Monitoring Detergent Waste Using pH, Temperature, and Turbidity Sensor Based on the Internet of Things

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Abstract – *The rapid increase in detergent waste due to urbanization poses significant environmental risks, particularly to water bodies. This study developed an IoT-based system to monitor detergent waste parameters—pH, temperature, and turbidity—using sensors integrated with an Arduino Mega 2560 microcontroller. The system ensures real-time data logging and visualization via a Blynk application, with thresholds set at pH 6–9, temperature <38°C, and turbidity <75 NTU, as per Indonesian environmental standards. Experimental results revealed that detergent waste samples exhibited pH levels of 4–5, temperatures of 27–28°C, and turbidity levels of 90–150 NTU, exceeding permissible limits. The system demonstrated high accuracy, with sensor errors below 1% for pH and temperature measurements. These findings underscore the need for advanced wastewater treatment processes and stricter regulatory enforcement. The IoT-based monitoring system proved effective for real-time environmental assessment, offering a scalable solution for urban wastewater management.*

Keywords: *pH, Turbidity, Sensor, IoT, Waste Management*

I. Introduction

The rapid population growth due to urban expansion will affect the amount of liquid waste generated from household activities. The condition of metropolitan waters is highly concerning. River water pollution is increasing, particularly in rivers that flow through densely populated urban and rural areas [1], [2]. This is because the domestic waste processing and disposal systems in major cities still follow traditional methods—directly dumping waste into rivers that flow into coastal or marine areas as the final disposal system. As a result, environmental damage can occur in household waste disposal sites such as rivers, swamps, and coastal waters [3], [4], [5]. Similarly, wells and other water sources are contaminated by the seepage of household waste from polluted sewers and drainage channels.

The quantity of liquid waste generated by home activities will be impacted by the rapid population rise brought on by settlement expansion. The state of the urban waters is really concerning. River water contamination is on the rise, particularly in those that traverse heavily inhabited rural and urban areas. This is due to the fact that large cities' residential waste processing and disposal systems continue to use the antiquated practice of dumping of waste straight into rivers that flow into the sea or coast. Therefore, areas like rivers, marshes, and coastal seas where domestic waste is disposed of may suffer environmental harm [6], [7]. Similarly, the seepage of domestic garbage from infected sewers and streams into wells and other water sources.

Detergent waste contributes to increased foam and air turbidity, and reduces dissolved oxygen levels [8], [9], [10]. Surfactants in detergents are toxic to air organisms, disrupt the balance of the ecosystem, and can accumulate in the food chain. In addition, phosphate content triggers eutrophication which causes algae blooms and decreases air quality. Handling detergent waste requires a special approach because it is resistant to natural decomposition. Conventional waste treatment systems are often ineffective in completely removing detergent chemical compounds. Therefore, strict regulations are needed regarding the composition of environmentally friendly detergents and improvements in domestic waste technology. The impact of detergent waste pollution is increasingly evident in urban areas with high population densities, where drainage systems are often directly connected to rivers without a filtration process [11], [12]. Long-term accumulation of detergent waste not only endangers the aquatic ecosystem but also has the potential to damage the community's drinking water sources.

According to certain sources, water quality refers to the overall state of the water and its chemical, physical, and biological components. Wastewater from industries is one factor that influences the quality of water. It is leftover trash from industrial production processes that is created in liquid form. Compared to domestic waste, industrial waste is produced in bigger amounts and has a greater environmental impact [13], [14]. As a result, it's essential to regularly check the quality of the water and test samples based on specific criteria. The characteristics of river water. Fresh water sources like rivers, lakes, streams, ponds, reservoirs, surface ground water, wells, cave water, and wetland water are typically monitored as part of this process. The purpose of this monitoring is to make sure that water supplies are secure for ingestion and is suitable for both animal and human requirements. Water quality is assessed to be adequate for everyday needs by taking into account the criteria of pH, temperature, and water turbidity, in accordance with Republic of Indonesia Minister of Health Regulation Number 416 of 1990. Consumption and may monitor the industrial waste. It can determine whether the liquid parameter's value is appropriate for being bounded. Utilizing an Arduino Mega 2560 microcontroller as a data collector [15], [16]. This study addresses this gap by developing an IoT-based system that combines pH, temperature, and turbidity sensors with a microcontroller and a user-friendly mobile interface. The system aims to enhance environmental compliance, support regulatory enforcement, and contribute to sustainable urban wastewater management. The findings will provide insights into the effectiveness of IoT solutions for mitigating detergent-related pollution in developing regions.

II. Methods

This study will focus on measuring two crucial water quality parameters, namely pH, temperature and turbidity, as the main indicators of domestic waste pollution, especially detergents. Water pH determines the level of acidity or alkalinity that can affect the solubility of chemical compounds and waste toxicity, while water temperature plays an important role in the chemical and biological processes of water. These two variables are interrelated, where changes in temperature can affect the pH value, so that simultaneous measurement is needed to comprehensively evaluate the impact of detergent waste on water quality. By monitoring these two parameters, this study aims to provide accurate data that can be the basis for developing a more effective household waste management system.

II.1. pH, Temperature and Turbidity Sensor

A pH sensor is an electronic device used to measure the acidity or alkalinity of a solution, including water. This sensor works by detecting the electrochemical potential between a reference electrode and a sensing electrode that is sensitive to hydrogen ions (H^+) [17], [18]. The normal pH value for clean water ranges from 6.5-8.5. pH measurement is very important in water quality analysis because changes in pH can affect the solubility of chemical compounds, the toxicity of pollutants, and the life of aquatic organisms. Modern pH sensors are usually equipped with temperature compensation to improve measurement accuracy.

Temperature sensors function to measure the amount of heat or coldness of a medium, in this case water. The working principle can be based on thermistors, thermocouples, or RTDs (Resistance Temperature Detectors) which convert temperature changes into electrical signals [19], [20]. Measuring water temperature is important because it affects various aspects of water quality, including: chemical reaction rates, dissolved oxygen levels, and aquatic organism metabolism. Significant temperature fluctuations can indicate thermal pollution or mixing with industrial/domestic waste.

Turbidity sensors measure the turbidity of water caused by suspended particles such as silt, microorganisms, or pollutants [21], [22]. These sensors generally use the principle of nephelometry (light scattering measurement) or light transmission. Turbidity is measured in NTU (Nephelometric Turbidity Units) and is an important indicator of water quality. These three sensors complement each other in comprehensive water quality monitoring, where the interaction between pH, temperature, and turbidity determines the health level of a water body.

Diagrams and flowcharts that can clearly illustrate the system are necessary for this research in order to provide an example of how an alat worker should operate, show in Figure 1 and Figure 2. Wiring diagrams also help in estimating the length of cables used and the location of components inside the device. By considering these factors in detail, the process of installing and connecting components can be done more efficiently and reduce the risk of errors during assembly. In addition, wiring diagrams are also useful references for future maintenance and troubleshooting, as they make it easier to identify problematic connections or Figure 3. 2 Prototype changes that may be needed in the system. Thus, creating a wiring diagram is a key step in designing reliable and efficient hardware. Detailed schematics allow for a smoother customization process. diagrams are used to understand the interactions between various components and predict the impact of proposed changes. This reduces the time required to make updates and ensures that changes do not impact the functionality of the existing system. A wiring diagram can be seen in Figure 3.

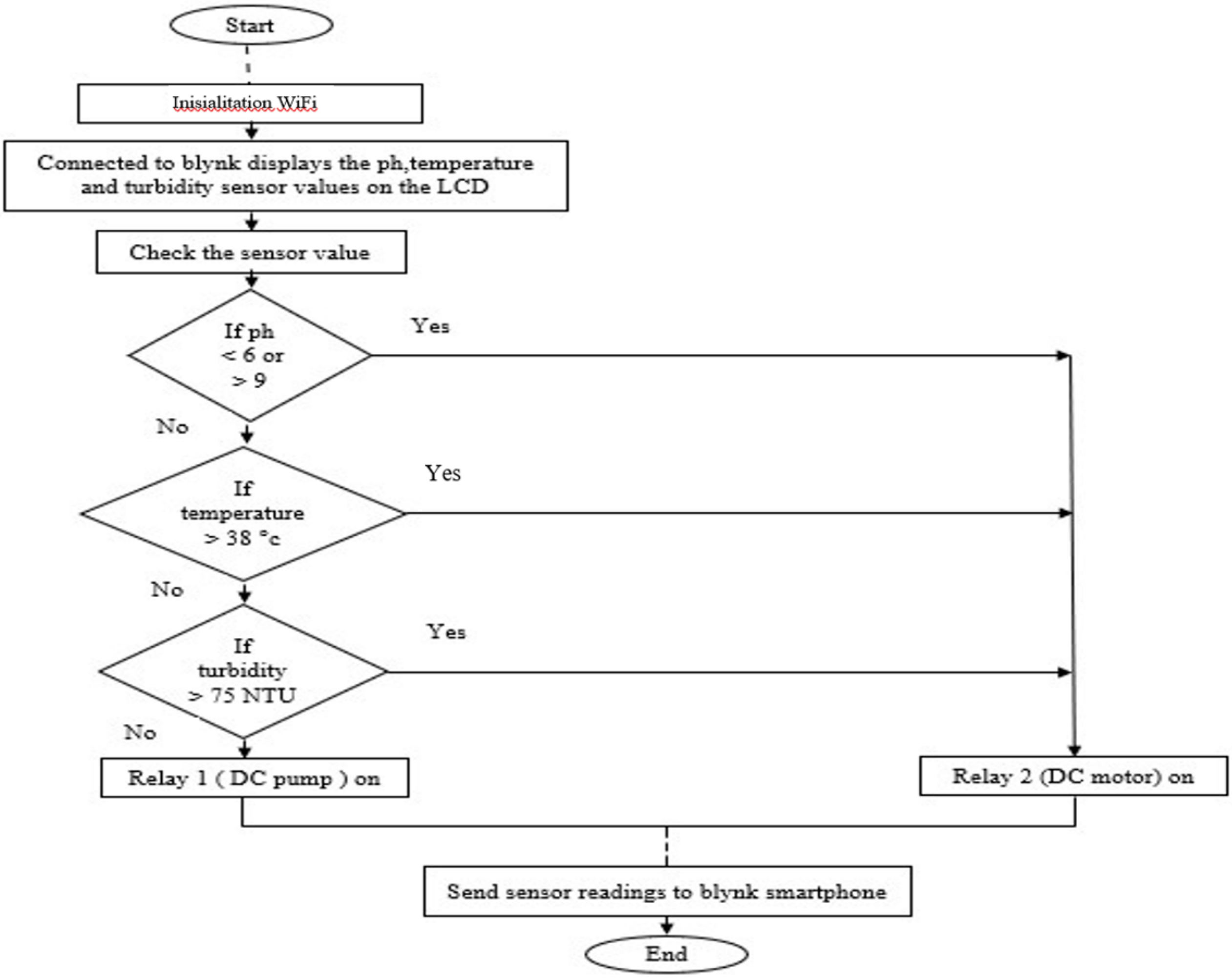

Fig 1. Flowchart

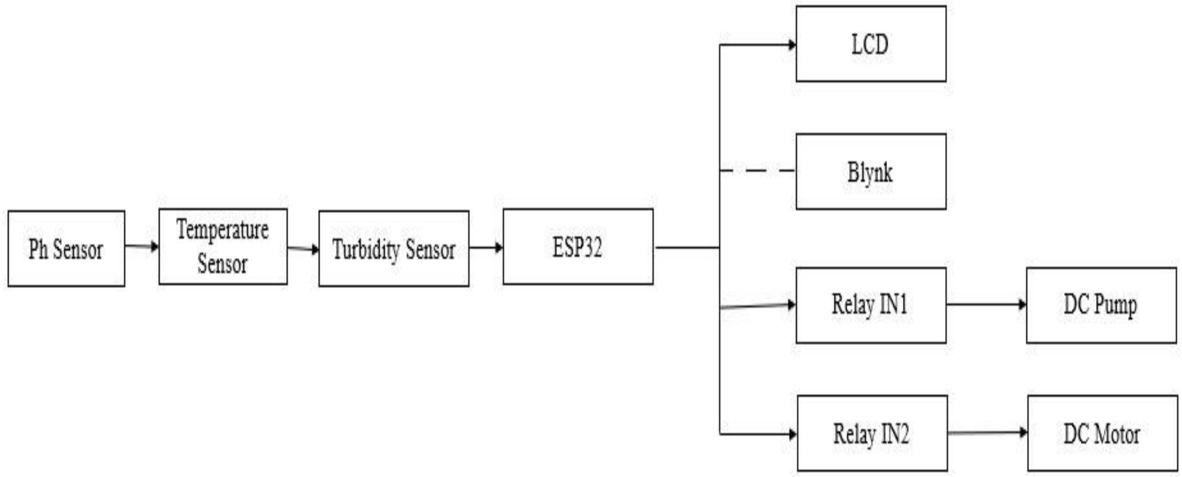

Fig 2. Block Diagram

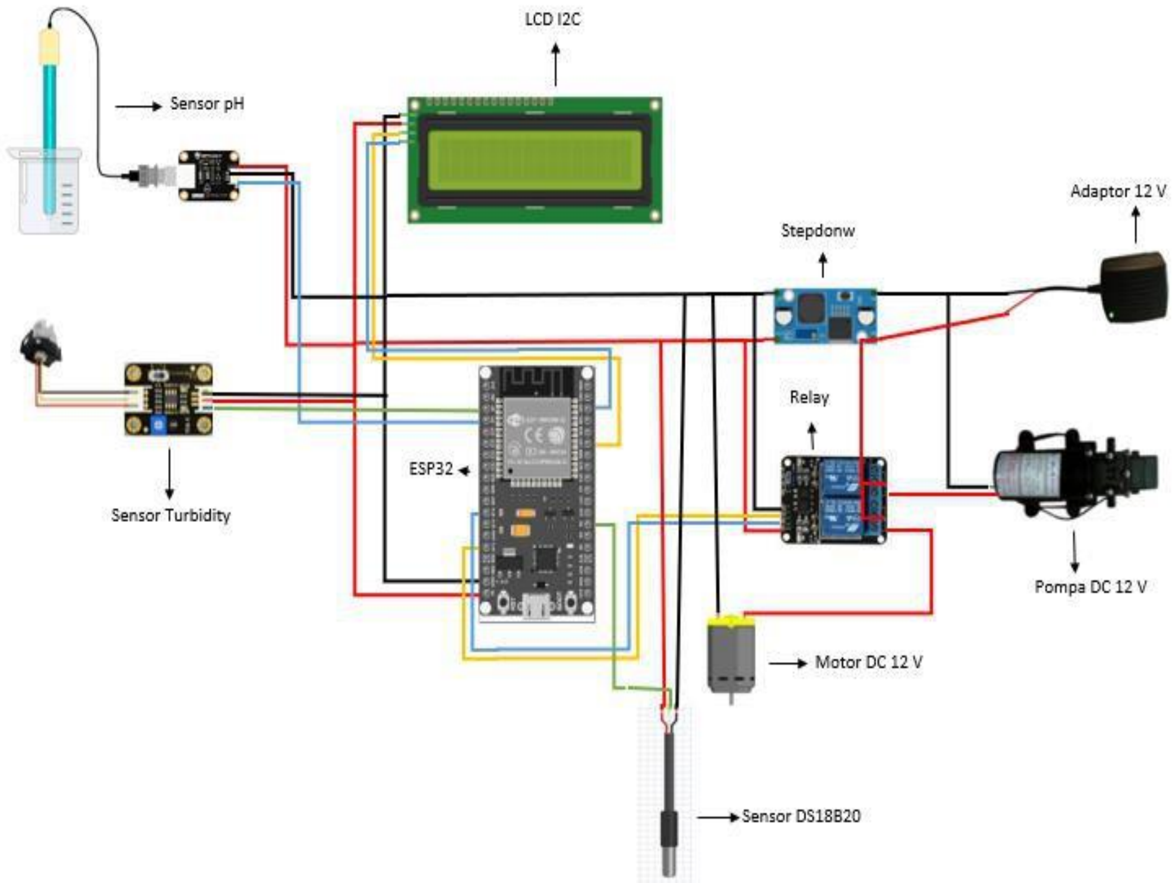

Fig. 3 Wiring Diagram

II.2. *Calibration sensor*

pH sensor calibration is carried out by comparing the sensor calibration with the pH buffer. The pH sensor is attached to the pH buffer to detect each individual pH buffer. This is done in order to determine whether the used pH sensor can function properly. As may be seen in Figure 4.

Fig 4. pH Sensor testing

According to Figure 4, this is a calibration process for a pH sensor in which each sensor's reading is obtained using a buffer of 4.01, 6.86, and 9.18 results from sensor readings displayed on an LCD I2C. This can be seen in Table 1, Table 2 and Table 3.

TABLE I
PH SENSOR TESTING

solution

No	Voltage (V)	pH	Error (%)
1	3,00	4,16	0,04
2	3,00	4,16	0,04
3	3,00	4,16	0,04
4	3,00	4,16	0,04
5	3,00	4,16	0,04
6	3,00	4,17	0,05
7	3,01	4,17	0,05
8	3,01	4,17	0,05
9	3,01	4,17	0,05
10	3,01	4,17	0,05
11	3,20	6,09	0,15
12	3,23	6,09	0,15
13	3,23	6,09	0,15
14	3,24	6,09	0,15
15	3,25	6,10	0,16
16	3,25	6,10	0,16
17	3,25	6,10	0,16
18	3,26	6,10	0,16
19	3,26	6,10	0,16
20	3,27	6,10	0,16
21	2,73	9,28	0,31
22	2,75	9,28	0,31
23	2,75	9,28	0,31
24	2,76	9,28	0,31
25	2,77	9,28	0,31
26	2,77	9,29	0,32
27	2,77	9,29	0,32
28	2,78	9,29	0,32
29	2,78	9,29	0,32
30	2,78	9,29	0,32

From the pH sensor calibration experiment, it can be concluded that the pH sensor used is accurate in measuring tofu wastewater.

The thermometer and temperature sensor DS18B20 are placed side by side to detect the presence of ai in the water and see each particle as it sinks. This is done in order to determine whether the used temperature sensor can function properly and reliably by looking at the error message from the process.can be seen in Figure 5.

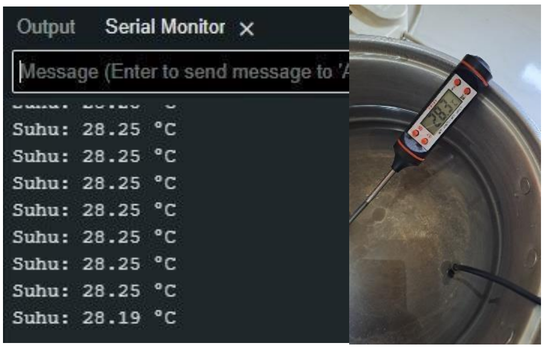

Fig 5. Temperature Sensor Testing

TABLE II
TEMPERATURE SENSOR TESTING

No	Time (second)	Sensor (°C)	Termometer (°C)	*Error* (%)
1	15	28,25	28,32	0,24
2	30	28,27	28,32	0,17
3	45	28,27	28,32	0,17
4	60	28,26	28,32	0,21
5	75	28,26	28,32	0,21
6	90	28,28	28,33	0,17
7	105	28,28	28,33	0,17
8	120	28,29	28,33	0,14
9	135	28,29	28,33	0,14
10	150	28,30	28,33	0,10

The turbidity sensor is used to measure the amount of muddiness present in the detergent air and uses saline air to perform comparisons. The sensor measures the amount of NTU present in the detergent air and saline air and displays the results of the measurement. As can be seen in Figure 6.

Fig 6. Testing of Turbidity Sensor

TABLE III
TESTING OF TURBIDITY SENSOR

No	Voltage (V)	NTU
1	0,72	73,02
2	0,73	74,05
3	0,74	74,50
4	2,10	210,01
5	2,11	211,70
6	2,12	211,78
7	2,13	212,75
8	2,26	225,88
9	2,26	226,12
10	2,27	227,01

III. Result and Discussion

After testing the three sensors, testing was carried out with detergent wastewater and clean water to measure or read the values in the detergent water and clean water that were read by the three sensors and the results of the readings on the detergent water and clean water were obtained. Result can be shown in Table 4 and Table 5.

TABLE IV
SYSTEM TESTING

Testing	pH	Temperature (°C)	Turbidity (NTU)
1	9.30	28.87	90
2	9.17	28.94	120
3	9.25	28.25	175
4	9.58	28.94	185
5	9.19	28.06	196
6	9.24	28.25	200
7	9.05	28.31	212
8	9.01	28.37	225
9	9.99	28.44	236
10	9.96	28.21	258
11	9.88	28.29	262
12	10.01	28.26	274
13	10.00	28.19	285
14	10.05	28.24	293
15	10.04	28.20	300
16	7.15	28.13	74
17	7.10	28.17	72
18	6.83	28.26	75
19	6.84	28.25	72
20	6.80	28.27	70

Table 4 presents the results of system testing on detergent wastewater samples with varying concentrations (1 to 15 spoons of detergent per liter) alongside control samples (clean water). The pH values for detergent waste ranged from 9.30 to 10.05, indicating a highly alkaline nature that exceeds the safe threshold of 6–9 pH as per environmental standards. This alkalinity is attributed to the surfactants and additives in detergents, which can disrupt aquatic ecosystems by increasing water toxicity. Temperature readings remained stable (27–28°C), within permissible limits (<38°C), suggesting that thermal pollution is not a primary concern in this context. However, turbidity levels showed a sharp increase from 90 NTU to 300 NTU with higher detergent concentrations, far surpassing the 75 NTU limit. This trend confirms that detergent waste introduces significant suspended solids, reducing water clarity and potentially harming aquatic life by blocking sunlight and clogging fish gills. In contrast, clean water samples (tests 16–20) exhibited near-neutral pH (6.80–7.15) and low turbidity (70–75 NTU), validating the system's ability to differentiate between polluted and unpolluted water.

TABLE V
POMPA TESTING

Testing	Motor	Pump
1	Active	Off
2	Active	Off
3	Active	Off
4	Active	Off
5	Active	Off
6	Active	Off
7	Active	Off
8	Active	Off
9	Active	Off
10	Active	Off
11	Active	Off
12	Active	Off
13	Active	Off
14	Active	Off
15	Active	Off
16	Active	Off
17	Active	Off
18	Active	Off
19	Active	Off
20	Active	Off

Table 5 details the system's response to the data collected in Table 4, specifically the activation of the DC motor or pump via relay control. For tests 1–15 (detergent wastewater), the ESP32 microcontroller consistently triggered the DC motor to initiate a stirring process, aiming to homogenize the waste for further treatment. This action reflects the system's design logic, where exceeding turbidity or pH thresholds activates remedial measures. In tests 16–20 (clean water), the pump was activated to allow safe discharge, demonstrating the system's decision-making capability based on real-time sensor inputs. The absence of pump activation in polluted samples underscores the system's precautionary approach, preventing untreated waste from being released into the environment. These results highlight the practicality of IoT automation in wastewater management, ensuring compliance with environmental standards while minimizing human intervention. The consistent motor activation for polluted samples also suggests opportunities for optimizing treatment protocols, such as integrating chemical dosing or filtration in future iterations.

Together, these tables underscore the system's effectiveness in monitoring and responding to detergent waste pollution, providing a foundation for scalable, real-time environmental management solutions. In Figure 7, the Blynk application uses 3 Gauge displays as indicators for monitoring temperature, pH and turbidity and 1 button with a pump mode switch to turn the stirring motor on and off.

Fig 7. Blynk display on smartphone

IV. Conclusion

The experimental results demonstrated that detergent waste consistently exceeded permissible environmental standards, with pH levels reaching 10.05 (beyond the 6–9 safe range) and turbidity levels climbing to 300 NTU (far above the 75 NTU threshold), while temperature remained within acceptable limits. The system's accuracy was validated through rigorous sensor calibration, achieving errors below 1% for pH and temperature measurements. The integration of the Blynk application enabled effective real-time monitoring and decision-making, as evidenced by the system's ability to activate remediation processes (e.g., stirring via DC motor) when pollution thresholds were breached. These findings highlight the critical need for advanced wastewater treatment solutions, particularly in urban areas where detergent pollution is prevalent.

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