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Design and Build an Internet of Things (IoT) Based Wastewater Monitoring System at Cirebon Pelabuhan Hospital

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ABSTRACT

Wastewater at Cirebon City Port Hospital that is not properly treated has the potential to cause serious environmental damage. To address this issue, technological innovations that enable automatic and precise monitoring of water quality are required. This study aims to develop and test a prototype of a Wastewater Treatment Plant (WWTP) monitoring system at Cirebon Port Hospital using Internet of Things (IoT)-based technology. The prototype was built with an ESP8266 microcontroller as the control unit, a turbidity sensor to measure water clarity, a DS18B20 sensor to measure water temperature, and a pH sensor to monitor acidity levels. Data from these sensors were transmitted and visualized in real time through the MIT App, integrated with Firebase. Calibration results indicated high accuracy across all sensors, with the pH sensor reaching 97.8%, the turbidity sensor 97.1%, and the DS18B20 temperature sensor 97.7%. However, testing in tubs 1 to 3 showed errors in turbidity readings above 30 due to the unfiltered condition of the wastewater. These findings highlight the effectiveness of IoT-based prototypes in monitoring WWTP performance, while also pointing to the need for improvements in filtration systems to ensure accurate monitoring. The developed system has the potential to support hospitals in enhancing environmental compliance and preventing water pollution.

INTRODUCTION

Wastewater at the Cirebon City Port Hospital is one of the most significant sources of environmental problems or pollution. Wastewater that is not treated properly can cause environmental damage, such as groundwater, rivers, and ocean pollution. In addition, wastewater can also be a source of disease for humans and animals (Lin et al., 2022). Therefore, hospital wastewater monitoring is very important to maintain the balance of the environment and public health. Often wastewater is directly discharged into the water body without further treatment, because the wastewater does not necessarily meet the wastewater quality standards that are applied (Sukarno et al., 2025).

In this case, technological advances are very rapid in the manufacture of sophisticated tools, namely tools that can work automatically and have high precision so that they can make the work done by users easier to be more practical and efficient in time and energy (Liu et al., 2024). The development of technology has encouraged human life to be fully automated. Therefore, what initially used all-manual is now switched to automatic (Christanto et al., 2020).

Therefore, in this study, we will make a prototype for monitoring the Wastewater Management Plant (WWTP), so hereby the author develops his research by directly applying the Wastewater Management Plant (WWTP) at the Cirebon Port Hospital.

Hospital wastewater treated using WWTP needs to know the quality content of its wastewater before it is released into the environment as a form of prevention of the impact of environmental pollution, both soil, water, and air as well as surrounding living things (Azwari et al., 2023).

Hospital wastewater is one of the most significant sources of environmental pollution, as it contains a mixture of chemical, biological, and pharmaceutical residues that can contaminate groundwater, rivers, and oceans if not properly treated. Untreated wastewater is also a potential source of infectious diseases for humans and animals. Previous studies have emphasized the urgency of effective monitoring systems. For example, Verlicchi et al. (2018) highlighted that hospital effluents contain a higher concentration of hazardous pollutants compared to domestic wastewater, yet monitoring systems in many developing countries remain limited and poorly integrated. Similarly, Dolar et al. (2016) examined advanced treatment methods and noted that while membrane bioreactors improved pollutant removal efficiency, real-time monitoring systems were still underdeveloped, leaving gaps in continuous quality control. These studies demonstrate progress in treatment technologies but show insufficient attention to automated, real-time monitoring of wastewater quality.

The novelty of this study lies in combining affordable IoT technology with environmental monitoring to improve accuracy, efficiency, and accessibility of hospital wastewater control. The objective is to ensure compliance with environmental quality standards, prevent waterborne pollution, and support sustainable hospital operations. The results are expected to benefit hospitals by strengthening environmental compliance, policymakers by providing a model for smart monitoring, and the community by reducing health risks associated with untreated wastewater.

RESEARCH METHOD

The research method applied in this study is an experimental quantitative method with a direct application experimental method. Starting with a literature study that studies aspects related to wastewater management systems In previous research journals The aspects studied include the performance of ESP8266 microcontrollers, turbidity sensors, DS18B20 sensors, and water pH sensors that will be the research material. This study involves the following steps in Figure 1:

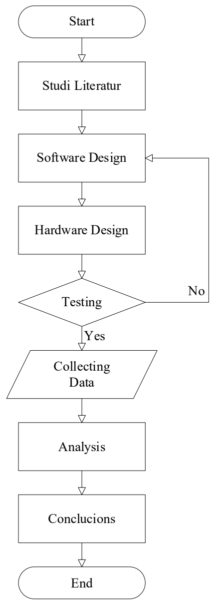

Figure 1. Flow of research steps

This research was conducted from July 13 to July 20, 2025. The location of this research is at the Wastewater Management Installation (WWTP) of the Cirebon City Port Hospital. To determine the level of wastewater used for the prototype benchmark so that it can measure the content of wastewater contained in accordance with the ISO 14001 / SNI National Standard carried out by the Government. data that is in accordance with the Government can be seen in the table below.

Table 1. Wastewater quality standards

Parameter	Up to Maximum
PH	0-5 (Abnormal / Too acidic)
	6-9 (Normal)
	10-14 (Abnormal / Too Basic)
Turbidity	0-25 (Normal)
	26 -100 (Normal)
Temperature	20- 40 C

The flow diagram of the wastewater quality monitoring work system is shown in figure

2.

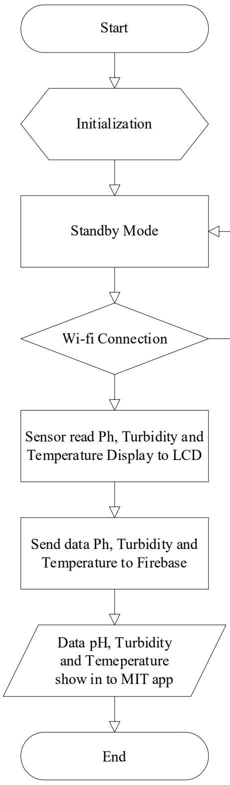

Figure 2. Flowchart Wastewater Quality Monitoring Work System

In the working system of this device, when the device is voltaged, the device will be in a standbay state when it is connected to wi-fi, then the arduino will read the PH, turbdity and DS18B20 sensors, then the arduini will add the data to the LCD and send it to the firebase then it will be read by the MIT APP.

Hardware Planning

The hardware design stage in this study starts from designing a series schematic for wastewater quality monitoring

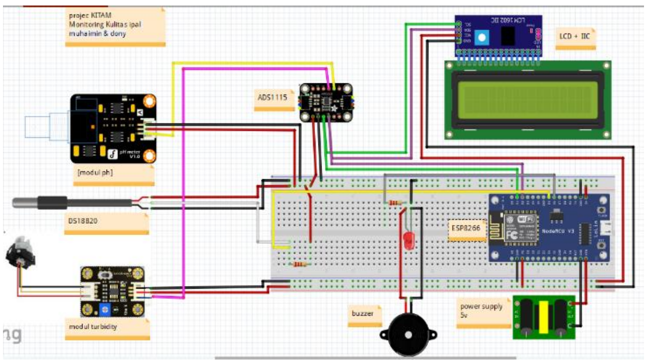

Figure 3. Monitoring of wastewater quality

The hardware design for wastewater quality monitoring uses the ESP 8266 microcontroller as the controller brain and the wifi connection module. monitoring wastewater quality to detect water content saturation using pH meter, turbidity and temperature sensors whose measurement results will later be displayed on the LCD. In addition to the data being displayed on the LCD, the data is also sent to the firebase and displayed through the MIT app, and also sends a "danger" message to the MIT app when one of the sensor readings exceeds the predetermined maximum limit and then returns to normal when the moisture content returns to normal.

RESULT AND DISCUSSION

This test is carried out with two stages of testing, namely sensor calibration testing, which aims to improve the accuracy of the values read by the sensor with the comparison of the corresponding values and wastewater sample testing.

Sensor Accuracy Testing

pH meter

Calibration of the pH meter this time by making a comparison between the ph powder dissolved with water with a ph sensor, this calibration is also used to determine the minimum and maximum limits and the maximum ph allowed for water to come out of the sewage from the wastewater into the river. The ph powder we use this time is from ph 4 to ph 11 powder. Table 2 is the result of calibration.

Table 2 pH meter calibration results

No	Dissolved pH powder	Prototype reading	Error
1	4,4	4.1	2,5%
2	5,5	5,11	2,2%
3	6,6	6,09	1,5%
4	7,7	7,12	1,71%
5	8,8	8,23	2,87%
6	9,9	9,18	2%
7	110	10,16	1,6%
8	111	11,35	3,18%
	Error Average		2,19%

Turbidity

The turbidity calibration this time is by making a comparison between the meter (to read the turbidity level of the water) and the turbidity sensor. This calibration is also used to determine the maximum turbidity limit allowed for water to exit the sewage discharge into the river. For the turbidity limit, which is 25 ntu (nephelomertric turbidity unit) ntu is used to measure the amount of light emitted by suspended particles in water. Table 3 is the result of turbidity calibration.

Table 3. Turbidity sensor calibration results

No	Turbidity Value Turbidity Measuring Instrument	Prototype Reading	Error
1	5,0 ntu	4,8 ntu	4 %
2	15,0 ntu	16,7 ntu	2 %
3	35,0 ntu	33,9 ntu	3,15 %
4	60,0 ntu	64,0 ntu	2,4 %
	Error Average		2,9 %

DS18b20

Temperature calibration this time by making a comparison between the digital thermometer (to read the temperature) and the DS18b20 sensor. This calibration is also used to determine the minimum and maximum temperature limits and maximum temperatures that are allowed for water to discharge from the wastewater into the river. . Table 4 is the calibration of the DS18b20 sensor.

Table 4 Calibration results DS18B20

No	Temperature values measured with digital thermometers	Prototype reading	Error
1	28 ^{o}c	27,6 ^{o}c	1,4%
2	29,5 ^{o}c	29,9 ^{o}c	1,3%
3	35,6 ^{o}c	36,9 ^{o}c	3,6%
4	39,8 ^{o}c	41,0 ^{o}c	3,01%
	Error Average		2,3%

Prototype Testing

The next stage of data collection (observation) in the field is measured to strengthen the data obtained from the measurements. The test measurement data in the WWTP laboratory is adjusted to the results of the measurement of pH, Turbidity, Temperature.The potential of wastewater from each trial includes tub 1, tub 2, tub 3 and tub 4.

pH meter testing

This ph sensor test uses the water method by sampling WWTP water at the Cirebon City Port Hospital. Then we get the results in table 5.

Table 5 pH sensor test results

No	Tub Name	pH 1 Result (10:00 a.m.)	pH 2 Results (12:00 p.m.)	pH 3 Results (14:00 p.m.)	pH 4 Results (16:00 p.m.)	Average	Status
1	Tub 1	8,25	7,91	8,05	7,89	8,02	Normal
2	Tub 2	8,21	8,15	8,50	8,60	8,36	Normal
3	Tub 3	7,97	7,99	7,52	7,21	7,67	Normal
4	Tub 4	6,89	6,73	7,42	7,91	7,20	Normal

Turbidity testing

This turbidity sensor test uses the water method by sampling WWTP water at the Cirebon City Port hospital. Then we get the results in table 6.

Table 6. Turbidity sensor test results

No	Tub Name	Result Turbidity 1 (10:00 a.m.)	Result Turbidity 2 (12:00 p.m.)	Result Turbidity 3 (14:00 p.m.)	Result Turbidity 4 (16:00 p.m.)	Average	Status
1	Tub 1	60,7 ntu	60,9 ntu	58,4 ntu	57,1 ntu	59,3 ntu	Abnormal
2	Tub 2	59,9 ntu	58,1 ntu	56,5 ntu	53,9 ntu	57,2 ntu	Abnormal
3	Tub 3	32,9 ntu	30,5 ntu	30,6 ntu	29,6 ntu	30,9 ntu	Abnormal
4	Tub 4	22,6 ntu	21,1 ntu	22,4 ntu	21,1 ntu	21,8 ntu	Normal

Temperature testing

The DS18B20 sensor test uses the water method by sampling WWTP water at the Cirebon City Port hospital. Then we get the results in table 7.

Table 7. DS18B20 sensor test results

No	Tub Name	Result Temperature 1 (10:00 a.m.)	Result Temperature 2 (12:00 p.m.)	Result Temperature 3 (14:00)	Result Temperature 4 (16:00)	Average	Status
1	Tub 1	28,7 ^{o}c	29.1 ^{o}c	28,6 ^{o}c	27,9 ^{o}c	28,6 ^{o}c	Normal
2	Tub 2	28,3 ^{o}c	28,4 ^{o}c	28,9 ^{o}c	28,5 ^{o}c	28,5 ^{o}c	Normal
3	Tub 3	27,5 ^{o}c	28,1^{o}c	27,2 ^{o}c	27,9 ^{o}c	27,7 ^{o}c	Normal
4	Tub 4	28,3 ^{o}c	28,5 ^{o}c	28,3 ^{o}c	28,4^{o}c	28,4 ^{o}c	Normal

Analysis

The calibration of the three sensors successfully lowers the reading error rate and produces accurate outputs for each parameter (pH, turbidity, and temperature). Field tests show that the monitoring system is able to distinguish water quality based on the specified parameters. The threshold values used to determine the "normal" or "abnormal" status are successfully applied in the system as a reference for the validation of the results. With the implementation of these sensors and microcontroller-based systems, wastewater monitoring systems can help with early detection of pollution, and provide a basis for decision-making before water is discharged into the environment.

Based on the results of the structural analysis of the 6-story hotel building in the Subang area, the floor structure consists of the following:

1. The design of this slab structure complies with and meets SNI 2847:2019 Requirements for Structural Concrete for Buildings.
2. The floor slab structure plan can be seen in the table below:

Table 1. Recapitulation of Plate Reinforcement

Structural Elements	Level	Location	Reinforcement Ø (mm)	Reinforcement Spasi X	Reinforcement Spasi Y
Floor plate h=140 mm	Lt 1	Mt	10	130	140
		Ml	10	130	140
	Lt 2	Mt	10	130	140
		Ml	10	130	140
	Lt 3	Mt	10	130	140
		Ml	10	130	140
	Lt 4	Mt	10	130	140
		Ml	10	130	140
	Lt 5	Mt	10	130	140
		Ml	10	130	140
	Lt 6	Mt	10	130	140
		Ml	10	130	140
Roof plate h=125 mm	Roof	Mt	10	150	170
		Ml	10	150	170

Table 6. Results Documentation

no	Tub Name	Documentation	Analysis Results
1	Tub 1		pH= 8,02 Tubidity= 59,3 ntu Temperature= 28,6 ºc Status= Abnormal (due to turbidity exceeding 25 ntu)
2	Tub 2		pH= 8,36 Turbidity= 57,2 ntu Temperature= 28,5 ºc Status= Abnormal (due to turbidity exceeding 25 ntu)
3	Tub 3		pH= 7,67 Turbidity= 30,9 ntu Temperature= 27,7 ºc Status= Abnormal (due to turbidity exceeding 25 ntu)

no	Tub Name	Documentation	Analysis Results
4	Tub 4		pH=7,20 Turbidity= 21,8 ntu Temperature= 28,4 ºc Status= normal

These findings are consistent with Nugroho et al. (2021), who found that IoT-based water quality monitoring significantly improved the accuracy and efficiency of detecting environmental pollution, especially in industrial and healthcare wastewater systems. Similarly, Yadav et al. (2020) highlighted that the integration of turbidity, temperature, and pH sensors within an IoT framework can deliver reliable real-time classification of water quality status, thereby supporting regulatory compliance and environmental protection. By applying these approaches specifically to hospital wastewater, this research fills the gap left by earlier studies that largely focused on domestic or industrial wastewater, showing that sensor-based monitoring is equally feasible and impactful in the healthcare sector.

This study not only validates the reliability of low-cost IoT monitoring systems but also demonstrates their adaptability in hospital wastewater contexts, where precise monitoring is crucial for preventing pollution. Future research could expand this prototype by adding dissolved oxygen (DO) and chemical oxygen demand (COD) sensors or by employing machine learning algorithms to improve predictive capabilities. Such developments would enhance both the precision and scalability of wastewater management solutions for broader environmental and public health benefits.

CONCLUSION

This research successfully designed and implemented a wastewater quality monitoring system using an ESP8266 microcontroller integrated with pH, turbidity, and DS18B20 temperature sensors, achieving high accuracy with error rates below 3%. The system effectively detected and classified wastewater conditions as normal or abnormal, providing a practical solution for early pollution detection and supporting compliance with environmental quality standards. This study also demonstrates the feasibility of low-cost IoT-based monitoring systems for hospital wastewater management. Future research should expand by incorporating additional sensors like dissolved oxygen (DO) and chemical oxygen demand (COD), developing predictive analytics through machine learning, and applying the prototype for real-time continuous monitoring at larger hospital wastewater treatment plants to further enhance environmental protection and public health.

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