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Development of a Microcontroller-Based Clean Bilge System Prototype with Power Monitoring for Community Empowerment

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Abstract: *Oil waste remains a significant contributor to marine pollution, primarily due to a lack of awareness and understanding regarding its proper management. This research focuses on addressing this issue through the development of a microcontroller-based clean bilge system prototype equipped with a power monitoring feature. The study is designed as a community engagement initiative aimed at fostering environmental consciousness and technological literacy among various societal groups. The methodology employs a participatory approach, starting with problem identification to understand the limited knowledge surrounding the importance of bilge systems on ships. Relevant literature on bilge systems and the environmental impacts of oil pollution is reviewed to inform the design of a practical solution. Stakeholders, including students and community members, are actively involved in the research process to ensure that the proposed innovation aligns with real-world needs. The results introduce a compact and user-friendly prototype that replicates the essential functions of a ship's bilge system. The integrated power monitoring system enhances operational efficiency by providing real-time feedback, allowing for immediate resolution of power-related issues. This innovation not only serves as a practical tool for educating communities about sustainable marine practices but also acts as a preventive measure to minimize the environmental harm caused by improper oil waste disposal. This study contributes to community service efforts by bridging the gap between environmental sustainability and technological education. The proposed solution has the potential to inspire further adoption of clean bilge systems and supports broader initiatives in marine conservation and community empowerment.*

Keyword: *Oil waste, Marine pollution, Bilge system, Environmental awareness*

Introduction

The bilge system is a critical safety feature on ships, primarily functioning as a water discharge mechanism during emergencies such as leaks caused by grounding or collisions[1][3]. In addition to its primary role, the bilge system also collects water seepage from cracked plate joints and leaks in the shaft tunnel[4][5]. Bilge systems are categorized into two types: the clean bilge system and the oily bilge system. The clean bilge system is designed to discharge water that is not contaminated with oil, which may originate from hull leaks[6][2]. On the other hand, the oily bilge system is responsible for collecting and filtering a mixture of oil and water from the engine room.

Marine pollution in Indonesia has shown a steady increase over time, with one of the significant contributors being illegal waste disposal by ships traversing Indonesian waters[7]. For instance, in 2019, KRI Siwar-646 apprehended a vessel illegally discharging waste in the waters west of Galang Island, Riau Archipelago. Such illegal waste disposal practices are often attributed to a lack of understanding and awareness regarding proper waste management.

According to the International Maritime Organization (IMO), oil waste may only be discharged if its concentration is less than 15 ppm, and ships are required to have oil filtering equipment[8].

To address the critical issue of inadequate knowledge and awareness regarding the disposal and management of oil waste, this study proposes the development of a prototype bilge system. The bilge system, as one of the key components of ship operations, plays a vital role in filtering and disposing of oil waste[9][11]. This prototype aims to serve as a practical educational tool for raising awareness among ship operators, students, and the broader community about sustainable waste management practices. By integrating innovative technology into the prototype, this initiative also supports broader community empowerment efforts by bridging environmental concerns with actionable solutions.

Methodology

This study focuses on evaluating the performance of an oily water separator (OWS) system utilizing microcontroller technology. The objectives include analyzing the effectiveness of oil-water separation and determining the time required for the separation process[10][12]. This research is a step forward in integrating modern technology into marine pollution management, contributing to environmental sustainability and raising awareness within communities involved in maritime operations[13].

Indonesia, the largest archipelagic country in the world, is blessed with abundant marine resources, encompassing 81,000 km of coastline, or 14% of the world's total coastline. Approximately two-thirds of Indonesia's territory consists of marine areas, with 3.1 million km² of sovereign waters and 2.7 million km² of Exclusive Economic Zone (EEZ) waters. Globally, oceans cover 70% of the Earth's surface, serving as a critical reservoir of natural resources, including marine biodiversity, which is vital for the prosperity and welfare of society[14][16].

However, marine pollution, particularly from oil spills, poses a significant threat to these resources. Sources of oil spills include ship operations, offshore drilling, and tanker accidents[15]. The Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) reports that approximately 6.44 million tons of hydrocarbon compounds enter the world's oceans annually. The consequences of oil spills are devastating, causing lethal and sub-lethal effects on marine organisms, disrupting ecosystems, and impairing fisheries and aquaculture activities.

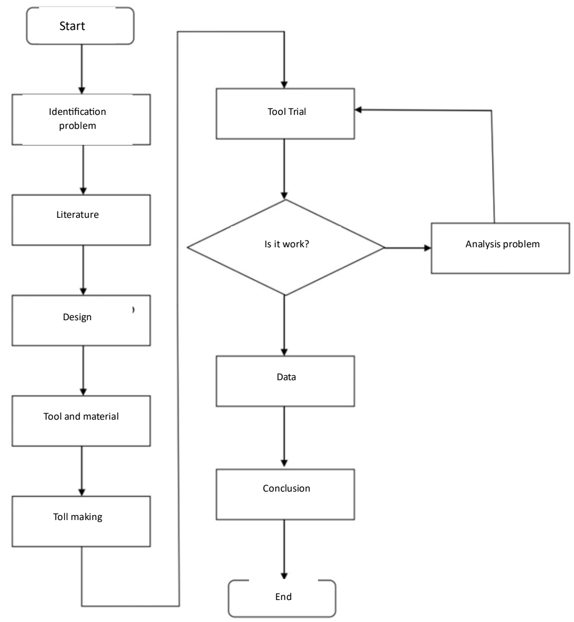
Addressing this challenge requires a coordinated approach involving government agencies such as the Ministry of Environment and Forestry, Ministry of Tourism, Ministry of Education, Ministry of Industry and Trade, Indonesian Navy, Police, Ministry of Transportation, and local governments. These stakeholders play a crucial role in preventing and mitigating marine pollution. Collaborative efforts involving physical, chemical, and biological methods are essential to manage oil spills effectively and sustainably.

The Oily Water Separator (OWS) is an auxiliary machinery designed to separate oil from wastewater, ensuring the oil concentration in discharged water is reduced to less than 15 ppm, in compliance with MARPOL 1973 Annex I[17]. This equipment is pivotal in preventing marine pollution and maintaining ecological balance.

One case study, conducted on the MT Ontari vessel from December 12, 2016, to October 26, 2017, identified several factors contributing to high oil concentrations in the OWS output. These included clogged coalescer filters, bilge wells contaminated with dirty oil, inadequate maintenance, and improper operating procedures.

To address these issues, the study employed a combined method of SHEL analysis and USG prioritization techniques. Recommendations included cleaning or replacing coalescer filters, cleaning bilge wells, and optimizing the maintenance and operation of the OWS system[18][19]. Implementing these corrective measures ensures compliance with operational guidelines and enhances the effectiveness of OWS systems, ultimately contributing to environmental conservation and raising operational standards in maritime industries.

1. Flowchart



Prototype testing is a critical stage in the development of any device, as it ensures the functionality and reliability of the system. This phase aims to assess whether the device operates as expected, providing valuable insights into its performance. In the context of the microcontroller-based clean bilge system prototype, testing is essential to evaluate the accuracy and efficiency of key components such as current sensors, TDS (Total Dissolved Solids) sensors, and voltage sensors. By conducting these tests, we can determine how well these components perform in real-world conditions and identify areas for improvement.

To accurately assess the performance of these components, two stages of data collection are required. First, data is gathered using standard measuring instruments, such as a TDS meter, to provide a baseline for comparison. Second, the data is collected using the sensors integrated into the prototype. By comparing the results from both methods, the error rate for each component can be calculated. This error value is crucial for refining the system and ensuring that the final product meets the necessary standards for environmental impact and community empowerment. Through these tests, the device's potential for enhancing community awareness of environmental protection and sustainable maritime practices is also evaluated, ensuring that it aligns with broader goals of promoting responsible waste management in coastal and maritime communities. Below is equation for error [20].

$$\%\text{Error} = \frac{sensor\ value - Measurement\ value}{Measurement\ value} \times 100$$

Results and Discussions

The results of the sensor measurements from this experiment are as follows:

The first test conducted involved measuring voltage and current using specific sensors. For the voltage, a DC voltage sensor module was employed, while for the current, the INA219 sensor was used. The INA219 is a sensor module designed to monitor both voltage and current in an electrical circuit. It utilizes I2C or SMBUS-compatible interfaces, making it capable of monitoring both the shunt voltage and the bus supply voltage. This sensor's versatility is particularly important in the context of a microcontroller-based clean bilge system, as it allows for accurate monitoring and real-time feedback regarding system performance.

The measurements obtained from these sensors provide valuable data on the operational efficiency of the clean bilge system prototype. Accurate monitoring of voltage and current is critical in ensuring the reliability of the device and its potential to reduce environmental contamination caused by oil waste. By employing these sensors, the project not only aims to create a functional system but also seeks to empower local communities by increasing awareness of environmental issues and promoting the use of sustainable, efficient technologies. The results of these sensor tests will help improve the system's design, ensuring it can be widely adopted for use in maritime and coastal areas, where oil waste management remains a significant challenge.

Table 1.Sensor variabel

Pump experiment	Variabel		
	Current(mA)	Voltage(V)	Power
1	290	11,5	3,33
2	300	11,8	3,54
3	288	11	3,19

The next stage of testing involved evaluating the Total Dissolved Solids (TDS) sensor. The primary goal of this test was to assess the accuracy of the TDS sensor's measurements. To calculate the percentage error, the data from the TDS sensor were compared with the readings from a standard measuring instrument, the TDS meter, which is commonly used for this purpose. This comparison is essential for validating the sensor's performance, ensuring that the clean bilge system prototype can reliably measure water quality, a key factor in addressing environmental pollution caused by oil waste in marine ecosystems.

For this experiment, three different liquids with varying TDS values were used: bottled mineral water, distilled water (aquades), and a test solution with a TDS value of 500 ppm. These liquids were selected to represent a range of potential water qualities that might be encountered in real-world applications, particularly in maritime and coastal settings where oil contamination is a major concern. The results from the TDS sensor will provide critical data on the effectiveness of the clean bilge system in monitoring water quality. By improving the accuracy of these measurements, the prototype can be better equipped to support environmental protection efforts, empowering communities to take an active role in safeguarding their natural resources.

Table 2.Sensor variabel

no	3 sample	Varibel	
		Sensor (ppm)	Measurement (ppm)
1	Aquades	0	0
2	Mineral Water	112	117
3	Liquid 500ppm	495	500

1. Discussion

- Table 1

The table above presents the results of an experiment involving a pump, where three different sets of data were recorded for various parameters: current (in mA), voltage (in V), and power (in watts). These measurements were taken to understand how the pump operates under different conditions. The experiment records the current, voltage, and power associated with each trial to provide insight into the pump's efficiency and electrical performance.

In the first experiment, the pump operated with a current of 290 mA and a voltage of 11.5 V, resulting in a power consumption of 3.33 watts. The second experiment showed a slight increase in the current (300 mA) and a marginal increase in voltage (11.8 V), leading to a power consumption of 3.54 watts. This shows that as both the current and voltage increased, the power consumption also slightly increased. In the third experiment, the current decreased to 288 mA and the voltage was lowered to 11 V, resulting in a power consumption of 3.19 watts.

From these results, it can be observed that the power consumed by the pump is closely related to the current and voltage. As both current and voltage fluctuate, power consumption follows a corresponding trend. These findings could be useful in optimizing the pump's operation for different electrical conditions, helping to design more energy-efficient systems. Understanding this relationship allows for better control of energy consumption in practical applications, ensuring that the pump functions optimally under various operating scenarios.

- Table 2

  The table provides data from an experiment that compares the sensor readings and the actual measurements of different liquids in terms of their parts per million (ppm) concentration. The three samples tested include Aquades, Mineral Water, and a Liquid with a known concentration of 500 ppm. For each sample, the experiment records both the sensor value and the actual measurement in ppm, allowing for an assessment of the sensor's accuracy in detecting the concentration of substances in liquid form.

  In the first sample, Aquades (distilled water) is tested, and both the sensor reading and the actual measurement indicate a value of 0 ppm. This result is expected since Aquades contains no dissolved solids or contaminants, making its concentration of substances effectively zero. This serves as a baseline for the experiment to gauge the performance of the sensor in detecting the absence of dissolved materials.

The second sample is Mineral Water, with a sensor reading of 112 ppm and an actual measurement of 117 ppm. The small difference between the two values (5 ppm) indicates that the sensor is relatively accurate in measuring the concentration of substances in the mineral water, with only a slight deviation from the actual value. The discrepancy could be due to sensor calibration or minor errors in measurement, but overall, it shows that the sensor is functioning reasonably well for this sample.

For the third sample, a Liquid with a known concentration of 500 ppm is tested. The sensor reading is 495 ppm, while the actual measurement is 500 ppm. Again, the sensor's reading is very close to the actual concentration, showing high accuracy with only a 5 ppm difference. This suggests that the sensor is quite effective in detecting higher concentrations of substances, making it a reliable tool for measuring ppm in various liquid samples.

Overall, the data highlights the accuracy of the sensor in different liquid samples, with small variations between the sensor readings and actual measurements, demonstrating its effectiveness in monitoring and evaluating the concentration of dissolved substances.

- Discussion all:

Following the individual component testing, the next phase involved the testing of the entire system. The testing began by pouring 1 liter of oil and 1 liter of distilled water (aquades) into the tank. Once the tank was full, the float sensor sent a signal to activate Pump 1. With Pump 1 running, the current and voltage sensors continuously monitored the power consumption, with real-time data displayed on the LCD. After Pump 1 had completed its task of emptying the tank, the separation process of oil and water began, using an LDR sensor and laser module. The system operates as follows: if the laser module reaches the LDR sensor, it indicates that the substance is water, and Pump 3 is activated. Conversely, if the laser cannot reach the LDR sensor, it suggests the substance is oil, triggering Pump 2.

The output from Pump 3 is then tested again using a TDS sensor, and the results are displayed on a second LCD. This process ensures that the water separated from the oil meets acceptable standards, supporting the overarching goal of reducing marine pollution and contributing to sustainable practices. The use of sensors for real-time monitoring and the automation of the system promotes effective waste management, directly benefiting local communities. By ensuring that oil waste is properly separated and disposed of, this system empowers communities, especially those in coastal areas, to manage their environmental impact more effectively.

Conclusion

- The testing of each individual sensor performed successfully, demonstrating accurate readings and reliable functionality.
- The overall system testing also proceeded smoothly, with all components working as expected in unison.
- Notable changes in power consumption were observed during the pumping process, indicating efficient operation and power monitoring capabilities.
- It is recommended to use a 24V pump instead of a 12V pump, as the 12V pump exhibited slower performance, increasing the overall time required for the pumping process.

This system prototype, through its integration of power monitoring and effective waste separation, holds potential to contribute significantly to community empowerment by enabling efficient and environmentally-friendly waste management practices. Its practical application could be crucial for coastal communities, helping to mitigate marine pollution and promote sustainability. By utilizing the right equipment, such as a 24V pump, the system could operate more effectively, further enhancing its impact on local environmental efforts.

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