Development of an Eco-Friendly Hydrocarbon-Absorbing Robotic Fish for Community Water Quality Improvement.

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Abstract

The discharge of domestic wastewater and grease residues constitutes a critical environmental issue that directly impacts aquatic ecosystems. Grease films obstruct water surfaces, hindering photosynthesis in aquatic flora, disrupting habitats, and inhibiting microbial biodegradation. Although conventional methods such as chemical dispersants or incineration are employed, they often result in secondary environmental impacts, including toxic accumulation and air pollution. Therefore, there is an urgent need for safer and more sustainable remediation strategies.

To address this challenge, this study developed a "Hydrocarbon-Absorbing Robot Fish" designed to treat community wastewater. The robot is constructed from Plaswood, a 100% recyclable material, with dimensions of 17 x 41.2 x 30 cm. It utilizes a buoy-based flotation system and side-mounted motor propellers for propulsion, controlled remotely via the Blynk IoT application. The system integrates ICT sensors for surface grease detection and a filtration unit containing a hydrocarbon absorption pad made from *Pennisetum pedicellatum* (Desho grass) flowers.

The results demonstrated that the robot achieved a grease absorption efficiency of 79.40% with a treatment capacity of 2 liters per minute. Post-treatment water quality analysis indicated the following parameters: temperature between 26.2–26.6°C, pH of 7.40–7.84, electrical conductivity of 173.6–188.0 mS/cm, dissolved oxygen (DO) of 7.2–7.4 mg/L, and transparency of 117.0–117.6 cm. The treated water meets standard effluent discharge criteria. This innovation offers an environmentally friendly solution that leverages technology to promote sustainable water quality management.

Keywords: Robot Fish, Hydrocarbon Absorption, Wastewater Treatment, *Pennisetum pedicellatum*, IoT Control, Sustainable Innovation.

Introduction

Field surveys conducted at Khlong Chang and the Bang Rak community in Mueang Trang District, Trang Province, revealed significant contamination of grease and oil residues originating from domestic wastewater. These residues are typically washed into drainage systems and subsequently discharged into local rivers. The accumulation of large quantities of grease degrades water quality and adversely affects aquatic ecosystems, primarily by reducing dissolved oxygen (DO) levels. This oxygen depletion hinders respiration in aquatic organisms, potentially leading to mortality, and disrupts natural biodegradation processes, resulting in the formation of organic-rich sludge and foul odors. These conditions negatively impact the quality of life in surrounding communities. Furthermore, communities reliant on

these water sources face risks related to food safety and water consumption, which are associated with carcinogenic risks (Anuch, 2018) and general environmental degradation.
Conventional methods for removing grease from wastewater prior to discharge often employ hydrophobic and oleophilic rubber nanocomposites. These materials typically utilize Carbon Black (CBNs) surface-modified with Vinyltrimethoxysilane (VTMS) to enhance separation efficiency. However, the structure of such developed rubber nanocomposites is characterized by high density and relatively low porosity, resulting in lower absorption capacities compared to highly porous materials (Fatemeh Ghasemi, 2024). Moreover, the use of carbon black can generate airborne particles, posing health risks to the respiratory and cardiovascular systems, and may increase the risk of serious conditions such as chronic obstructive pulmonary disease (COPD) (Ghasemi, 2024).

In contrast, natural materials offer a viable alternative for grease absorption. Water Hyacinth (*Eichhornia crassipes*), an aquatic weed characterized by its fibrous and porous structure, possesses high buoyancy and effective oil absorption capabilities. Although its rapid proliferation poses ecological challenges, utilizing it as a biomaterial for oil absorption effectively reduces oil content in water bodies while remaining biodegradable (Mahalingam et al., 2014). Similarly, Desho grass (*Pennisetum pedicellatum*) consists of florets with fine hairs that facilitate rapid oil absorption via capillary action within the interstitial spaces. Research indicates that this grass can effectively absorb engine oil and diesel, with a retention rate of up to 96% after 24 hours (Baharuddin et al., 2021). Developing an absorbent pad combining Water Hyacinth and *Pennisetum pedicellatum* would yield a durable, environmentally safe, and highly efficient solution for sustainable water quality restoration.

To address these issues, the research team designed and developed a "Hydrocarbon-Absorbing Robot Fish." This innovation utilizes natural absorbent pads to eliminate grease from community water sources. The robot's body is constructed from Plaswood, a material chosen for its moisture resistance, lightweight properties, and 100% recyclability. The internal system is equipped with absorbent pads made from Water Hyacinth and *Pennisetum pedicellatum*, which exhibit oleophilic and hydrophobic properties, allowing for effective grease absorption without excessive water uptake. The robot also integrates sensors for water quality monitoring, including a TDS sensor (for detecting impurities associated with grease), pH sensor, and temperature sensor. Data is displayed in real-time via the Blynk IoT application, allowing for post-operation water quality verification. The robot is powered by a Lithium-Polymer battery and propelled by a propeller controlled by a 12V 150RPM DC motor.
The development of this grease-absorbing robot not only addresses the problem of surface grease in community water sources but also mitigates drainage clogging and flood risks. By

seamlessly integrating technology with natural materials, this project offers an eco-friendly approach to water quality restoration and represents a sustainable solution applicable for future environmental management.

Research Questions

1) Is there a difference in water quality between Khlong Chang and the Nong Trut community area in Mueang District, Trang Province? If so, how do they differ?

2) Can the developed robotic fish absorb grease contamination present in community water sources? If so, how does it work?

3) Is there a difference in water quality before and after treatment using the grease-absorbing robotic fish in community water sources? If so, how do they differ?

Research Hypothese

1) The water quality at Khlong Chang and the Nong Trut community area in Mueang District, Trang Province is significantly different.

2) The developed robotic fish is capable of absorbing grease contamination in community water sources.

3) water quality before and after treatment using the grease-absorbing robotic fish in community water sources is significantly different.

Materials

1. *Pennisetum pedicellatum flowers*	2. Hot air dryer
3. ESP32 development board	4. Plaswood sheet
5. Motor and propeller	6. 12 V water pump
7. Float (8 × 29 cm)	8. Lithium-polymer battery
9. TDS sensor	10. pH sensor
11. Temperature sensor	12. Dissolved oxygen (DO) meter
13. Turbidity Tube	14. Conductivity meter

Methods

1) Study sites

This study was conducted through field investigations at two selected study sites in Mueang Trang District, Trang Province, Thailand. The first study site was located at Khlong Chang (7.553280° N, 99.555686° E). The second study site was situated in the Nong Trut community area (7.593727° N, 99.562140° E). These locations were selected to represent different community water environments and are illustrated in Figure 1.

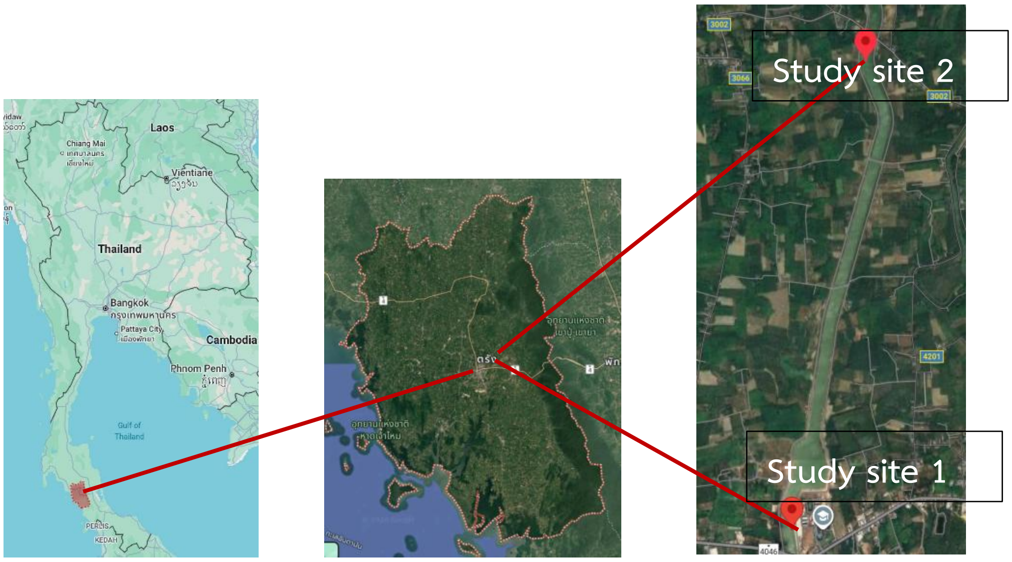


Figure 1 shows the study sites located at Khlong Chang and the Nong Trut community in Mueang Trang District, Trang Province, Thailand.

2) Water Quality Data Collection

The research team conducted field surveys to assess water quality at the study sites following the protocols of the GLOBE Program (Global Learning and Observations to Benefit the Environment). The measured parameters included water temperature, pH, Dissolved Oxygen (DO), electrical conductivity, and transparency. The specific procedures were as follows:

2.1 Water Temperature Measurement A thermometer was submerged in the water to a depth of approximately 10 cm for a duration of 3–5 minutes. Readings were taken at eye level while the thermometer remained submerged to ensure accuracy. Data was recorded, and the measurement was performed in triplicate.

2.2 pH Measurement A pH meter was utilized by submerging the probe into the water until the glass bulb was fully immersed. The displayed pH value was read and recorded. This process was repeated three times.

2.3 Dissolved Oxygen (DO) Measurement A DO meter probe was immersed in the water to detect the dissolved oxygen level. The value was read and recorded. The measurement was performed in triplicate.

2.4 Electrical Conductivity Measurement A conductivity meter probe was submerged in the water. The electrical conductivity reading was observed and recorded. This process was repeated three times.

2.5 Water Transparency Measurement Water samples were poured into a transparency tube (turbidity tube). The transparency level was determined, read, and recorded. This procedure was repeated three times.

2.6 Data Entry The collected data regarding temperature, pH, DO, electrical conductivity, and transparency were subsequently entered into the GLOBE Data Entry system.

3) Design and Development of the Hydrocarbon-Absorbing Robotic Fish

Based on the water quality survey conducted at the Ban Nong Trut community, Mueang District, Trang Province, significant grease contamination was detected in the local water sources. To address this issue, the research team conceptualized the development of a Hydrocarbon-Absorbing Robot Fish. The development process involved drafting a preliminary design, which was then reviewed by subject matter experts. Expert recommendations were integrated to refine and finalize the design. Subsequently, the finalized blueprint was utilized to construct the hydrocarbon (grease) absorbing robot fish.

4) Performance Evaluation of the Hydrocarbon-Absorbing Robotic Fish

4.1 Hydrocarbon (Grease) Absorption Efficiency of the Robot Fish Using Natural Absorbent Pads. This section evaluates the absorption performance of the robot fish utilizing absorbent pads derived from the following natural materials: Water Hyacinth (*Eichhornia crassipes*) Desho Grass Flowers (*Pennisetum pedicellatum*) Luffa Sponge (*Luffa aegyptiaca*) A Composite Mixture of Water Hyacinth and *Pennisetum pedicellatum*.

$$Hydrocarbon\ absorption\ efficiency(\%) = \frac{(Initial\ oil\ content - Final\ oil\ content)}{Initial\ oil\ content} \times 100$$

4.2 Water Quality After Hydrocarbon Absorption Treatment : Water quality parameters after treatment using the hydrocarbon-absorbing robotic fish were measured to evaluate its effectiveness in improving water quality.

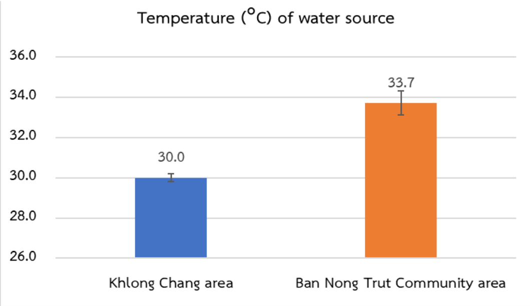
5) Data Analysis

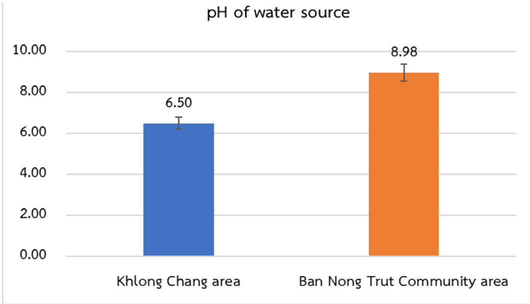
The collected data regarding water temperature, pH, Dissolved Oxygen (DO), electrical conductivity, and water transparency were analyzed using mean and standard deviation (S.D.).

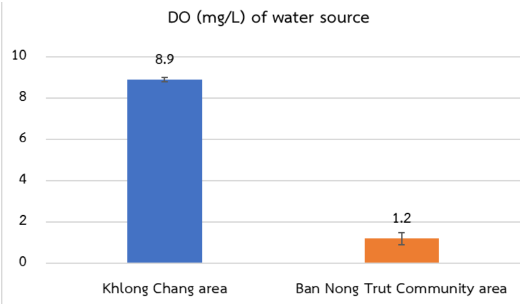
Results

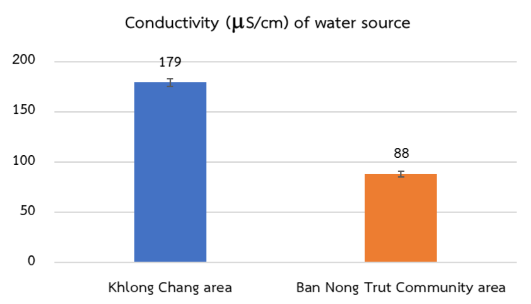
Part 1: Water Quality Assessment at Khlong Chang and Bang Rak Community, Mueang Trang District, Trang Province

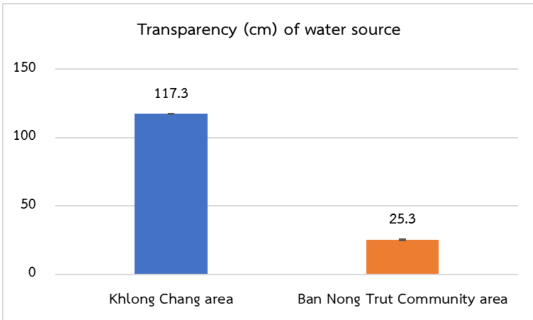
The results of the water quality assessment—comprising temperature, pH, DO, electrical conductivity, and transparency—at Khlong Chang and the Ban Nong Trut community*, Mueang Trang District, Trang Province, are presented in **Figures 2–6**.











Figures 2–6 illustrate the water quality conditions at Khlong Chang and the Nong Trut community in Mueang Trang District, Trang Province, Thailand.

Based on the water quality assessment conducted at Khlong Chang and the Nong Trut community, the parameters analyzed included water temperature, pH, dissolved oxygen (DO), electrical conductivity, and water transparency. The results indicated that the Nong Trut community area, which is a residential zone, exhibited lower DO levels, electrical conductivity, and water transparency compared to Khlong Chang. In contrast, water temperature and pH values at the Nong Trut community were higher than those observed at Khlong Chang. Additionally, visible grease contamination was observed in the Nong Trut community area, which was primarily attributed to the discharge of household wastewater into natural water bodies.

Part 2: Design and Development of the Robotic Fish

This study developed a hydrocarbon-absorbing robotic fish constructed from lightweight, recyclable Plaswood (17 × 41.2 × 30 cm). It utilizes 8 × 29 cm floats for stability and is powered by an 11.1 V battery. The system features an ESP32 control board driving 12

V DC motors for propulsion. A water pump directs contaminated water into a filtration unit containing sand, gravel, activated carbon, and absorbent pads made from *Pennisetum pedicellatum* flowers . Integrated sensors (TDS, pH, Temperature) monitor water quality throughout the process (Figures 7–9).

Internal design of a robotic fish that absorbs hydrocarbons.

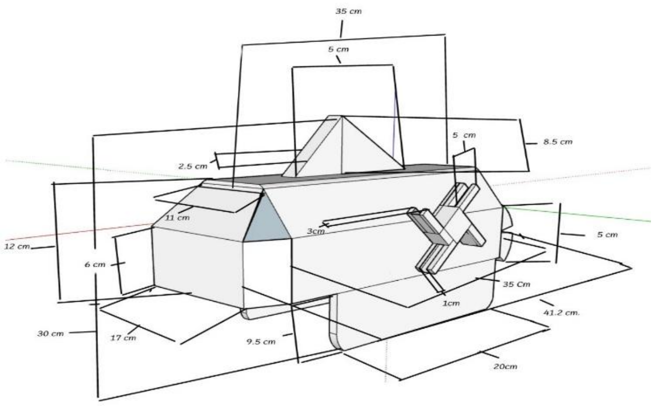


Figure 7: Overall draft.

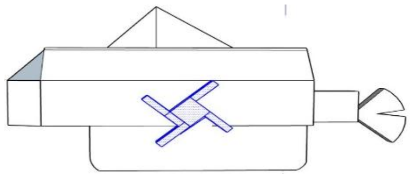


Figure 8: Side view sketch.

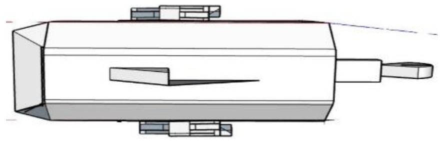


Figure 9: Top draft.

Figure 7-9: External design sketch of a hydrocarbon-absorbing robotic fish.

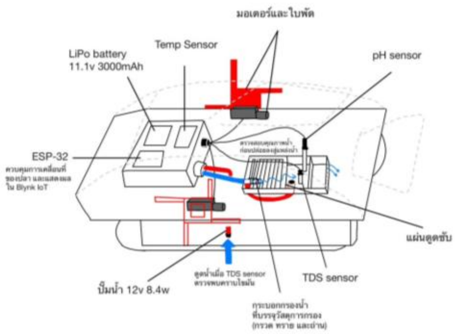


Figure 10. Internal structure of the hydrocarbon-absorbing robotic fish.

Source: Figures 7-10 created by the developer using SketchUp software.

Image of a robotic fish absorbing hydrocarbons.

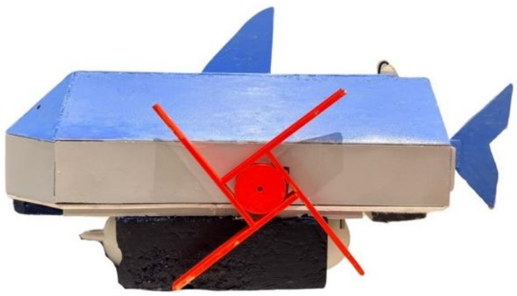


Figure 11: Side view.

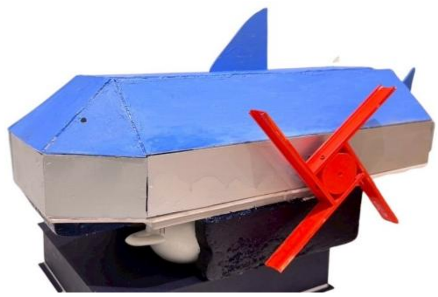


Figure 12. Oblique view.

Image 13: Front view.

Image 14: Inside the robotic

11-14. The image shows a robotic fish absorbing hydrocarbons.

Source: Photo taken by the developer.

Operation of the Hydrocarbon-Absorbing Robotic Fish

When deployed in grease-contaminated water, the TDS sensor detects hydrocarbon contamination and sends the signal to the ESP-32, which transmits the data to the Blynk IoT application. After detection, the operator activates the water treatment system, and the robot begins the treatment process as shown in the workflow diagram.

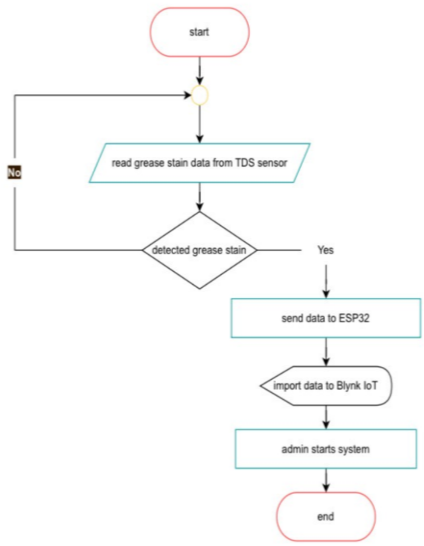


Figure 15. Diagram of the operating instructions for the robotic fish that sucks up liquid.

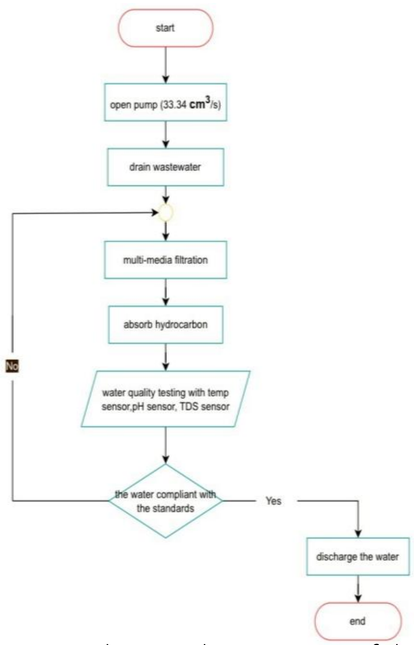


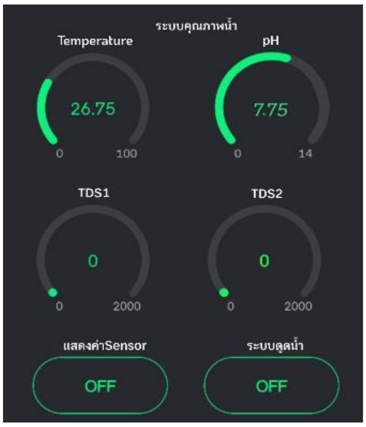
Figure 16: Diagram showing the operation of the water treatment system inside the hydrocarbon-absorbing robotic fish.

Operation of the Water Treatment System

Upon activation via the app, the robotic fish pumps water at 33.34 cm^3/s through sand, gravel, activated carbon, and a grease-absorbing pad made from *Pennisetum pedicellatum* Real-time quality metrics (Temp, pH, TDS) are displayed on the app. If standards are met, the operator triggers a water barrier to lower for discharge. Otherwise, the barrier remains raised, diverting water through a bottom pipe for recirculation.Movement

Control of the Robotic Fish

The robotic fish remains buoyant via a basal float. It navigates to the target area using a motor-driven propeller, with directional control (forward, backward, left, right) managed through the Blynk IoT application.



Figures 17-18 show the display screen on the Blynk

Part 3: Efficiency Evaluation of the Hydrocarbon-Absorbing Robot Fish in Community Water Sources

3.1 Results of Grease Absorption Capacity of Natural Absorbent Pads This section presents the absorption performance of pads derived from natural materials, specifically Water Hyacinth (*Eichhornia crassipes*), *Pennisetum pedicellatum* flowers, Luffa Sponge, and a Composite Mixture of Water Hyacinth and *Pennisetum pedicellatum*. The results are summarized in Table 1.

Table 1: Hydrocarbon Absorption Capacity of Water Hyacinth, *Pennisetum pedicellatum*, Luffa Sponge, and the Composite Mixture.

Natural material absorbent pads	Oil quantity (milligrams per liter)		Absorption capacity (%)
	Before	After	
water hyacinth	50.00	36.37	$27.01^{a}\pm0.25$
Pennisetum *pedicellatum*	50.00	10.85	$79.40^{b}\pm0.99$
Loofah sheet	50.00	21.82	$55.62^{c}\pm0.74$
A mixture of water hyacinth and Pennisetum *pedicellatum* flowers	50.00	17.27	$63.92^{d}\pm1.36$

Note: Different superscript letters within rows indicate significant differences as determined by one-way ANOVA at a significance level of 0.05.

The study reveals that Pennisetum pedicellatum pads achieved the highest oil absorption efficiency at 79.40%, significantly outperforming the Water Hyacinth-Kajonjob blend, Loofah, and Water Hyacinth, respectively. This superior performance is attributed to the florets' fine hairs, which create interstitial spaces that facilitate rapid oil uptake while minimizing water absorption. The material’s low density further ensures high buoyancy and optimal contact with surface oil. These findings align with Baharuddin et al. (2021), confirming the plant’s efficacy in absorbing various oils. This eco-friendly approach not only valorizes invasive weeds but also ensures the treated water meets the Pollution Control Department’s effluent standard for oil and grease (< 20 mg/L).3.2 Water Quality after Using the Hydrocarbon-

Absorbing Robotic Fish

Water quality parameters, including temperature, pH, dissolved oxygen (DO), electrical conductivity, and water transparency, were measured before and after treatment with the robotic fish, as presented in Table 2.

Indicators	Water quality	
	before	after
temperature (°C)	27.3±0.2	26.4±0.2
pH	8.32±0.20	7.62±0.22
DO (mg/L)	1.5±0.1	7.3±0.1
Electrical conductivity (µS/cm)	88.4±5.0	180.8±7.2
Transparency value (cm)	24.4±0.5	117.3±0.3

The results indicated that the water quality after treatment by the robotic fish showed temperatures ranging from 26.2–26.6 °C and pH values of 7.40–7.84, indicating neutral conditions. Electrical conductivity ranged from 173.6–188 μS/cm, which is characteristic of non–oil-contaminated water, as oil contamination generally reduces conductivity due to the non-polar nature of hydrocarbons. Dissolved oxygen (DO) values were 7.2–7.4 mg/L, and water transparency ranged from 117.0–117.6 cm, indicating high clarity. Overall, the treated water met the discharge standards for natural water bodies in accordance with national environmental quality regulations.

Discussion and Conclusions

This study originated from water quality assessments in the Khlong Chang and Ban Nong Trut communities, Trang Province, which revealed significant grease contamination. Consequently, a hydrocarbon-absorbing robotic fish was developed to sustainably remediate household wastewater. The design process underwent iterative refinement through expert consultation to finalize a prototype integrated with IoT control and standard discharge monitoring.

The robotic fish features a Plaswood structure (17 × 41.2 × 30 cm) supported by floats, powered by an 11.1 V battery and controlled by an ESP32 system. The treatment unit incorporates a multi-stage filtration chamber (sand, gravel, activated carbon) and absorbent pads made from *Pennisetum pedicellatum* flowers, monitored by TDS, pH, and temperature sensors.

Performance evaluations demonstrated that the *Pennisetum pedicellatum* pads achieved a grease absorption efficiency of 79.40%. Post-treatment analysis indicated significant water quality improvements, with parameters meeting environmental discharge standards: temperature 26.2–26.6°C, pH 7.40–7.84, conductivity 173.6–188 μS/cm, dissolved oxygen (DO) 7.2–7.4 mg/L, and transparency 117.0–117.6 cm. These results confirm the robot's effectiveness in reducing grease contamination and restoring water quality before release into natural environments.

Acknowledgements

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GLOBE's databases

Water data on GLOBE DATA ENTRY

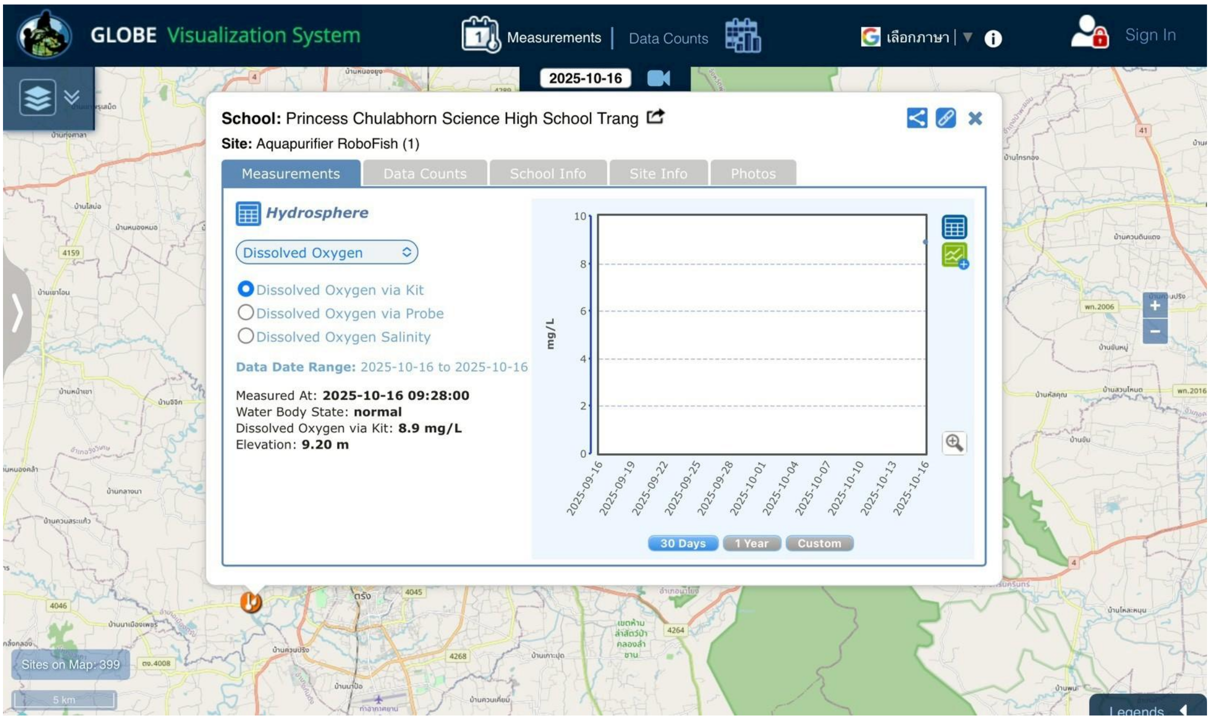

Figure 19 : Shows the water Dissolved Oxygen data at Khlong Chang on GLOBE DATA ENTRY

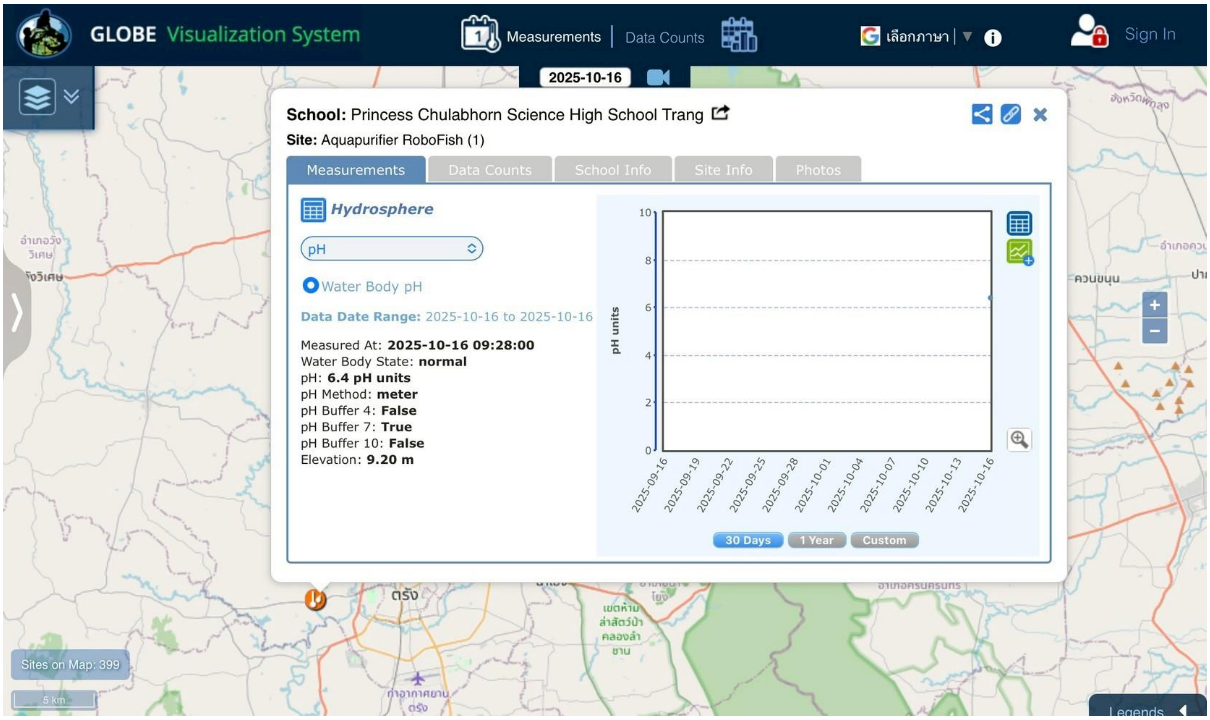

Figure 20 : Shows the water pH data at Khlong Chang on GLOBE DATA ENTRY

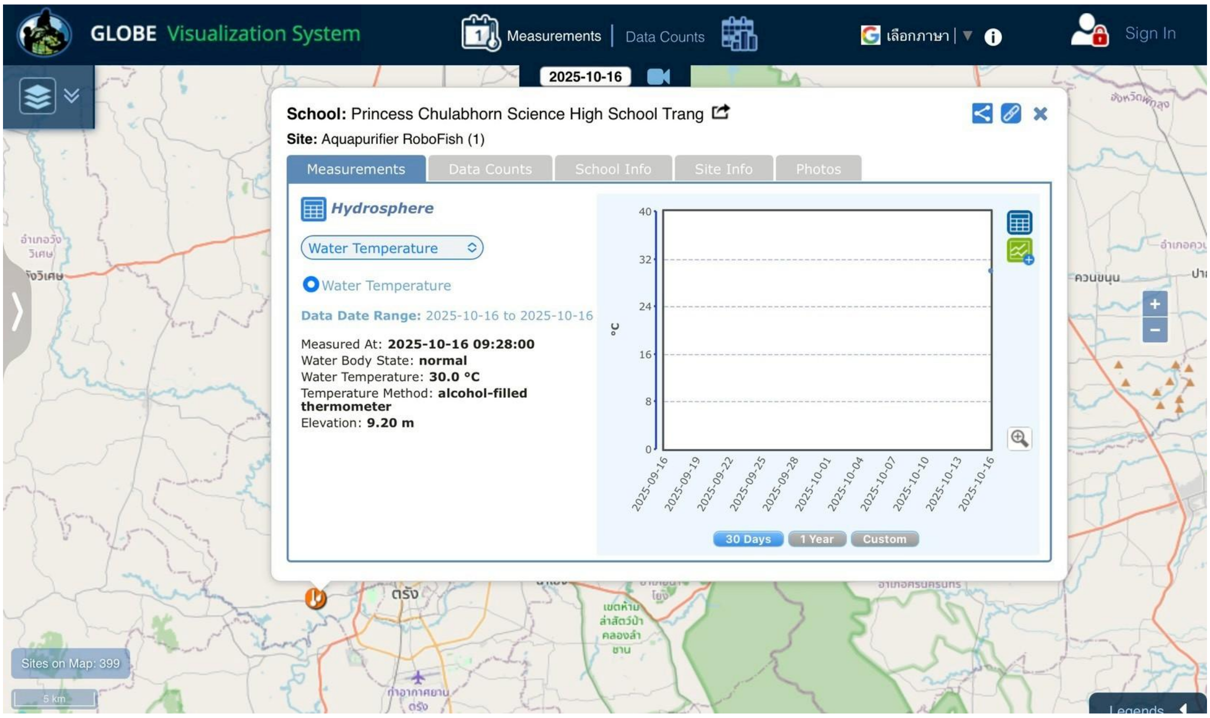

Figure 21 : Shows the water temperature data at Khlong Chang on GLOBE DATA ENTRY

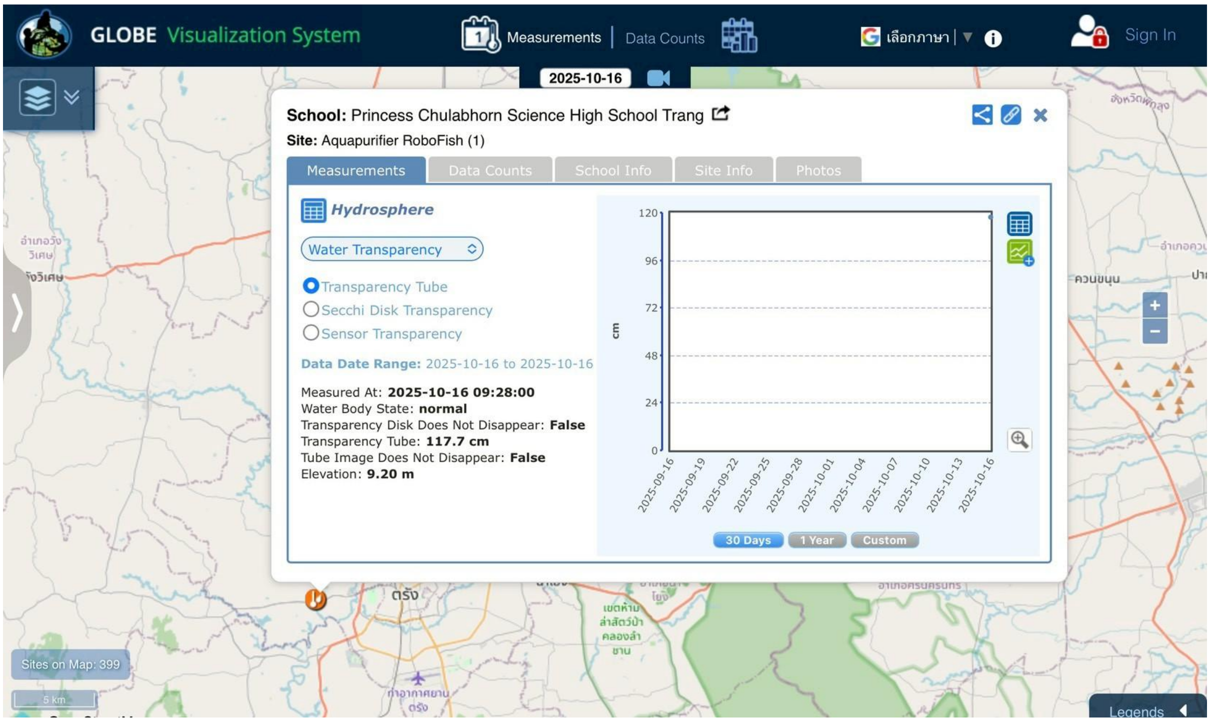

Figure 22 : Shows the water transparency data at Khlong Chang on GLOBE DATA ENTRY

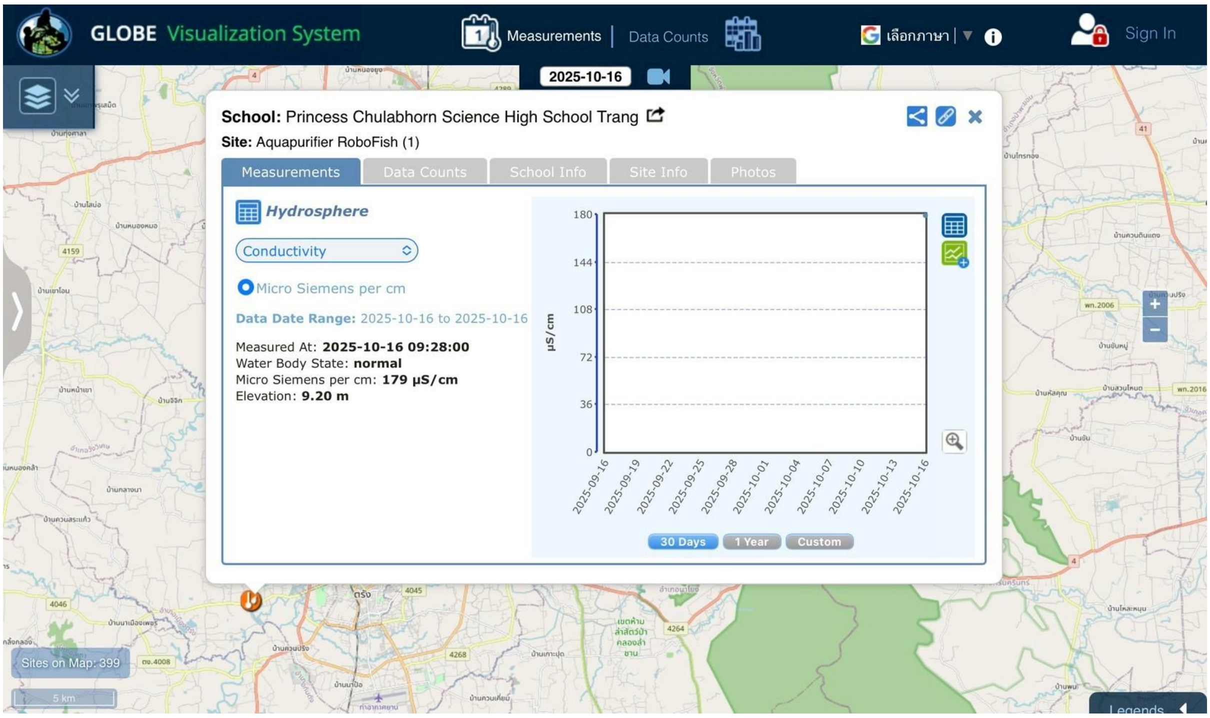

Figure 23 : Shows the water conductivity data at Khlong Chang on GLOBE DATA ENTRY

(Optional)Bage

I am an Engineer

This research applies fundamental engineering principles to the design and development of the Aquapurifier RoboFish. The process initiated with a systematic analysis of community water bodies, examining variables such as grease characteristics, water flow dynamics, and physical site constraints. Subsequently, the structural design was optimized to ensure stability, agility on the water surface, and effective access to grease-accumulation zones. The robot features a propulsion system controlled by an ESP32 microcontroller, integrated with a motor driver and water pump. This configuration facilitates a systematic cycle of movement, grease absorption, and the discharge of treated water back into the source. Furthermore, water quality sensors, including pH and temperature modules, were installed to enable real-time environmental monitoring via a mobile application.

The entire development adhered to the Engineering Design Process, encompassing problem identification, design, prototyping, testing, and continuous refinement. This approach resulted in an innovation that is practical for community deployment, cost-effective, and scalable for future advanced applications.

I make an Impact

Grease contamination in water sources poses a direct threat to both the environment and the quality of life of local residents. Water contaminated with grease generates foul odors, serves as a breeding ground for pathogens, and depletes dissolved oxygen levels. This condition endangers aquatic life, leading to ecosystem degradation and a decline in natural food sources. The Hydrocarbon-Absorbing Robot Fish provides a concrete solution to significantly reduce grease accumulation in community water sources. It helps restore water quality to standards suitable for aquatic life and enhances the overall environmental condition of the community. Furthermore, this project creates a significant social and educational impact. It stands as an exemplary model of youth-led innovation, demonstrating that local challenges can be effectively addressed through science and technology. Therefore, this research aims not only to resolve environmental issues but also to cultivate a consciousness of water resource conservation. It seeks to inspire the community and youth to recognize the value of utilizing innovation for sustainable social development.

I am a Problem Solver

The researcher went beyond merely identifying the issue of oil and grease pollution in wastewater; I developed a concrete solution through the application of natural materials—specifically Water Hyacinth, *Pennisetum pedicellatum* (Desho grass), Luffa Sponge, and composite mixtures—to absorb hydrocarbons. This was achieved through a systematic scientific approach, ranging from experimental design and data collection to analysis and the comparative evaluation of each material's efficiency. The results indicated that natural materials, particularly *Pennisetum pedicellatum*, effectively reduced oil and grease levels to meet standard effluent criteria. This solution not only resolves water pollution but also adds value to invasive weeds, reduces environmental impact, and aligns with Earth System Science principles that connect natural resources, ecosystems, and human well-being. Thus, this project demonstrates the researcher's role as a true "Problem Solver" who utilizes scientific knowledge and creativity to transform environmental challenges into opportunities for sustainable innovation, with the potential for real-world application in environmental protection and restoration.