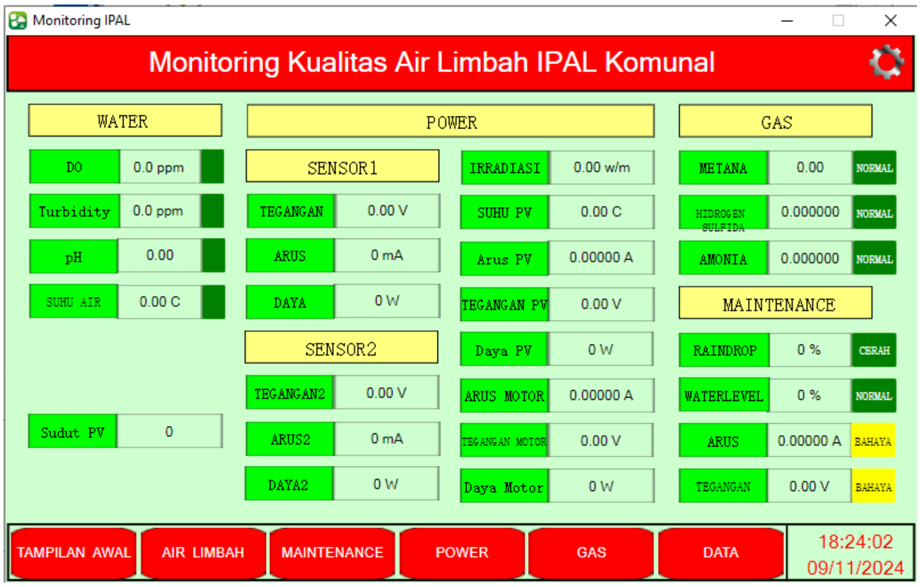


**Figure 4. Appearance of the HMI main display.**

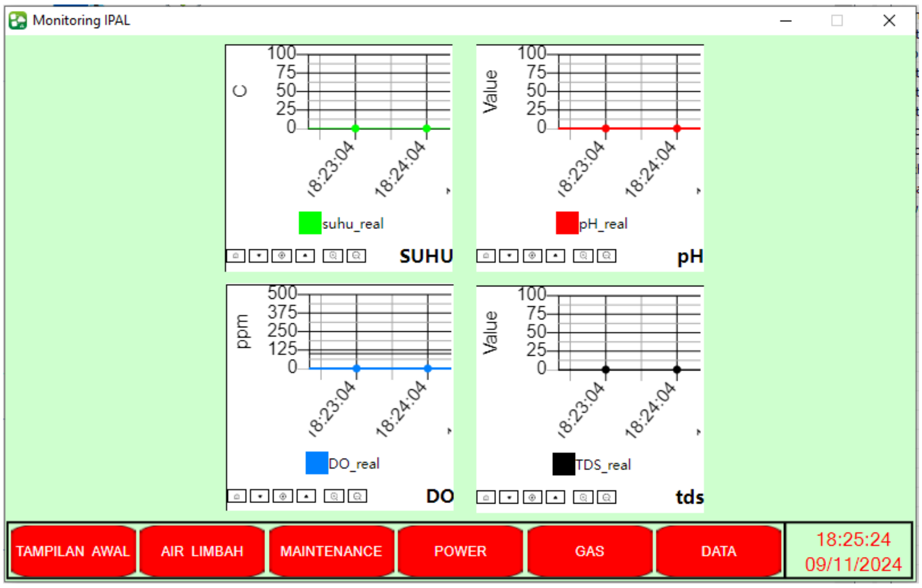


**Figure 5. Appearance of HMI water sensor graphical display.**

**Table 4. Timeout on first experiment (time interval=300ms)**

| No. | Time | Timeout duration |
|---|---|---|
| 1 | 12:44:25 | 1 second |
| 2 | 12:44:40 | 1 second |
| 3 | 12:45:31 | 1 second |
| 4 | 12:46:56 | 2 seconds |
| 5 | 12:47:30 | 1 second |
| 6 | 12:48:00 | 1 second |
| 7 | 12:48:39 | 1 second |
| 8 | 12:49:26 | 1 second |
| 9 | 12:49:58 | 1 second |
| 10 | 12:50:15 | 1 second |
| 11 | 12:50:30 | 1 second |
| 12 | 12:50:46 | 1 second |
| 13 | 12:51:33 | 2 second |
| 14 | 12:51:53 | 1 second |
| 15 | 12:52:05 | 3 second |
| 16 | 12:52:58 | 1 second |

**Table 5. Timeout on second experiment (time interval=500ms)**

| No. | Time | Timeout duration |
|---|---|---|
| 1 | 21:34:26 | 5 seconds |
| 2 | 21:34:41 | 3 seconds |
| 3 | 21:35:20 | 4 seconds |
| 4 | 21:35:36 | 3 seconds |
| 5 | 21:36:15 | 5 seconds |
| 6 | 21:37:26 | 4 seconds |
| 7 | 21:37:44 | 3 seconds |
| 8 | 21:38:38 | 4 seconds |
| 9 | 21:38:54 | 4 seconds |
| 10 | 21:39:49 | 4 seconds |
| 11 | 21:40:05 | 4 seconds |
| 12 | 21:41:33 | 3 seconds |
| 13 | 21:41:48 | 4 seconds |
| 14 | 21:42:05 | 3 seconds |
| 15 | 21:42:59 | 4 seconds |

**Table 6. Timeout on third experiment (time interval=1000ms)**

| No. | Time | Timeout duration |
|---|---|---|
| 1 | 21:59:16 | 4 seconds |
| 2 | 22:00:10 | 5 seconds |
| 3 | 22:00:28 | 5 seconds |
| 4 | 22:01:38 | 4 seconds |
| 5 | 22:02:34 | 4 seconds |
| 6 | 22:03:45 | 4 seconds |
| 7 | 22:04:17 | 4 seconds |
| 8 | 22:05:12 | 4 seconds |
| 9 | 22:06:51 | 4 seconds |
| 10 | 22:07:34 | 5 seconds |
| 11 | 22:07:51 | 4 seconds |
| 12 | 22:08:45 | 4 seconds |

## 4. CONCLUSION

The IoT-based SCADA system was developed to monitor wastewater using low-cost sensors, namely pH, temperature, turbidity, and DO. The Haiwell CBOX is employed as the master unit of the SCADA system. It provides easy remote access through the Internet and a graphical tool for developing a user-friendly graphical interface. The proposed SCADA system can be used to monitor wastewater efficiently.

In the future, the proposed system will be extended to handle more complex wastewater parameters. Further, its actual implementation in the fields will be carried out, as will its reliability.

### Acknowledgment

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