International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Oil Sorption Potential Using Flower-Based Cogon (*Imperata Cylindrica*) Pads: In Vitro and in Situ Simulations

Noelah Jane Loregas

Davao City National High Scholar

ABSTRACT

This study explores the effectiveness of cogon grass-based absorbent pads, reinforced with nonwoven fabric and filter layers, in the remediation of oil spills under varying conditions. The experiments were conducted across four distinct setups: diesel oil mixed with seawater (with and without stirring), diesel oil only, and seawater only, to evaluate the sorption capacity of the pads. Results indicate that the pads exhibit a high sorption capacity for oil, particularly in oil-only environments, with diminished yet effective performance in oil-water mixtures. The results in all the pure diesel oil setups from the first and second testings show a range of 64.56% to 86.5% oil absorption within 5 minutes of observation. In contrast, the water retention of the sorbent was consistently below 1%, with the lowest measurement being 0.29%. The liquid absorption capacity of the pads across the testing ranged from 0.19 (in pure seawater setup) to 10.50 (in pure diesel setup). This demonstrates the pads' hydrophobic properties and their effectiveness as an oil absorbent, as they successfully retained minimal water while absorbing a significant percentage of oil. Minimal water absorption was observed in the seawater-only setup, reinforcing the hydrophobic properties of the pads. Dynamic systems, such as those with stirring, introduced complexities in sorption behavior, however, the pads maintained good oil absorption even under these conditions. The findings suggest that cogon grass-based pads are a sustainable and effective solution for oil spill remediation, offering potential for real-world applications in both static and dynamic marine environments.

Keywords: *Cogon grass, oil spill remediation, oil sorption capacity*

1. Introduction

Oil spills are a significant issue we face in today's world, caused by various factors such as human error, lack of knowledge, technical malfunctions, system failures, poor implementation, incompetence among those in charge, and even natural disasters (Ishak et al., 2019). Crude oil and a range of refined products, such as diesel, gasoline, kerosene, lubricating oil, jet fuel, and more, are involved in these spills (Hettithanthri et al., 2024). Once oil is released into a body of water, it can severely harm aquatic life, disrupt the environmental balance, and greatly impact human health.

Surrounded by many seas, the Philippines is home to numerous fishermen who rely on the waters for their livelihood. However, on February 28, 2023, the tanker M/T Princess Empress, carrying 800,000 liters of industrial fuel, capsized off Naujan, Oriental Mindoro. This incident led to a massive oil spill that impacted tens of thousands of fishermen around Mindoro Island, causing an estimated 7 billion pesos in damage (Lagniton, 2024). NOAA's Office of Response and Restoration (OR&R) is helping with an oil spill from the tanker Terranova, which sank in Manila Bay, Philippines, on July 25, 2024. The Philippine tanker was carrying 396,000 gallons of industrial fuel oil and now lies 130 feet underwater off the coast of Bataan.

The Department of Agriculture-Bureau of Fisheries and Aquatic Resources (DA-BFAR) monitored the situation and recommended maintaining fishing bans in affected areas due to the ongoing risk of oil contamination. Research indicates that oil spills can lead to significant economic losses for fishermen due to decreased fish populations and tainted catches. For instance, a study found that fishermen's incomes can decline by up to 76% following an oil spill due to reduced fish availability and contamination (Sulistyono, 2021). This situation also posed health risks for those living in coastal areas. Oil exposure can cause long-term ecological damage, affecting not only fish but also marine mammals and birds (NOAA, 2024).

In response to this, Cogon grass (*Imperata cylindrica*), a resilient and widely invasive plant in Asia that is also abundantly found in the Philippines (Global Invasive Species Database [GISD], 2023), has emerged as a promising natural solution for oil spills. Given its abundance in the country, cogon grass is readily available and easier to obtain. One of the most significant advantages of cogon grass is its exceptional ability to rapidly absorb oil from contaminated water surfaces (Ibrahim et al., 2018). This high oil absorption capacity is attributed to the plant's hydrophobic properties, which repel water but attract oil, making it particularly effective in capturing and retaining oil molecules (Kamar et al., 2024). In addition to its oil absorption capabilities, cogon grass is also known for its biodegradability. Unlike syntheticmaterials that can persist in the environment for years, cogon grass can naturally break down over time, minimizing the long-term environmental impact of oil spills (Jumaidin et al., 2020).

The composition of cogon grass includes 34.1% carbon, 6.6% hydrogen, 1% sulfur, 0.8% nitrogen, 35.1% cellulose, 27.6% hemicellulose, and 16.5% lignin. Its structure, primarily made of cellulose chains from glucose, gives it the ability to absorb fluids, particularly those with high viscosity like oil (Loh et al., 2020). The flowers of cogon grass have fine, hair-like structures that increase the surface area, enhancing capillary action, which aids in oil absorption. This combination of

hydrophobic (water-repelling) and oleophilic (oil-attracting) properties makes cogon grass a suitable natural sorbent for oil spill remediation (Parker, 2022). The focus of our study is the fluffy, cotton-like inflorescence, which usually measures 5-20 cm in length. These spikelets are densely covered with silky hairs, adding to their oil-absorbing potential. Each spikelet is around 3.5-5.0 mm long, surrounded by silky hairs, with grains that are 1-1.5 mm long (Khalid et al., 2021).

In conclusion, the increasing frequency of oil spills threatens marine ecosystems and human health, especially in vulnerable regions like the Philippines. Cogon grass flower (*Imperata cylindrica*) offers a promising, cost-effective, and eco-friendly solution for oil spill cleanup. Its excellent oil absorption and biodegradability make it ideal for tackling oil pollution. Utilizing this natural resource supports effective cleanup while promoting sustainable practices that benefit local communities and ecosystems. Further research on cogon grass in oil spill response could help mitigate the impact of these environmental disasters.

- **Methods1. Collection and Preparation of the Materials**

1. The researchers began the process by carefully identifying and selecting suitable locations for the collection of cogon flowers *(Imperata cylindrica)*. The cogon flowers were collected from various parts of Mandug in Ciudades Subdivision and Santa Cruz, Davao Del Sur and Islid, Panabo City. The cogon flowers were then sent to Ateneo de Davao University. It was identified and authenticated by Abdul Aziz l. Juhuri.

Once gathered, the flowers were transported to a controlled environment where they underwent sun-drying for 2-3 days. This drying process was essential to reduce the moisture content of the flowers, as excess moisture could interfere with fiber extraction and weaken the structural properties of the final product. The researchers monitored the drying area to ensure it was kept free from dust or debris, and the flowers were spread out evenly to allow for consistent air circulation.

Figure 1. Collection Site

To maintain the purity of the fibers, the flowers were harvested with clean tools such as scissors and placed into a clean, designated sack to avoid any foreign materials being introduced during the collection phase.

Figure 2. Collection of Cogon Grass Flower

Figure 3. Drying of Cogon Grass Flower

After sufficient drying, the researchers began the extraction of fibers. The researchers did it manually, through the process of ginning in order to separate the fibers carefully. The ginning was selected based on the condition of the flowers and the desired texture of the fibers. During this phase, the researchers focused on isolating the fine fibers, which were more suitable for absorbing oil due to their high surface area and flexible structure. The process was repeated as necessary to ensure that the maximum amount of usable fiber was extracted from the flowers, while discarding any coarse or damaged portions. This careful preparation of the cogon flower fibers was crucial to the success of the subsequent stages of pad formation and absorbency testing.

Figure 4. Ginning of Cogon Flowers

Next, the researchers purchased 2 liters of diesel oil from a local Shell gasoline station located at Brgy Duterte, Agdao, Davao City. Diesel oil was specifically chosen for this study due to its frequent involvement in marine oil spills, making it an ideal candidate for testing the oil absorption capabilities of cogon flower-based cotton pads (Mohammed et al., 2020). The diesel oil was authenticated by Engineer Devorah Gundaya of Davao City National High School.

The decision to use diesel oil was made after careful consideration of its environmental impact and the relevance of its use in real-world spill situations. The researchers stored it in a large container to ensure that it was protected.

Once the diesel oil was obtained, the researchers proceeded to collect seawater from Brgy Duterte, Agdao, Davao City to ensure that the testing would be accurate. The seawater was put into a large container. The seawater was stored properly, ensuring that during the testing, the salinity of the water remained the same.

The researchers then stored the seawater and other materials at room temperature in a controlled environment. This step ensured that the water quality remained stable and unaffected by external factors, such as changes in temperature or contamination, which could potentially alter the experimental results.

2. Formation of the Cotton Pads

2.1 - First Batch of Cotton Pad Formation

Following the extraction of the cogon flowers, the researchers proceeded to the critical stage, which was the pad formation. At this point, the cogon flowers underwent additional processing. The researchers meticulously cleaned the fibers by removing any remaining impurities, such as dust, dirt, or plant debris, that may have been introduced during the collection or drying phases.

Then proceeded with the fabrication of the pads using nonwoven fabric and a filter layer. These materials exhibit water-resistant properties and are good for absorbing oil, with minimal absorption of water. Non-woven fabrics can be designed to be absorbent, breathable, and water-resistant. They are also used for filtering air and gasses (Karthik et al., 2017).

Figure 5. Preparation of the Non-woven Fabric

The nonwoven fabric material is recognized for its high absorbency and hydrophobic properties, enabling it to absorb oil while repelling water. Research indicates that nonwoven fabrics can absorb up to 20 times their weight in oil, making them ideal for spill cleanup applications. For instance, a study demonstrated that diesel soot-coated nonwoven fabrics achieved over 95% separation efficiency in oil-water mixtures, highlighting their superior performance in practical applications (Sharma et al., 2019). Additionally, a review of textile sorbents noted that nonwoven materials are increasingly favored for their ability to separate oil from water effectively (Zaarour & Liu 2023).

The inclusion of filter layer enhances the functionality of the pads by preventing water passage while allowing oil absorption. This is critical in marine environments affected by oil spills, as it ensures effective interaction with the oil without becoming saturated with seawater. The HeiQ Oilguard fabric exemplifies this principle, as it is designed to absorb crude oil while repelling seawater, achieving up to 1200% absorption of its dry weight (HeiQ, 2024).

Figure 6. Preparation of the Filter Layer

The combination of cogon fibers with nonwoven fabric and filter layers was intended to maximize oil absorption while reducing water absorption, ensuring the pads were highly effective in scenarios involving oil spills in marine environments.

Before the researchers measure the respective weights of the cogon grass and pads to be made, the researchers cut the fabric to a length of 9 cm and a width of 11 cm for pad making, the researchers then proceeded to the sewing area, where a machine was used to sew them together for uniform and precise results. This step was crucial to maintain consistency across the pads, as variations in pad size or construction could lead to inconsistencies in the absorption tests.

Figure 7. Stitching Process for Pad Creation

The average weight of the bag is

0.98 grams, while the cogon flower weighs

2.52 grams, resulting in a total weight of

3.50 grams for each pad containing cogon flowers.

Figure 8. Weighing the Pad Layer with Cogon Flowers

Upon creating a total of 24 pads, the researchers then compressed them to simulate the compaction of cogon grass and pads. This compression was achieved by manually applying pressure using heavy objects, which effectively shaped and compacted the cogon flowers. Achieving the right balance between thickness and density is key to ensuring the pads' effectiveness in oil absorption while maintaining their durability and flexibility for practical use in oil spill cleanups.

2.2 - Second Batch of Cotton Pad Formation

For the second batch of the formation of the cotton pads, the researchers prepared 6 cotton pads which were conducted in the laboratory using large glass containers, each measuring 23 cm in length and 14.5 cm in width. The average weight of each cotton pad was recorded at 3.55 grams, while the cogon flower weighed 11.45 grams, resulting in a total weight of **15 grams** for each pad containing cogon flower.

Figure 9. Weighing the Pad Layer with Cogon Flowers

2.3 - Third Batch of Cotton Pad Formation

For the third batch of sea area simulation conducted in San Juan, Agdao, Davao City, researchers prepared twelve cotton pads, each measuring 23.5 cm in length and 29.5 cm in width. The average weight of each cotton pad was recorded at 7.30 grams, while the cogon flower weighed 17.7 grams, resulting in a total weight of **25 grams** for each pad containing cogon flower.

Figure 10: Weighing the Pad Layer with Cogon Flowers

3. Testing for the absorbency of Cogon Cotton Pads

3.1 - First Testing (Laboratory: Plastic Containers)

To test the absorbency of the cogon pads, the researchers prepared a controlled laboratory setup that simulates real-world oil spill scenarios using diesel oil and salt water. The oil was stored in containers to ensure accurate handling during the experiment. Each container was filled with a specific volume of diesel oil to maintain consistency across all tests. The experiment consisted of four setups, each designed to simulate different oil spill scenarios:

- Setup 1: Six plastic containers containing each 100 g of seawater and 50 g of Diesel Oil (without stirring).
- Setup 2: Six plastic containers containing each 50 g of Diesel Oil only.
- Setup 3: Six plastic containers each containing 100 g of seawater only.
- Setup 4: Six plastic containers each containing 100 g of seawater and 50 g of Diesel Oil (with stirring).

Each setup utilized six replicates to ensure statistical validity. mixed with seawater under static conditions. This scenario mimicked an oil spill situation where there is little to no agitation in the water body. Six plastic containers contained 100 g of seawater and 50 g of diesel oil, ensuring that no stirring occurred.

After preparing the mixtures in each container without stirring them, one cogon pad was carefully immersed into each container. The stopwatch started immediately upon immersion as researchers allowed each pad to soak for 5 minutes, providing ample time for absorption.

Once soaking was complete, researchers gently removed each cogon pad from its respective container using tongs and tweezers to prevent loss of absorbed oil during handling. The soaked pads were placed on a mesh net for a standardized draining period of 15 minutes, allowing excess liquid to drip off naturally before weighing again.

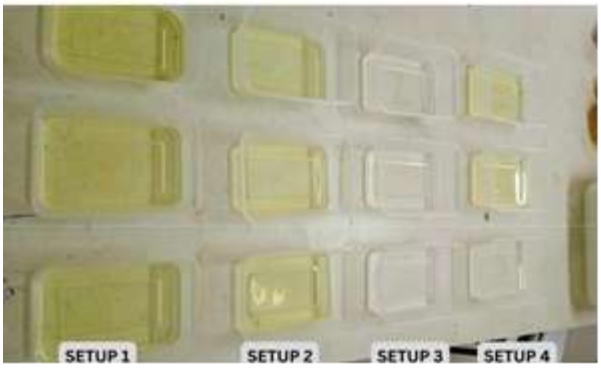

Figure 11: Preparation of Four Experimental Setups

Figure 12: Weighing the Seawater and Diesel Oil

Setup 1: Diesel Oil Mixed with seawater (Without Stirring)

The first setup evaluated how well cogon grass pads can absorb diesel oil when

Figure 13. Pad Submersion Process for Setup 1 Before, During, and After

Setup 2: Diesel Oil Only

The second setup focused on assessing how well cogon grass pads can absorb diesel oil without any interference from water or other liquids. This scenario simulated direct exposure to a situation where only diesel oil was present. Six plastic containers contained only 50 g of diesel oil each.

Researchers began by weighing each cogon pad on a digital scale to determine its dry weight. Each pad was then immersed in pure diesel oil, with a stopwatch started immediately. After soaking for 5 minutes to allow for absorption, the pads were carefully removed using tongs and tweezers, avoiding any liquid loss. They were placed on a mesh net for 15 minutes to drain excess oil before being weighed again.

Setup 3: Seawater Only

The third setup was designed to evaluate the absorbency of cogon grass pads when exposed to seawater under agitated conditions. Six plastic containers were with 100 g of seawater each. Before immersion, each cogon pad was weighed using a digital scale to determine its initial dry weight, which was essential for calculating the amount of liquid absorbed later. Once stirring was complete, one cogon pad was carefully immersed into each container, ensuring full submersion without touching other pads or the sides of the container. A stopwatch was started immediately upon immersion, allowing the pads to soak in the seawater for 5 minutes.

After the soaking period, each cogon pad was gently removed from its respective container using tongs and to avoid squeezing or wringing out excess liquid. The soaked pads were placed on a mesh net for a standardized draining period of 15 minutes, allowing any excess seawater to drip off naturally.

Figure 14. Pad Submersion Process for Setup 2 Before, During, and After

Figure 15. Pad Submersion Process for Setup 3 Before, During, and After

Setup 4: Diesel Oil Mixed with seawater (With Stirring)

The fourth setup aimed to assess the absorbency of cogon flower-based pads when exposed to a mixture of diesel oil and seawater while being stirred. This scenario simulated an oil spill situation where water currents occur, affecting how well the absorbent material interacts with both oil and water. To initiate this setup, six plastic containers were filled with 100 g of seawater and 50 g of diesel oil each.

After adding both liquids to each container, researchers used a manual stirring rod to mix the contents gently for about 1-2 minutes. This agitation dispersed the diesel oil throughout the seawater, creating an environment that could enhance oil absorption by the cogon pads.

Researchers weighed each cogon pad to establish its dry weight before immersing it in pure diesel oil, starting a stopwatch upon immersion. After 5 minutes of soaking, the pads were removed using tongs and tweezers to prevent liquid loss. They then drained on a mesh net for 15 minutes before being weighed again.

Figure 16. Pad Submersion Process for Setup 4 Before, During, and After

MEASUREMENTS OF DIFFERENT OIL SPILL SCENARIOS (PLASTIC CONTAINERS)

Number of the containers	**Setup 1: Diesel Oil Mixed with seawater (Without Stirring)**	**Setup 2: Diesel Oil only**	**Setup 3: seawater Only**	**Setup 4: Diesel Oil Mixed with seawater (With Stirring)**
1st container	100 g of seawater & 50 g of diesel oil	50 g of diesel oil	100 g of seawater	100 g of seawater & 50 g of diesel oil
2nd container	100 g of seawater & 50 g of diesel oil	50 g of diesel oil	100 g of seawater	100 g of seawater & 50 g of diesel oil
3rd container	100 g of seawater & 50 g of diesel	50 g of diesel oil	100 g of seawater	100 g of seawater & 50 g of diesel

	oil			oil
4th container	100 g of seawater & 50 g of diesel oil	50 g of diesel oil	100 g of seawater	100 g of seawater & 50 g of diesel oil
5th container	100 g of seawater & 50 g of diesel oil	50 g of diesel oil	100 g of seawater	100 g of seawater & 50 g of diesel oil
6th container	100 g of seawater & 50 g of diesel oil	50 g of diesel oil	100 g of seawater	100 g of seawater & 50 g of diesel oil

Table 1. Different oil spill scenarios measurements

This table outlines the measurements taken from four different oil spill scenarios involving diesel oil and seawater in six containers. These setups were designed to assess how the presence of stirring and the mixture of substances affects the overall behavior of the oil spill.

3.2 - Second Testing (Laboratory: Glass Containers)

This time, large glass containers were utilized to ensure that the flower-based cotton pads would not submerge, allowing them to effectively absorb oil despite their large size.

Figure 17: Preparation of Four Experimental Setups

Figure 18: Weighing the Seawater and Diesel Oil

Prior to testing, the researchers weighed each cogon pad of the second batch on a digital scale to document the initial dry weight, which is essential for calculating the precise amount of oil absorbed later in the experiment. The experiment included four same setups as testing 1 but with increased volume of liquid measurement.

Setup 1: Diesel Oil Mixed with seawater (Without Stirring)

Six glass containers were prepared, each containing 1000 g of seawater and 100 g of diesel oil, ensuring that no stirring occurred

The stopwatch started upon immersion, allowing each pad to soak for 5 minutes for absorption. After soaking, the pads were carefully removed using tongs and tweezers to minimize oil loss. They were placed on a mesh net for a 15-minute draining period before being weighed again.

Setup 2: Diesel Oil Only

This setup assessed cogon grass pads' absorption of pure diesel oil. Six containers were filled with 100 g of diesel oil each. Initial dry weights of the pads were measured before one pad was gently submerged in each container. The stopwatch was activated upon immersion, allowing a 5-minute soak.

After soaking, pads were removed carefully to prevent oil loss and placed on a mesh net for a 15-minute draining period before weighing.

Figure 19. Pad Submersion Process for Setup 1 Before, During, and After

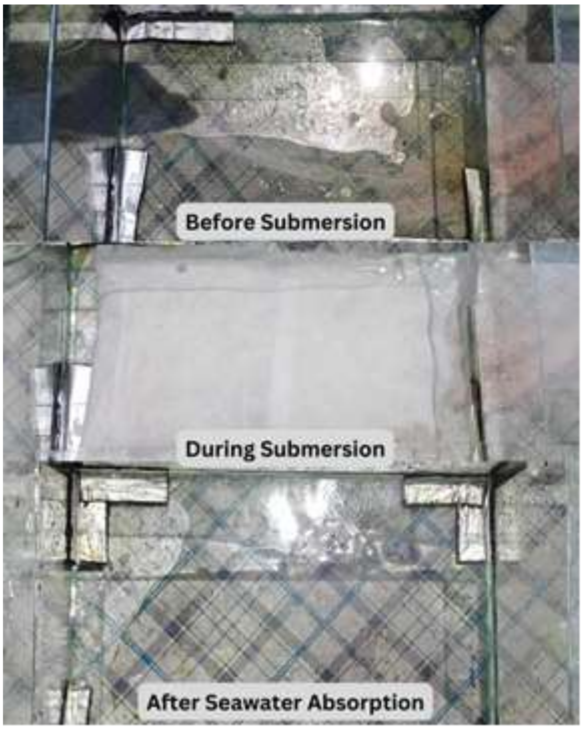

Figure 20. Pad Submersion Process for Setup 2 Before, During, and After

Setup 3: Seawater Only

This setup evaluated cogon grass pads' absorbency in agitated seawater, simulating saline ecosystems. Six containers were filled with 1000 g of seawater, which was stirred

for 1-2 minutes for uniform salinity. Initial dry weights of the pads were recorded before immersion. One pad was submerged in each container, and the stopwatch started for a 5-minute soak. Afterward, pads were gently removed using tongs and placed on a mesh net for a 15-minute draining period. stopwatch started for a 5-minute soak. After soaking, pads were carefully removed and placed on a mesh net for a standardized 15-minute draining period.

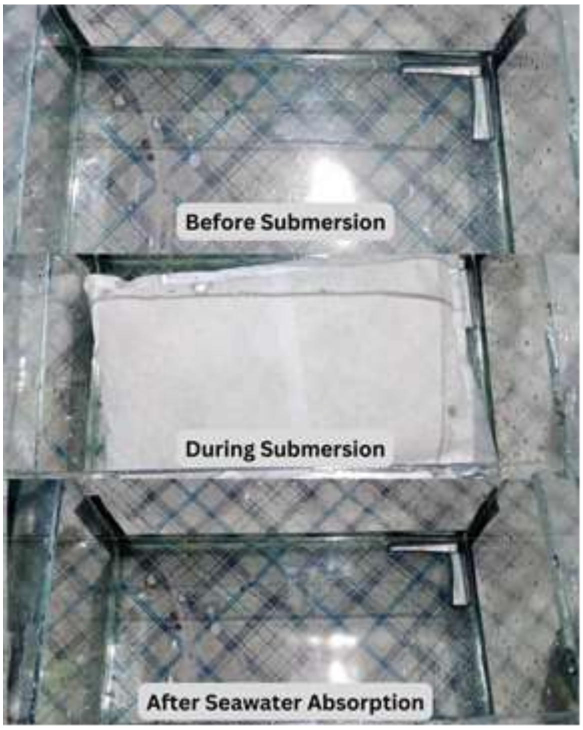

Figure 21. Pad Submersion Process for Setup 3 Before, During, and After

Setup 4: Diesel Oil Mixed with seawater (With Stirring)

This setup evaluated absorbency when cogon pads were exposed to stirred diesel oil and seawater, simulating conditions during an oil spill. Six containers received 1000 g of seawater and 100 g of diesel oil, which were mixed for 1-2 minutes.

Initial dry weights of the pads were measured before immersion. One pad was submerged in each container, and the

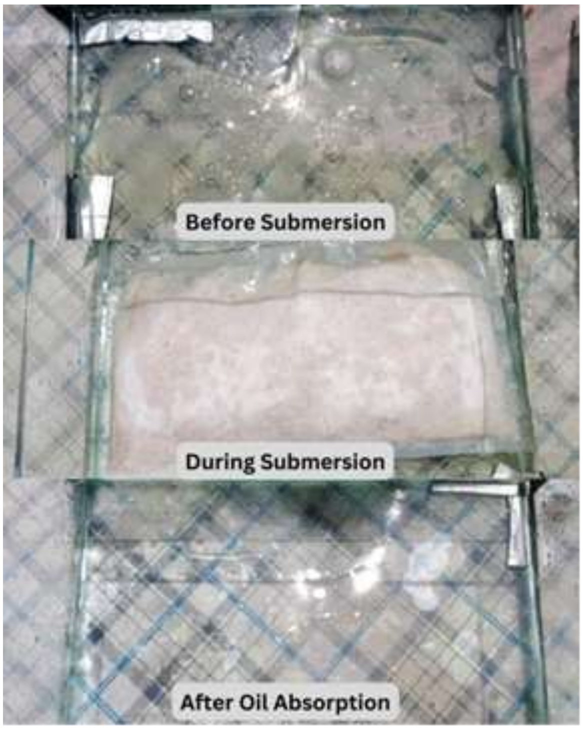

Figure 22. Pad Submersion Process for Setup 4 Before, During, and After

MEASUREMENTS OF DIFFERENT OIL SPILL SCENARIOS (LARGE GLASS CONTAINERS)

Number of the container	**Setup 1: Diesel Oil Mixed with seawater (Without Stirring)**	**Setup 2: Diesel Oil only**	**Setup 3: seawater Only**	**Setup 4: Diesel Oil Mixed with seawater (With Stirring)**
1st glass container	1000 g of seawater & 100 g of diesel oil	100 g of diesel oil	1000 g of seawater	1000 g of seawater & 100 g of diesel oil
2nd glass container	1000 g of seawater	100 g of diesel oil	1000 g of seawater	1000 g of seawater

	& 100 g of diesel oil			& 100 g of diesel oil
3rd glass container	1000 g of seawater & 100 g of diesel oil	100 g of diesel oil	1000 g of seawater	1000 g of seawater & 100 g of diesel oil
4th glass container	1000 g of seawater & 100 g of diesel oil	100 g of diesel oil	1000 g of seawater	1000 g of seawater & 100 g of diesel oil
5th glass container	1000 g of seawater & 100 g of diesel oil	100 g of diesel oil	1000 g of seawater	1000 g of seawater & 100 g of diesel oil
6th glass Container	1000 g of seawater & 100 g of diesel oil	100 g of diesel oil	1000 g of seawater	1000 g of seawater & 100 g of diesel oil

Table 2. Different oil spill scenarios measurements

This table presents the measurements obtained from four different oil spill scenarios involving diesel oil and seawater across six containers. In Setup 1, diesel oil was combined with seawater without stirring, resulting in each container containing 1000 g of seawater and 100 g of diesel oil. Setup 2 consisted solely of 100 g of diesel oil. In Setup 3, the containers held only 1000 g of seawater and were stirred. Lastly, Setup 4 involved stirring a mixture of 1000 g of seawater and 100 g of diesel oil, maintaining the same mass distribution as in Setup 1. These setups were created to evaluate how stirring and the mixture of substances influence the overall behavior of the oil spill.

3.3 - Third Testing

The researchers conducted preliminary tests in the laboratory to evaluate the efficiency and characteristics of cogon flower-based pads. After conducting multiple setups and tests in the laboratory, the researchers were able to simulate the experiment in a real-world setting at the sea area in San Juan, Agdao, Davao City. Before conducting our simulation in this location, the researchers obtained the necessary permission from the Department of Environment and Natural Resources, Environmental Management Bureau (EMB). Following their guidance, the researchers proceeded to seek approval from the local barangay of San Juan, Agdao. We were subsequently granted permission to carry out our activity in the area, with strict adherence to all required safety protocols and regulations.

12 pads were prepared—6 pads for testing the absorption of pure seawater (with stirring) and another 6 pads for testing the absorption of oil floating on the seawater's surface (also with stirring). For the oil absorption test, 350 grams of oil were used.

The third experiment was conducted to test the absorbency of cogon grass pads under real sea conditions, simulating a typical spill-prone area.

Setup 1: Cogon Pad absorption in Pure Seawater

The seawater was stirred to create a dynamic environment that would encourage interaction between the cogon pads and the water. A manual stirring stick was used to gently mix the seawater for approximately 1 to 2 minutes. The cogon pad was carefully immersed into the seawater, and a stopwatch was used to time the process. The pads were allowed to soak in the stirred seawater for 5 minutes to observe their absorption capacity.

After the soaking period, each cogon pad was carefully lifted from the actual sea area. The soaked pads were then placed on a mesh net for a standardized draining period of 15 minutes, allowing any remaining seawater to drip off naturally.

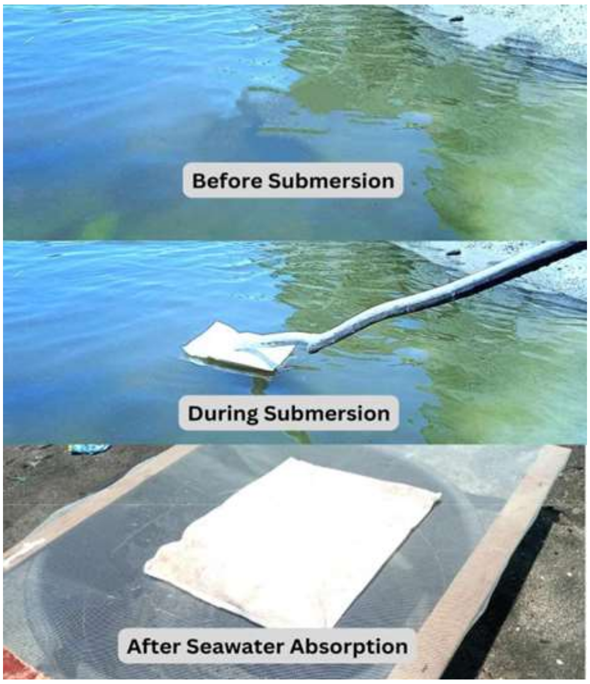

Figure 23. Pad Submersion Process for Trial 1 Before During and After

Setup 2: Cogon Pad absorption in Seawater with Diesel Oil.

The second setup aimed to evaluate the absorbency of cogon flower-based pads when exposed to a mixture of diesel oil and seawater in a real marine environment. This scenario simulated an oil spill, where water currents or mechanical mixing could occur, to observe how the pads interact with both oil and water, and to assess their effectiveness.

A total of 350 grams of diesel oil was carefully poured into the selected portion of the sea area. The mixture of oil and seawater was then gently stirred for 1 to 2 minutes to simulate the dynamic conditions of an oil spill. After completing the stirring process, the cogon flower-based pad was carefully immersed in the water, and the stopwatch was immediately started, allowing the pads to soak for 5 minutes, consistent with the procedure from previous trials.

After the soaking period, each cogon pad was carefully removed from the water using the stirring stick to minimize the loss of absorbed oil. The soaked pads were then placed on a mesh net for a standard draining period of 15 minutes, ensuring an accurate measurement of oil absorption.

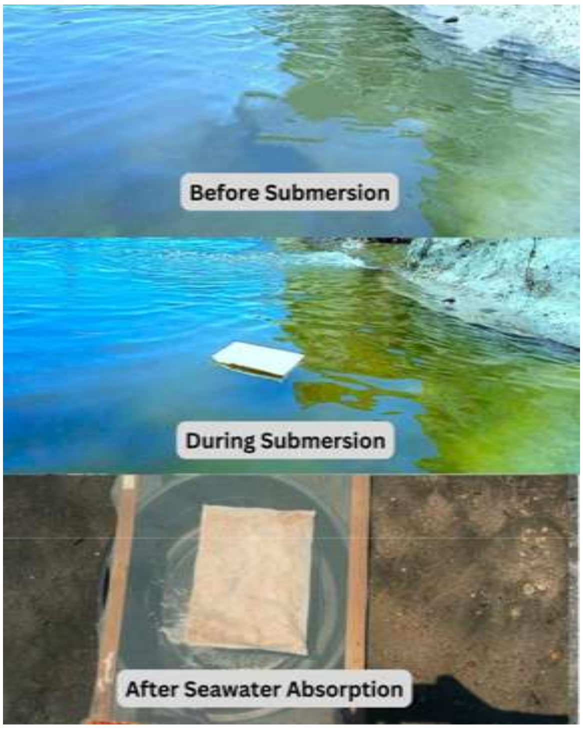

Figure 24. Pad Submersion Process for Trial 2 Before During and After

III. Risk and Safety

In the process of conducting this study, the researchers prioritize our safety at all stages. The collection of cogon flowers was done using scissors for efficiency, while gloves were worn to prevent contact with the irritating fibers of the grass. When ginning the cogon flowers, masks were again used to protect against dust and dirt that may have attached to the flowers. Afterward, the researchers ensured proper hygiene by washing our hands thoroughly, as cogon flowers can emit a distinct odor and cause skin irritation.

Prior to laboratory testing, diesel oil was purchased and securely sealed to prevent the risk of spills. During the laboratory testing, gloves and masks were worn, and precautions were taken to ensure the environment was free from fire hazards, given the presence of diesel, which presents a potential risk. Additionally, all laboratory equipment and tools were properly cleaned after use, as well as our hands.

Figure 25. Cleaning Protocol for Tools and Hands

Proper waste management protocols were observed, particularly with the disposal of oil and seawater, ensuring the laboratory was left clean and free from diesel odors.

Figure 26. Waste Disposal

- **Results and Discussion Data Analysis**

In this study, several formulas were employed to quantify the sorbent's performance in absorbing oil and water. Each formula serves a specific purpose in evaluating the sorption capacity and efficiency of the sorbent material.

1) **Total Net Amount of Sorption**

Net Sorption = Wet Sorbent Mass − Dry Sorbent Mass

This basic formula calculates the total net amount of liquid (oil or water) absorbed by the sorbent during the test. The dry sorbent mass is the initial weight of the sorbent before exposure to the liquid, while the wet sorbent mass is its weight after absorption. The difference between the two gives the total amount of liquid taken up by the sorbent. This formula is crucial in understanding how much liquid the sorbent has retained, forming the basis for further calculations of sorption capacity.

2. Liquid Sorption Capacity

Liquid Sorption Capacity = (Sst - So)/So

Where So is the initial dry sorbent mass, Sst is the mass of sorbent with liquid at the end of the sorption test, and the quantity (Sst

i. So) the net liquid sorbed. This formula measures the sorbent's ability to absorb oil/water, relative to its dry mass. The use of this ratio allows for comparison between different sorbents or experimental conditions, regardless of the initial mass of the sorbent. This formula is widely used in sorption studies to evaluate the performance of materials in oil spills (Das et al., 2013).

3. Percentage absorbed

%absorbed = (Total Net Amount of Sorption/Total Liquid in Container) x 100

This formula expresses the percentage of total liquid absorbed by the sorbent relative to the total liquid available in the container. It provides a sense of the efficiency of the sorbent by showing how much of the available liquid was taken up. This percentage is especially useful in large-scale applications like oil spill cleanups, where knowing the proportion of absorbed liquid can help estimate the overall efficacy of the sorbent in removing contaminants from water.

Results

1. Lab Test: Plastic Containers

1.1 Setup 1: Diesel Oil Mixed with seawater (Without Stirring) demonstrated the behavior of the sorbent in a mixed environment where the diesel oil and seawater were left to naturally separate without agitation.

Setup 1: Diesel Oil Mixed with seawater (Without Stirring)

Pad	**Wet Sorbent**	**Total net amount of**	**Liquid Sorption Capacity**	**% absorbed**	**%absorbed (OIL)**

		sorption			
1	35.52 g	32.02 g	9.15	21.35	64.04
2	35.38 g	32.08 g	9.17	21.39	64.16
3	36.83 g	33.33 g	9.52	22.22	66.66
4	35.56 g	32.06 g	9.16	21.37	64.12
5	35.72 g	32.22 g	9.21	21.48	64.44
6	35.46 g	31.96 g	9.13	21.31	63.92
Mean	**35.75 g**	**32.28 g**	**9.22**	**21.52**	**64.56**

Table 3. Average Oil Sorption for Diesel Oil Mixed with seawater (Without Stirring)

In the experiment where diesel oil was mixed with seawater without stirring, the sorbent's ability to absorb oil was analyzed. The results, presented in Table 9, indicate that the wet sorbent had an average mass of 35.75 g, with a total net sorption of 32.28 g. The liquid sorption capacity was 9.22, and the percentage of liquid absorbed averaged 21.52 %. Given that each container initially contained 50 g of diesel oil, the percentage of oil absorbed by the sorbent can be calculated. On average, the sorbent absorbed 64.56 % approximately of the available oil. This shows that the sorbent was effective in selectively absorbing the oil, even in a mixed environment where oil and seawater were left to separate naturally.

However, without stirring, the natural separation of oil and water likely reduced the sorbent's efficiency, preventing it from fully exploiting the available oil. This suggests that while the sorbent performs well in selective absorption, mechanical agitation could help increase the amount of oil absorbed by minimizing the separation of the oil and water layers, improving overall sorption capacity.

1.2 Setup 2: Diesel Oil Only tested the sorbent's performance in an environment where only diesel oil was present, and the results confirmed its strong oleophilic properties.

	Setup 2: Diesel Oil only			
Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**	**% absorbed**
1	44.63 g	41.13 g	11.75	89.26
2	33.76 g	30.26 g	8.65	67.52
3	38.96 g	35.46 g	10.13	77.92
4	42.53 g	39.03 g	11.15	85.06
5	40.34 g	36.84 g	10.53	80.68
6	41.22 g	37.72 g	10.78	82.44
Mean	**40.24 g**	**36.74 g**	**10.50**	**80.48**

Table 4. Average Oil Sorption for Diesel Oil Only

The results, shown in Table 10, indicate that the wet sorbent had a mean mass of 40.24 g, with a total net sorption averaging 36.74 g. The liquid sorption capacity reached a mean value of 10.50, and the percentage of oil absorbed averaged 80.48 %. This significant absorption demonstrates that the sorbent operates optimally when solely exposed to oil, without interference from water, which could hinder its absorption capacity. The high net sorption values highlight the effectiveness of the sorbent in environments where oil spills occur without the presence of water, making it particularly suitable for applications requiring rapid oil absorption, such as in controlled environments or on land during cleanup operations.

1.3 Setup 3: Seawater Only was designed to assess the sorbent's hydrophobicity, and the results showed a minimal absorption of water.

Setup 3: Seawater Only

Pad	Wet Sorbent	Total net amount of sorption	Liquid Sorption Capacity	% absorbed
1	4 g	0.5 g	0.14	0.5
2	3.93 g	0.43 g	0.12	0.43
3	4.7 g	1.2 g	0.34	1.2
4	3.6 g	0.1 g	0.029	0.1
5	4.1 g	0.6 g	0.17	0.6
6	3.67 g	0.17 g	0.49	0.17
Mean	**3.97 g**	**0.4 g**	**0.21**	**0.4**

Table 5. Average Oil Sorption for Seawater Only

The results, presented in Table 11, indicate that the mean wet sorbent mass was 3.97 g, with a total net sorption of only 0.4 g, reflecting the sorbent's strong resistance to water uptake. The liquid sorption capacity was very low, averaging 0.21, and the percentage of water absorbed averaged just 0.4%. These findings confirm the sorbent's hydrophobic properties, demonstrating its inefficacy in absorbing seawater. The low net absorption values highlight the sorbent's ability to remain dry when exposed to water, which is critical in scenarios where the goal is to remove oil from water without also absorbing significant quantities of water. This characteristic enhances the sorbent's selectivity for oil in the presence of water.

1.4 Setup 4: Diesel Oil Mixed with seawater (With Stirring) involved the same mixture of diesel oil and seawater as Setup 1, but with mechanical agitation.

Setup 4: Diesel Oil Mixed with seawater (With Stirring)

Pad	Wet Sorbent	Total net amount of sorption	Liquid Sorption Capacity	% absorbed	%absorbed (OIL)
1	34.63 g	31.13 g	8.89	20.75	62.26
2	39.15 g	35.65 g	10.19	23.77	71.30
3	41.85 g	38.35 g	10.96	25.57	76.70
4	38.49 g	34.99 g	10.0	23.33	69.98
5	36.54 g	33.04 g	9.44	22.03	66.08
6	35. 88 g	32. 38 g	9.25	21.59	64.76
Mean	**37.76g**	**34.26 g**	**9.79**	**22.84**	**68.52**

Table 6. Average Oil Sorption for Diesel Oil Mixed with seawater (With Stirring)

In Setup 4, the experiment involved a mixture of diesel oil and seawater, similar to Setup 1, but this time with mechanical agitation. The results, shown in Table 12, indicate that the mean wet sorbent mass was 37.76 g, with a total net sorption of 34.26 g. The liquid sorption capacity averaged 9.79, and the percentage of liquid absorbed was 22.84 %. In this setup, each container contained 50 g of diesel oil mixed with 100 g of seawater. The sorbent absorbed 34.26 g of the available oil, resulting in an absorption efficiency of 68.52 %. The presence of seawater and mechanical stirring allowed for increased interaction between the sorbent and the oil, improving oil absorption efficiency compared to the static conditions of Setup 1. These results suggest that while mechanical stirring helps in achieving better oil uptake in mixed environments, the sorbent's overall performance remains superior in oil-only situations, further emphasizing its oleophilic nature.

2. Lab Test: Glass Containers

2.1 Setup 1: Diesel Oil Mixed with Seawater (Without Stirring) showed how the sorbent performed in a mixed environment where diesel oil and seawater were allowed to separate naturally without any stirring.

Setup 1: Diesel Oil Mixed with seawater (Without Stirring)

Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**	**% absorbed**	**%absorbed (OIL)**
1	92.18 g	77.18 g	5.15	7.02	77.18
2	96.30 g	81.30 g	5.42	7. 39	81.30
3	91.00 g	76.00 g	5.07	6.91	76.00
4	96. 23 g	81.23 g	5.42	7.38	81.23
5	98.44 g	83.44 g	5.56	7.59	83.44
6	93.21 g	78.21 g	5.21	7.11	78.21
Mean	**94.56 g**	**79.56 g**	**5.31**	**7.23**	**79.56**

portion of the available oil (approximately 79.56% out of 100 g). However, the absence of stirring likely limited the sorbent's efficiency by allowing natural separation between the oil and water layers, which could hinder optimal absorption rates. This suggests that while the sorbent demonstrates strong selective absorption capabilities, introducing mechanical agitation could enhance its performance by promoting better interaction with the oil.

2.2 Setup 2: Diesel Oil Only evaluated the sorbent's effectiveness in a setting containing only diesel oil, and the findings validated its excellent oleophilic characteristics.

Setup 2: Diesel Oil only

Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**	**% absorbed (OIL)**
1	99.98 g	84.98 g	5.67	84.98
2	112.40 g	97.40 g	6.49	97.40
3	100.76 g	85.76 g	5.72	85.76
4	95.88 g	80.88 g	5.39	80.88
5	100.38 g	85.38 g	5.69	85.38
6	99.60 g	84.6 g	5.64	84.6
Mean	**101.5 g**	**86.5 g**	**5.77**	**86.5**

Table 7. Average Oil Sorption for Diesel Oil Mixed with seawater (Without Stirring)

In this experiment, the sorbent's ability to absorb oil was assessed in a scenario where diesel oil was mixed with seawater without agitation, as illustrated in Table 13. The average wet sorbent mass was 94.56 g, yielding a total net sorption of 79.56 g and a liquid sorption capacity of 5.31. Notably, the average percentage of oil absorbed was approximately 79.56%, indicating that the sorbent effectively captured a significant

Table 8. Average Oil Sorption for Diesel Oil Only

Setup 2: Diesel Oil only

Pad	***Wet Sorbent***	***Total net amount of sorption***	***Liquid Sorption Capacity***	***% absorbed (OIL)***

1	*99.98 g*	*84.98 g*	*5.67*	*84.98*
2	*112.40 g*	*97.40 g*	*6.49*	*97.40*
3	*100.76 g*	*85.76 g*	*5.72*	*85.76*
4	*95.88 g*	*80.88 g*	*5.39*	*80.88*
5	*100.38 g*	*85.38 g*	*5.69*	*85.38*
6	*99.60 g*	*84.6 g*	*5.64*	*84.6*
Mean	***101.5 g***	***86.5 g***	***5.77***	***86.5***

As shown in Table 14, the results from this setup indicate that the average wet sorbent mass was 101.5 g, with a total net sorption averaging 86.5 g and a liquid sorption capacity of 5.77 across all trials, resulting in an impressive average oil absorption rate of 86.5%. Given that each container contained 50 g of diesel oil, this translates to an approximate absorption of 73% of the available oil (i.e., 36g out of the initial amount). These findings suggest that the sorbent performs optimally when it interacts solely with oil, free from any interference by water, which can otherwise limit absorption efficiency, making it suitable for applications requiring rapid oil absorption, such as in controlled environments or on land during cleanup operations.

2.3 Setup 3: Seawater Only was intended to evaluate the sorbent's hydrophobic properties, and the results indicated very low water absorption.

Setup 3: Seawater Only

Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**	**% absorbed (WATER)**
1	16.84 g	1.84 g	0.12	0.18
2	18.77 g	3.77 g	0.25	0.38
3	18.34 g	3.34 g	0.22	0.33
4	18. 66 g	3.66 g	0.24	0.37
5	17.67 g	2.67 g	0.18	0.28
6	16.98 g	1.98 g	0.13	0.20
Mean	**17. 88 g**	**2.88 g**	**0.19**	**0.29**

Table 9. Average Oil Sorption for Seawater Only

The results presented in Table 15 indicate that the mean wet sorbent mass was 17.88g, with a total net sorption of only 2.88g, reflecting the sorbent's strong resistance to water uptake and confirming its hydrophobic properties. The liquid sorption capacity averaged only 0.19, while the percentage of water absorbed averaged just 0.29 % across all trials. These findings illustrate that the sorbent exhibits minimal efficacy in absorbing seawater, demonstrating its hydrophobic nature effectively by remaining dry when exposed to water—an essential characteristic for scenarios aimed at removing oil from water without significant water uptake.

2.4 Setup 4: Diesel Oil Mixed with seawater (With Stirring) involved the same mixture of diesel oil and seawater as in Setup 1, but this time it included mechanical agitation.

Setup 4: Diesel Oil Mixed with seawater (With Stirring)

Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**	**% absorbed**	**%absorbed (OIL)**
1	81.98 g	66.98 g	4.47	6.09	66.98

2	90.76 g	75.76 g	5.05	6.89	75.76
3	88. 76 g	73.76 g	4.92	6.71	73.76
4	91. 56 g	76.56 g	5.10	6.96	76.56
5	89. 55 g	74.55 g	4.97	6.78	74.55
6	89.98 g	74.98 g	5.00	6.82	74.98
Mean	**88.77 g**	**73.77 g**	**4.92**	**6.71**	**73.77**

Table 10. Average Oil Sorption for Diesel Oil Mixed with seawater (With Stirring)

The results, summarized in Table 16, showed an average wet sorbent mass of 88.77 g and a total net sorption of approximately 73.77 g, yielding a liquid sorption capacity of 4.92 and an overall oil absorption percentage of 73.77%. The mechanical stirring slightly decreased oil absorption efficiency compared to the static conditions of Setup 1. The presence of seawater still slightly constrained overall performance relative to pure oil environments, emphasizing that optimal performance is achieved when the sorbent interacts solely with oil.

1) Real Marine Condition Test in Sorbent Performance

3.1 Setup 1: Pure Seawater was aimed at assessing the hydrophobic properties of the sorbent.

Setup 1: Seawater Only

Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**
1	27.23 g	2.23 g	0.089
2	26.43 g	1.43 g	0.057
3	26.98 g	1.98 g	0.079
4	27. 33 g	2.33 g	0.093
5	27.48 g	2.48 g	0.099
6	26. 21g	1.21 g	0.048
Mean	**26.94 g**	**1.94 g**	**0.778**

Table 11: Water Absorption Performance of the Sorbent in Pure Seawater

The findings from Setup 1 indicate that the sorbent achieved a total net amount of sorption of 1.94 g, with a mean liquid sorption capacity of 0.778 across all trials. This relatively low water retention suggests that the sorbent possesses a favorable balance of oleophilic (oil-attracting) and hydrophobic (water-repelling) properties, which is essential for enhancing oil absorption efficiency in subsequent setups involving oil.

3.2 Setup 2: Seawater with 350 g of Diesel Oil involved the mixture of diesel oil and seawater, utilizing the natural motion of waves in the water to demonstrate the oil absorption capacity and efficiency of the product in a realistic marine environment. The setup involved mixing 350 g of diesel oil with seawater, allowing the natural motion of waves to facilitate interaction between the oil and the sorbent.

Setup 2: 350 g Diesel Oil Mixed with Seawater

Pad	**Wet Sorbent**	**Total net amount of sorption**	**Liquid Sorption Capacity**	**%Absorbed (OIL)**
1	266.86 g	241.86 g	9.67	69.10
2	298.70 g	273.70 g	10.95	78.20
3	271.98 g	246.98 g	9.88	70.57
4	278.88 g	253.88 g	10.16	72. 54
5	284.32 g	259.32 g	10.37	74.09

6	272.98 g	247.98 g	9.92	70.85
Mean	**278.95 g**	**253.95 g**	**10.16**	**72.56**

Table 12: Oil Absorption Performance of the Sorbent in Seawater with 350 g of Diesel Oil

The results from Setup 2 demonstrate that the sorbent exhibited significant oil absorption efficiency, absorbing an average of 72.56% of the diesel oil present in the mixture, with a total net amount of sorption reaching 253.95 g out of an initial 350 g of diesel oil. This performance indicates that the sorbent is highly effective in mitigating oil spills in real-world scenarios, particularly in dynamic environments where seawater and wave action facilitate better interaction between the oil and the sorbent material. The liquid sorption capacity averaged at 10.16, highlighting the sorbent's ability to retain a substantial volume of liquid relative to its weight—an essential factor for practical applications during oil spill cleanups. Utilizing the natural motion of waves likely enhanced the interaction between the oil and the sorbent, promoting better absorption compared to static conditions.

The contrast between the data from the first setup and second setup demonstrates the sorbent's ability to absorb large quantities of oil while minimizing the retention of seawater. This testing also demonstrated excellent buoyancy of the flower, as it stayed afloat on the water's surface even after stirring. The sorbent's ability to absorb oil while repelling water is critical in marine environments, where the presence of water can otherwise dilute or hinder the effectiveness of conventional oil cleanup methods.

4. Microscopic Structure of Cogon Grass

Flower

The composition of cogon grass includes 34.1% carbon, 6.6% hydrogen, 1% sulfur, 0.8% nitrogen, 35.1% cellulose, 27.6% hemicellulose, and 16.5% lignin. Its structure, primarily made of cellulose chains from glucose, gives it the ability to absorb fluids, particularly those with high viscosity like oil (Loh et al., 2020).

The flowers of cogon grass have fine, hair-like structures that increase the surface area, enhancing capillary action, which aids in oil absorption. This combination of hydrophobic (water-repelling) and oleophilic (oil-attracting) properties makes cogon grass a suitable natural sorbent for oil spill remediation (Parker, 2022).

The focus of our study is the fluffy, cotton-like inflorescence, which usually measures 5-20 cm in length. These spikelets are densely covered with silky hairs, adding to their oil-absorbing potential. Each spikelet is around 3.5-5.0 mm long, surrounded by silky hairs, with grains that are 1-1.5 mm long (Khalid et al., 2021).

Below is an image of the cogon flower as viewed under a 15X microscope, displaying its intricate structure both with and without the presence of diesel oil.

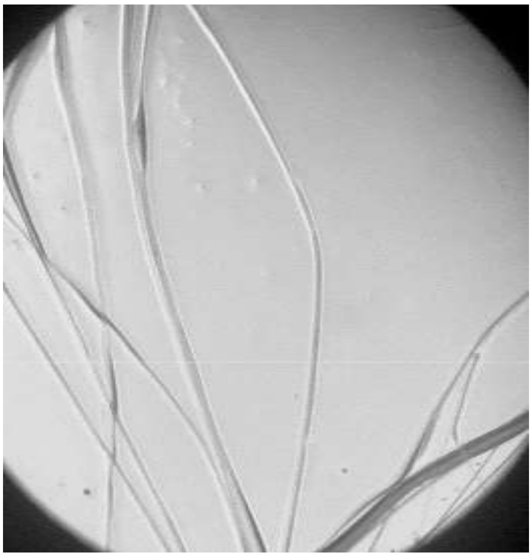

Figure 27. Cogon flower under a 15X microscope before oil sorption

It presents the cogon flower fibers under a microscope before oil absorption, as observed by the researchers. The image reveals the long, thin, and smooth fibers characteristic of the Cogon (*Imperata cylindrica*) Flower. These fibers appear straight and semi-transparent, which likely enhances their ability to absorb oil. The surface is clean and free from external substances, indicating that it is in its untreated state. This microscopic view provides a detailed look at how the fibers might interact with oil molecules during the absorption process on cogon flower-based cotton pads.

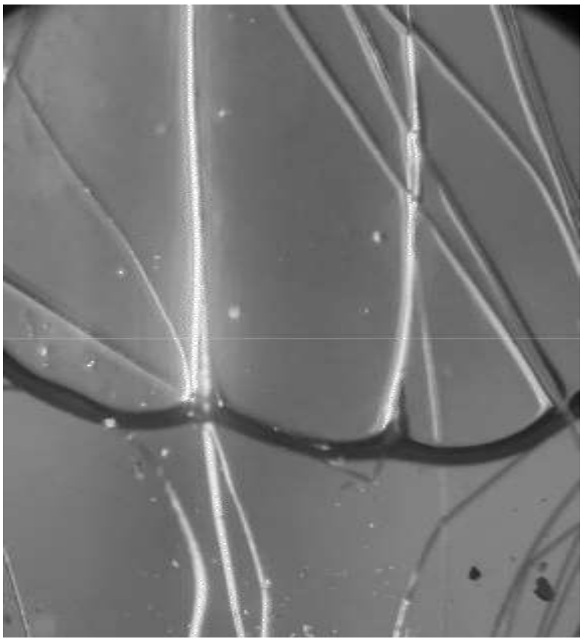

Figure 28. Cogon flower under a 15X microscope after oil sorption

It shows the cogon flower fibers under a microscope after the oil sorption process. In this image, the once clean and smooth fibers now display signs of interaction with oil, appearing darker in certain areas, which could indicate the oil coating or being absorbed into the fiber structure. There are small particles and slight distortions on the surface, suggesting that the oil has altered the physical characteristics of the fibers. This microscopic view highlights how the cogon flower fibers have absorbed the oil, demonstrating their potential effectiveness in oil spill cleanup.

V. Conclusion and Recommendations

Conclusion

The study demonstrates that cogon grass-based cotton pads exhibit significant oil sorption capabilities, especially in marine environments. The results indicate that the pads perform optimally in pure diesel oil conditions, achieving an average oil absorption of approximately 80.48% to 89.26%. Across the different setups, it is clear that the pads perform better when exposed to diesel oil compared to seawater. The sorption capacity was higher in setups with oil, particularly in pure oil conditions, where the absence of water allowed for maximum absorption. The introduction of water, whether stirred or not, slightly reduced the pads' efficiency in absorbing oil, highlighting the complexity of oil-water interactions. In comparison, the pads displayed minimal water absorption across all experiments, with average water uptake consistently below 1%. This suggests that the cogon pads could be highly useful in oil spill scenarios, with the ability to separate oil from water effectively. However, factors such as stirring and the ratio of oil to water play a significant role in influencing the pads' absorption efficiency. In realistic testing environments, such as when exposed to wave motion, the sorbent demonstrated substantial oil absorption efficiency, indicating that natural environmental factors can significantly enhance its performance. The average total net sorption reached 253.95 g of oil, underscoring the effectiveness of the pads in mitigating oil spills in dynamic marine settings. Overall, the findings confirm that cogon grass pads have potential practical applications in mitigating oil spills, though further optimization may be needed for environments with complex oil-water mixtures.

Recommendation

Based on the findings, it is recommended that further research be conducted to optimize the performance of cogon grass pads in real-world oil spill scenarios, particularly where oil and water are mixed or agitated. While the pads showed strong potential for oil sorption, the presence of water introduces complexities that affect overall absorption efficiency. Therefore, additional testing in more diverse environmental conditions, such as varying water salinity, temperature, and oil types, would help refine the material's design and usage. Future studies could focus on testing different sorbent configurations, varying the amounts of diesel oil, or introducing additional wave motion to maximize oil absorption. Conducting multiple trials with varied conditions will provide more robust data on the sorbent's performance, helping to refine its practical applications in oil spill scenarios.

It is also advisable to explore potential enhancements to the cogon pad structure, such as integrating additional filtration layers or using chemical treatments to further improve oil absorption while minimizing water uptake.

Moreover, expanding the scope of the study to include large-scale field trials would provide valuable insights into the practical application and scalability of these pads for oil spill response efforts. With further development, these biodegradable, low-cost sorbents could offer an eco-friendly solution to managing marine oil spills.

VI. References

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