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DESIGN OF A WATER SYSTEM MONITORING AND SEAWATER QUALITY STUDY AT THE FLOATING DOCK OF PT PAL INDONESIA

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ABSTRACT

Design of a Water System Monitoring and Seawater Quality Study at the Floating Dock of PT PAL Indonesia. *As ship repair and maintenance activities increase in the floating dock area of PT PAL Indonesia, they consequently affect the surrounding seawater quality. However, at present, the determination of seawater pollution levels is still conducted through manual sampling followed by laboratory analysis, which requires a considerable amount of time. Therefore, an IoT-based seawater quality monitoring system is proposed as a solution to this problem. The objectives of this study were to determine the level of seawater pollution in the floating dock area and to analyze the relationship between independent variables and the dependent variable. This study employed a quantitative research method consisting of three stages: first, the design and assembly of the monitoring device; second, sampling at each predetermined location; and third, correlation testing to determine the relationship between independent variables and the dependent variable using the Pearson correlation method. The results showed that the average values of pH, temperature, turbidity, salinity, and dissolved oxygen were 7.04, 27.60 °C, 4.88 NTU, 32.25 ‰, and 8.25 ppm, respectively. The study concludes that the seawater quality in the floating dock area still meets the seawater quality standards in accordance with the Decree of the Minister of Environment of the Republic of Indonesia Number 51 of 2004, and that there are two independent variables that are significantly correlated with the dependent variable.*

INTRODUCTION

A floating dock is a facility where ships are docked for repair and maintenance processes by vertically floating and submerging the dock structure [(1)]. Ship repair and maintenance activities are generally conducted at shipyards once a year for passenger ships and at least once every five years for non-passenger ships.

As one of the largest shipyards in Indonesia, PT PAL Indonesia is capable of performing ship maintenance, new ship construction, and other manufacturing activities in the maritime and energy sectors. Based on the company's inventory data in 2023, PT PAL Indonesia completed repair and maintenance work on 50 vessels, including passenger ships, tankers, submarines, warships, and cranes. These shipyard activities inevitably generate waste runoff that cannot be fully contained and eventually mixes with the surrounding seawater.

The waste runoff originates from blasting processes, painting activities, fuel tank draining, oil spills, and other operational activities, which contribute to changes in seawater quality in the floating dock area. Shipyard operations affect seawater quality, as indicated by increased turbidity levels and decreased dissolved oxygen concentrations [2].
Therefore, testing seawater parameters is necessary to monitor seawater quality, which has direct implications for marine ecosystems. However, in the era of the Industrial Revolution 4.0, many monitoring activities are still conducted manually, including the collection of seawater samples for pollutant parameter analysis. Each sampling activity requires appropriate and reliable methods to accurately determine the level of water pollution.
The sampling process generally involves sending personnel to collect seawater samples for laboratory testing. This process typically takes approximately ten to thirty days from initial sampling to the receipt of laboratory results [3], indicating inefficiency in monitoring activities. To minimize this limitation, a real-time seawater quality monitoring system is required to improve efficiency and reduce the time needed for data acquisition [4]. Real-time monitoring systems enable continuous measurements to assess environmental changes over both short- and long-term periods and provide real-time information on water quality status at the monitoring location [5].
Based on this research gap, the present study was conducted to reduce the duration of seawater quality testing by providing real-time monitoring data through an IoT (Internet of Things)-based system in the floating dock area of PT PAL Indonesia. The objectives of this study are to determine the level of seawater pollution in the floating dock area and to analyze the relationship between independent variables and the dependent variable.

MATERIALS AND RESEARCH METHODS

The research was conducted in three stages. The first stage involved the design and assembly of an IoT-based seawater quality monitoring device utilizing five seawater parameters: pH measured using a SEN0161 sensor, temperature measured using a DS18B20 sensor, turbidity measured using a TS300B sensor, and salinity as well as dissolved oxygen measured using a SEN0237-RK5-2F.5 sensor. The system was controlled by a Wemos D1 R32 microcontroller equipped with a Wi-Fi module, enabling data transmission to the Blynk IoT application for real-time visualization of measurement results.
The second stage consisted of seawater sampling conducted in the floating dock area at four predetermined measurement points: point 1 (7°12′4.09″ S, 112°44′26.34″ E), point 2 (7°12′3.70″ S, 112°44′26.26″ E), point 3 (7°12′3.31″ S, 112°44′26.15″ E), and point 4 (7°12′2.88″ S, 112°44′26.09″ E). Measurements were carried out during three different time periods, namely in the morning (07:00–08:00), afternoon (11:00–12:00), and evening (16:00–17:00). The measurement results were then compared with the seawater quality standards stipulated in the Decree of the Minister of Environment of the Republic of Indonesia Number 51 of 2004, which served as the reference for determining the pollution category in the floating dock area.

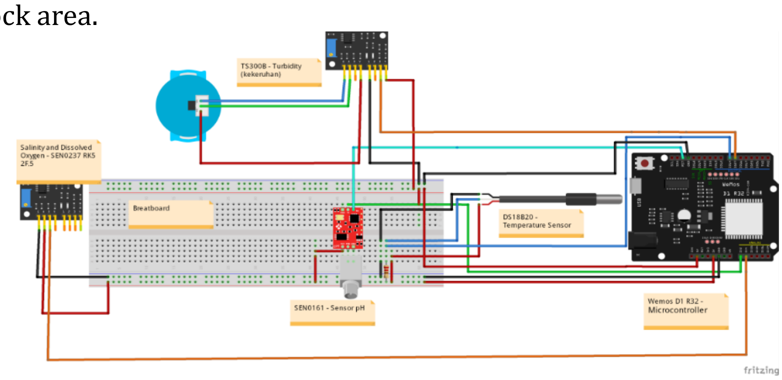

Figure 1. Water System Monitoring Design Source: Research Result, 2024

The third stage involved a correlation analysis to examine the relationship between independent variables and the dependent variable using the Pearson correlation method.

Figure 2. Sampling Point in Floating Dock Area Source: Google Earth, 2024

There are 5 dependent variables, namely the values of the pH parameter, temperature, turbidity, salinity, and dissolved oxygen. The values of several parameters were obtained during sampling in the floating dock area based on the predetermined time and measurement points.

There are 2 independent variables, namely wind velocity and the depth of the sampling point. Data kecepatan angin diperoleh dengan melakukan pengukuran di masing- masing titik sampling menggunakan 5 in 1 environmental meter. Then, the depth of the sampling points is 0 cm or sea surface level, 50 cm below sea surface level, and 100 cm below sea surface level.

RESEARCH RESULTS AND DISCUSSION

Here is the prototype display of the IoT-based seawater quality monitoring device design, which can detect pH, temperature, turbidity, salinity, and dissolved oxygen parameters. Then, the values captured by each sensor will automatically connect to the Blynk IoT application in real time.

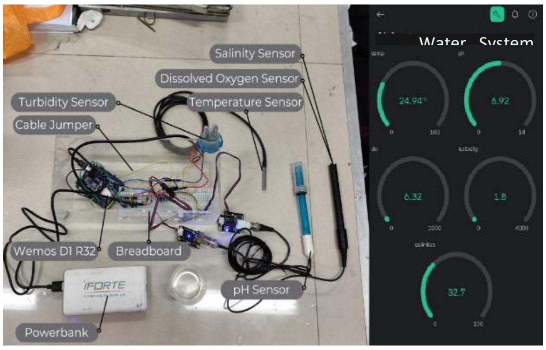

Figure 3. implementation of design water system monitoring Source: Research Result, 2024

Here are the measurement data in the floating dock area during the morning (06:00- 07:00), afternoon (11:00-12:00), and evening (16:00-17:00) at 4 sampling points.

Table 1. Sampling Result In Floating Dock Area

Time	Sampling Point	Wind Velocity (m/s)	Depth (cm)	pH	Temp (°C)	Turbidity (NTU)	Salinity (‰)	DO (ppm)
06.00–07.00 am	1	3.4	10	6.99	26.91	1.85	31.06	8.68
			50	7.05	26.53	2.39	32.02	8.3
			100	7.07	26.44	2.77	31.55	7.98
	2	1.1	10	6.96	26.93	1.86	32.31	8.64
			50	6.97	26.46	2.78	31.21	7.94
			100	7.02	26.55	2.4	33.94	8.26
	3	0.8	10	7.05	27.01	1.91	32.17	8.72
			50	7.11	26.63	2.45	31.7	8.34
			100	7.06	26.54	2.83	32.46	8.02
	4	2.9	10	7.01	24.83	2.56	31.25	8.67
			50	6.95	25.21	2.02	34.09	8.29
			100	6.96	24.74	2.94	32.21	7.97
11.00-12.00	1	5.8	10	7.05	28.28	5.55	31.15	8.77
			50	7.11	27.9	6.09	32.11	8.39
			100	7.06	27.81	6.47	31.64	8.07
	2	3.7	10	7.08	27.92	6.1	34.03	8.73
			50	7.02	28.3	5.56	32.4	8.35
			100	7.03	27.83	6.48	31.3	8.03
	3	1.6	10	7.11	28.38	5.61	32.26	8.81
			50	7.12	27.91	6.53	32.55	8.43
			100	7.17	28	6.15	31.79	8.11
	4	3.9	10	7.01	26.58	5.72	34.18	8.76
			50	7.07	26.2	6.26	31.34	8.38
			100	7.02	26.11	6.64	32.38	8.08
16.00–17.00 pm	1	5.8	10	7.02	29.47	5.61	31.23	8.7
			50	7.08	29.27	6.15	32.19	8.32
			100	7.03	29.18	6.33	31.72	8.06
	2	4.0	10	6.99	29.67	5.62	32.48	8.66
			50	7.05	29.29	6.16	34.11	8.28
			100	7.07	29.2	6.34	31.58	7.98
	3	1.9	10	7.08	29.75	5.67	32.34	8.74
			50	7.14	29.37	6.21	31.87	8.36
			100	7.09	29.28	6.39	32.83	8.04
	4	2.2	10	6.98	27.95	5.78	34.26	8.69
			50	7.04	27.57	6.32	31.42	8.31
			100	6.99	27.48	6.7	32.38	7.97
Average				**7.04**	**27.60**	**4.88**	**32.25**	**8.25**

Source: Research Result, 2024

Level of Seawater Pollution Based on Sampling Results

Based on measurements of the pH parameter, an average value of 7.04 was obtained. This value showed no significant variation throughout the measurement period. The relatively stable pH condition is attributable to the large volume of seawater, which buffers against substantial pH fluctuations. This finding is consistent with a study conducted in the coastal waters of Mimika, West Papua[6], which reported that seawater pH tends to remain stable with a maximum variation of ±1. According to the applicable seawater quality standards stipulated in the Decree of the Minister of Environment Number 51 of 2004 (Appendix III),

the acceptable pH range is 7.0–8.5. These results indicate that the environmental conditions at the study site remain suitable for marine biota.
Measurements of the temperature parameter yielded an average value of 27.60 °C. Previous research[7] indicates that seawater temperature may vary in response to temperature changes in surrounding waters. This condition is also influenced by weather conditions during sampling, which were predominantly clear and cloudless. Referring to the seawater quality standards outlined in the Decree of the Minister of Environment Number 51 of 2004 (Appendix III), the permissible temperature deviation is <2 °C from the natural temperature. Natural temperature represents the normal thermal condition of an environment, where surface seawater temperatures typically range from 20–30 °C[8]. Therefore, the seawater surface temperature at the study location remains within normal limits.
Based on turbidity measurements, an average value of 4.88 NTU was recorded. Previous studies[9] have shown that seawater turbidity is strongly influenced by anthropogenic activities in surrounding waters. In this study, the floating dock is located adjacent to a naval base, where frequent vessel movement occurs. The passage of these vessels can generate turbulent water flow, resuspending bottom sediments into the water column. In addition, occasional oil spills associated with ship traffic may also contribute to increased turbidity. According to the seawater quality standards specified in the Decree of the Minister of Environment Number 51 of 2004 (Appendix III), the allowable turbidity level is <3 NTU. Lower NTU values indicate clearer water conditions[10]. These findings suggest that the turbidity condition at the study site still complies with the applicable quality standards.
Measurements of salinity produced an average value of 32.25 ‰. A study conducted in the coastal waters of Bangka Belitung[11] reported salinity values ranging from 30.67–33.67 ‰, which are considered normal, as salinity fluctuations of less than 5 ‰ are permitted under the Decree of the Minister of Environment Number 51 of 2004. This condition is consistent with the study site, where the floating dock is designed in a U-shaped configuration, allowing surface waters to remain relatively calm even under strong wind conditions. Consequently, salinity values at the study location tend to remain stable. According to the quality standards outlined in the Decree of the Minister of Environment Number 51 of 2004 (Appendix III), allowable salinity variation is <5 ‰ from the seasonal average. Natural salinity represents the normal salt concentration of seawater, which typically ranges from 32–34 ‰[12]. These results indicate that salinity levels at the study site remain within acceptable limits.
Measurements of dissolved oxygen (DO) yielded an average concentration of 8.25 ppm. Dissolved oxygen is a critical factor for the survival of aquatic biota[13]. Previous research[14] suggests that an optimal dissolved oxygen concentration for aquatic ecosystems is approximately 7.2 ppm. Dissolved oxygen also plays a vital role in the microbial decomposition of organic matter, which subsequently supports respiratory processes in aquatic organisms[15]. Furthermore, dissolved oxygen is a key indicator of water body fertility and overall ecological health[16]. Variations in seawater depth also influence dissolved oxygen levels, with deeper waters generally exhibiting lower oxygen concentrations[17]. According to the seawater quality standards established in the Decree of the Minister of Environment Number 51 of 2004 (Appendix III), the minimum acceptable dissolved oxygen concentration is >5 ppm. Therefore, the dissolved oxygen conditions in the floating dock area meet the established quality standards.

Correlation Between Wind Velocity and Seawater Parameters

Correlation analysis was conducted to examine the relationship between wind velocity at each measurement point and variations in seawater parameters, including pH, temperature, turbidity, salinity, and dissolved oxygen (Figure 3).

Pairwise Pearson Correlations

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
pH	Wind Velocity	36	-0.069	(-0.388, 0.266)	0.691
Temperature	Wind Velocity	36	0.294	(-0.038, 0.568)	0.082
Turbidity	Wind Velocity	36	0.442	(0.132, 0.673)	0.007
Salinity	Wind Velocity	36	-0.169	(-0.472, 0.169)	0.323
Dissolved Oxygen	Wind Velocity	36	0.016	(-0.314, 0.343)	0.925

Figure 3. Results of Wind Velocity Correlation Tests
to pH, Temperature, Turbidity, Salinity, and Dissolved Oxygen

Correlation tests are used to assess the strength and direction of relationships between dependent and independent variables and are commonly referred to as linearity assumption tests[18]. Based on the measured seawater parameters in the floating dock area, correlation analysis was performed between wind velocity and each parameter.

Hypotheses:

a. H_0: Wind velocity has no relationship with pH
   H_1: Wind velocity is related to pH
b. H_0: Wind velocity has no relationship with temperature
   H_1: Wind velocity is related to temperature
c. H_0: Wind velocity has no relationship with turbidity
   H_1: Wind velocity is related to turbidity
d. H_0: Wind velocity has no relationship with salinity
   H_1: Wind velocity is related to salinity
e. H_0: Wind velocity has no relationship with dissolved oxygen
   H_1: Wind velocity is related to dissolved oxygen

Decision criteria:

P-value < 0.05 → H_0 rejected, H_1 accepted
P-value > 0.05 → H_0 accepted, H_1 rejected

The Pearson correlation analysis between wind velocity and pH yielded a P-value of 0.082 (>0.05), indicating that H_0 is accepted. Thus, wind velocity does not significantly influence pH variation. This result reflects the buffering capacity of seawater, which maintains relatively stable pH conditions. Significant pH changes generally occur only during large-scale phytoplankton blooms[19].

Correlation analysis between wind velocity and temperature produced a P-value of 0.691 (>0.05), indicating no significant relationship. This finding is consistent with previous studies[20] reporting relatively stable sea surface temperatures.

The correlation between wind velocity and turbidity resulted in a P-value of 0.007 (<0.05), leading to the rejection of H_0. The correlation coefficient was 0.442, indicating a moderate positive correlation within the range of 0.40–0.60[21]. This finding aligns with previous research[22] showing that increased ship traffic around floating docks can resuspend sediments, thereby increasing turbidity.

Correlation analysis between wind velocity and salinity yielded a P-value of 0.473 (>0.05), indicating no significant relationship. This result is consistent with findings that seawater salinity generally remains stable within the range of 30.67–33.67 ‰[11], except under specific conditions such as heavy rainfall, which can dilute seawater and reduce salinity levels[23].

Finally, correlation analysis between wind velocity and dissolved oxygen produced a P-value of 0.925 (>0.05), indicating no significant relationship. Previous studies[17] suggest that dissolved oxygen levels in seawater only change significantly when wind-induced turbulence generates large-scale wave activity.

Correlation Between Sampling Depth and Seawater Parameters
Correlation analysis was also conducted to evaluate the relationship between sampling depth and variations in seawater parameters (Figure 4).
Using the same analytical approach[18], correlation tests were performed between sampling depth and each measured seawater parameter.
Hypotheses:

Pairwise Pearson Correlations

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
pH	Sampling Depth	36	0.048	(-0.285, 0.371)	0.779
Temperature	Sampling Depth	36	-0.112	(-0.425, 0.225)	0.517
Turbidity	Sampling Depth	36	0.173	(-0.165, 0.474)	0.313
Salinity	Sampling Depth	36	-0.123	(-0.434, 0.214)	0.473
Dissolved Oxygen	Sampling Depth	36	-0.938	(-0.968, -0.881)	0.000

Figure 4. Results of Sampling Depth Correlation Tests
to pH, Temperature, Turbidity,Salinity, and Dissolved Oxygen

a. H_0: Sampling depth has no relationship with pH
H_1: Sampling depth is related to pH
b. H_0: Sampling depth has no relationship with temperature
H_1: Sampling depth is related to temperature
c. H_0: Sampling depth has no relationship with turbidity
H_1: Sampling depth is related to turbidity
d. H_0: Sampling depth has no relationship with salinity
H_1: Sampling depth is related to salinity
e. H_0: Sampling depth has no relationship with dissolved oxygen
H_1: Sampling depth is related to dissolved oxygen

Correlation analysis between sampling depth and pH yielded a P-value of 0.779 (>0.05), indicating no significant relationship. This result is consistent with the buffering nature of seawater, where significant pH changes typically occur only during large phytoplankton blooms[19].
The correlation between sampling depth and temperature produced a P-value of 0.517 (>0.05), indicating no significant relationship. This finding reflects the relatively uniform temperature distribution observed across sampling depths.
Correlation analysis between sampling depth and turbidity yielded a P-value of 0.313 (>0.05), indicating no significant relationship. Although seawater appeared visually turbid, actual water samples were relatively clear. This visual discrepancy is likely caused by seabed sediments affecting light dispersion, making the water appear turbid to the naked eye[24].
The correlation between sampling depth and salinity resulted in a P-value of 0.473 (>0.05), indicating no significant relationship. This finding reflects the relatively stable salinity of seawater, which typically ranges from 30.67–33.67 ‰[25], except during heavy rainfall events that may cause seawater dilution[23].
In contrast, correlation analysis between sampling depth and dissolved oxygen yielded a P-value of 0.000 (<0.05), leading to the rejection of H_0. The correlation coefficient was −0.938, indicating a strong inverse relationship within the range of 0.80–1.00[21]. This finding is consistent with previous studies[26], which report that increasing seawater depth reduces sunlight penetration, thereby decreasing dissolved oxygen concentrations.

CONCLUSIONS AND RECOMMENDATIONS
The fly density measurements at the four observation points in Market X, Malang City, ranged Based on the research findings, it can be concluded that the level of seawater pollution in the floating dock area, as assessed using parameters aligned with the seawater quality standards

stipulated in the Decree of the Minister of Environment Number 51 of 2004, indicates that the average values of pH, temperature, turbidity, salinity, and dissolved oxygen were 7.04, 27.60 °C, 4.88 NTU, 32.25 ‰, and 8.25 ppm, respectively. Overall, the seawater quality in the floating dock area remains within the established quality standards.

The results of the correlation analysis demonstrate that wind velocity does not exhibit a significant relationship with variations in pH, temperature, salinity, or dissolved oxygen. However, wind velocity shows a moderate relationship with turbidity, as indicated by a correlation coefficient of 0.442. Furthermore, sampling depth does not show a significant relationship with changes in pH, temperature, salinity, or turbidity. In contrast, sampling depth exhibits a very strong inverse relationship with dissolved oxygen concentration, as evidenced by a correlation coefficient of −0.938.

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