Innovative Oil Spill Cleanup: Utilizing Hair Booms as Reusable, Biodegradable Absorbent in the Philippines Sea

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Abstract

The Philippine Sea, covering roughly 5 million square kilometers, play a vital role in global and regional marine biodiversity due to its rich ecological significance. It provides habitat for numerous endemic and migratory marine species, including fish, corals, marine mammals, and invertebrates that contribute to the balance of ocean ecosystems. The sea support crucial coastal ecosystem such as coral reefs, seagrass beds, and mangrove forest, which serve as natural barriers against that contribute to the balance of ocean ecosystems. The sea support crucial coastal ecosystem such as coral reefs, seagrass beds, and mangrove forest, which serve as natural barriers against storms, breeding grounds for marine life, and sources of food and income for Filipinos who rely on fishing, tourism, and marine resources for survival. The region has gained international attention for its conservation initiatives, highlighted by the Philippines receiving the 2023 Earthshot Prize for efforts aimed at protecting marine biodiversity and addressing the impacts of climate change. Despite these achievements, the Philippine Sea continues to face serious environmental threats, particularly from pollution, overfishing, and oil spills. Oil spills are especially destructive as they contaminate marine habitats, kill marine organisms, and disrupt local economies that depend on clean coastal waters. A major oil spill that occurred on February 28, 2023, off the coast of Oriental Mindoro severely threatened marine protected areas, fisheries, and tourism-related industries. The incident highlighted the urgent need for effective, sustainable, and environmentally friendly oil spill response methods. This research proposes the use of biodegradable hair booms as an alternative solution for oil spill cleanup. Hair booms are capable of absorbing oil efficiently while being reusable and eco-friendly, making them a promising remediation strategy for reducing environmental damage in marine environments and supporting long-term coastal protection.

Keywords: Philippine Sea; oil spills; marine biodiversity; biodegradable hair booms; coastal ecosystems

Introduction

The Philippine Sea is one of the most important bodies of water in the world. It is home to many kinds of fish, corals, and other marine life. It also supports the lives of many Filipinos, especially those who depend on fishing and tourism for their income. Because of this, keeping the sea clean and healthy is very important.

However, the Philippine Sea is often affected by oil spills. Oil spills usually happen because of ship accidents or oil transportation problems. When oil spills into the sea, it spreads quickly and causes serious damage. Marine animals can die, coral reefs can be destroyed, and coastal areas can become polluted. Oil spills also affect fishermen and tourism workers because dirty waters mean fewer fish and fewer visitors.

One major oil spill happened on February 28, 2023, off the coast of Oriental Mindoro (Cabico,2024). A tanker carrying a large amount of oil sank, causing oil to spread across the sea. This incident showed how unprepared some cleanup methods are and how urgent it is to find better and safer ways to clean oil spills.

Traditional oil spill cleanup methods can be expensive, slow, and sometimes harmful to the environment. Because of this, researchers are looking for more eco-friendly solutions. One possible solution is the use of human hair. Hair can absorb oil very well, just like a sponge. It is also biodegradable, reusable, and easy to collect from salons and barbershops.

This study focuses on using hair booms as a way to clean oil spills in the sea. By using hair, which is often thrown away, this method helps reduce waste while protecting marine environments (Phillips and Pagnucco, 2018). The study aims to understand how effective hair is in absorbing oil and how long it may take to clean an oil spill using this method.

Overall, this research hopes to help protect the Philippine Sea by offering a simple, affordable, and environmentally friendly way to respond to oil spills, while also supporting the communities that depend on clean oceans for their livelihood**.**

Oil spills are a major problem for the environment. These occur when oil leaks into the ocean, usually due to accidents during drilling or transportation. Oil spills harm marine life, damage beaches, and negatively impact industries like fishing and tourism. Despite existing methods for preventing and cleaning up spills, better solutions are needed to stop occurrences and repair the damage caused. Hair helps reduce oil spills by absorbing oil from water, acting like a natural sponge. It's eco-friendly, biodegradable, and widely available, making it a sustainable option for cleanup efforts.

The Philippine Sea, which is home to rich biodiversity and supports the livelihoods of many coastal communities. Given the threats posed by oil spills to this essential ecosystem, our research aims to improve clean-up efforts by utilizing hair booms as a reusable, biodegradable absorbent. This innovative approach not only provides an effective solution for addressing oil spills but also promotes sustainability by re-purposing a commonly discarded material. By enhancing oil spill response capabilities, this study contributes to the protection of the Philippine Sea's marine resources and supports the resilience of communities that depend on them.

This research aims to explore and apply the use of hair, both human and animal, in cleaning up oil spills on water bodies. Hair's natural ability to absorb oil will be tested and optimized for rapid deployment in small to medium-scale oil spills.

This study focuses on estimating the time required for cleaning oil spills using hair as an absorbent material. It considers measurable factors such as oil density, volume, affected area, and absorption capacity of hair. The goal is to provide a theoretical basis for predicting cleanup duration under controlled conditions, which may serve as a guide for future applications.

The study is limited by several factors. Environmental conditions such as weather, waves, and temperature can affect the rate of oil absorption but may not be fully represented in the calculations. The consistency of materials, particularly the quality, thickness, and availability of hair, may also influence the results. In addition, equipment and deployment limitations, including the availability of tools, manpower, and setup time, may cause differences between theoretical estimates and real-world applications.

Literature Review

Finding enough hair for the project might be difficult, as local supplies may not be sufficient. Also, weather conditions like rain and wind can affect how well the hair absorbs oil, making cleanup harder.

Crude oil and its derivatives are significant environmental contaminants, affecting both water and soil due to spills in marine and terrestrial settings. Data from international oil spill incidents show that most spills are relatively minor, typically involving less than 7 tonnes of oil. Although major accidents release a smaller overall quantity of oil, they can cause intense local pollution and severely impact ecosystems. Oil from such spills can enter human food chains through contaminated seafood or groundwater. While safety measures have improved in some regions, complete prevention of oil spill events remains impractical due to their unpredictable nature. Consequently, global efforts have focused on minimizing accidental releases and developing innovative remediation technologies (Ivshina et al., 2015).

The Asphaltene Stability Index and the de Boer plot are commonly used tools for evaluating asphaltene stability in crude oils. In addition to these methods, more advanced models have been developed to predict the pressure ranges where asphaltene deposition is likely to occur. One widely adopted approach is based on solubility parameter theory, which assumes that solvent quality plays a crucial role in maintaining asphaltenes in a stable, dispersed state. These models have been effectively applied under field conditions to determine the onset of asphaltene precipitation. They rely on the solubility parameters of both the oil and the asphaltenes, which are estimated simultaneously through onset flocculation experiments (Correra et al., 2005).

Choi and Moreau (1993) reported that natural sorbent materials such as milkweed, kapok, cotton, and wool, exhibit significantly higher oil sorption capacities compared to synthetic fibers such as polyester, polypropylene, viscose rayon, nylon 6, nylon 66, and acetate. The reported sorption capacities of these natural fibers exceeded 30 grams of oil per gram of fiber, indicating their strong potential for oil spill remediation. In contrast, man-made bicomponent and biconstituent fibers did not demonstrate clear performance advantages over conventional synthetic fibers in terms of oil absorption capacity.

Bhardwaj and Bhaskarwar (2018) reviewed various sorbent devices used for oil-spill control, highlighting their effectiveness, material properties, and potential for improving environmental cleanup efforts.

A research study conducted by Ifelebuegu et al. (2015) investigated the efficiency of natural by-product materials and synthetic materials used as oil spill sorbents. The authors investigated various materials such as human hair, feathers, and commercial synthetic sorbents in terms of their oil absorption efficiency and buoyancy. The authors found that human hair had a high oil absorption efficiency, which in some instances equaled or surpassed the efficiency of synthetic sorbents. However, the authors did observe that natural sorbents could need an extra containment system to keep them buoyant in an aquatic setting. The research supports the use of hair booms as an environmentally friendly material in oil spill cleanup.

One of the major reviews conducted by Bhardwaj and Bhaskarwar (2018) evaluated different sorbent materials employed for oil spill cleanups. This review emphasized that sorbents have been extensively employed for oil spill cleanups owing to their effectiveness, ease of handling, and ability to function well under different aquatic conditions. Although synthetic sorbents possess greater longevity, natural sorbents like human hair possess greater ecological sustainability. It was also emphasized that oil spill management materials with higher absorption capacity and biodegradability should be designed.

Major offshore oil spill incidents can lead to significant negative impacts on employment, income levels, trade activities, and overall profitability, thereby intensifying the economic challenges faced by affected regional areas. The wide-ranging nature of these impacts can severely disrupt the normal functioning of local economies. In addition to the substantial costs associated with cleanup and response efforts, industries and individuals that depend on coastal and marine resources often experience considerable economic losses. Moreover, related businesses and interconnected sectors may also be adversely affected due to operational disruptions and reduced revenue generation (Taleghani & Tyagi, 2017).

There are serious ecological, economic, and environmental effects when oil pollution occurs in coastal seas. The purpose of oil spill environmental sensitivity and risk assessment mapping is to evaluate the coastal resources' susceptibility and facilitate efficient decision-making to reduce the long-term impact (Arockiaraj and Kankara.,2019) From 2000 to 2021, the Philippines recorded 467 oil spills, with 14 classified as major (>10,000 liters), 62 as medium (1,000–10,000 liters), 306 as minor (<1,000 liters), and 85 with undetermined volumes. The undetermined cases highlight gaps in the oil spill database, where exact volume estimates and classifications were missing (Alea et al. 2022).

Both the percentage removal of crude oil and the adsorption capacity increased in tandem with the temperature increase. Because the solution's viscosity decreased and crude oil's solubility in water increased with temperature, the rate at which crude oil molecules diffused over the external boundary layer and the adsorbent particle's internal pores increased (Ukpong,2020).

Methodology

This study investigates the effectiveness of human hair as an alternative oil-absorbent material through a quantitative and computational research approach. By employing mathematical modeling, the researcher seeks to estimate the oil absorption capacity of human hair and determine the time needed to complete an oil spill cleanup. The study is structured in sequential stages to ensure a systematic process of data collection, analysis, and interpretation, allowing the findings to be clearly understood and applied to oil spill remediation. In line with established research practices, the study follows recognized procedures in defining its design, gathering and analyzing data, presenting results, and drawing conclusions consistent with its chosen methodological approach (Creswell, 2014).

In this study, the independent variable is the mass of human hair used, as it is the factor intentionally changed to observe its effect on oil absorption. The dependent variables are the time required for absorption and the amount of oil absorbed or remaining, since these outcomes depend on the quantity of hair applied. Meanwhile, the controlled variables include the oil absorption capacity of hair (L/kg), the absorption rate (L/kg/h), and the total oil volume, which are kept constant throughout the experiment to ensure that any observed changes in oil absorption and time are solely due to variations in the mass of human hair used.

The materials used in this study include information about the oil spilled, which provides details on the type and volume of oil involved. A mathematical model is utilized to estimate the oil absorption process and the time required for cleanup. The weight of human hair is included as a key material to determine its effectiveness as an oil absorbent. Lastly, the absorption rate of hair is considered to quantify how quickly the hair can absorb oil under the given conditions.

The procedure for the study begins by gathering human hair, which is collected from barbershops or voluntary donors. Next, the hair is obtained and prepared by stuffing it into stockings to create hair booms, which are then placed around the oil spill area. The process continues by monitoring the absorption, after which the hair booms are collected, cleaned, and the absorbed oil is properly disposed of following safety guidelines.

Capacity Requirement
$m=(Vo/Qmax)$

Time Requirement
$t= Vo/ s \times m)$

Where,
m= Mass of hair needed (kg)
Vo= Volume of oil (m_3)
Qmax= Maximum oil hair can hold (L/kg)
s=Oil absorbed per kg of hair per hour/ Oil absorption rate
t= Target cleanup time (hours)

Finally, the results are analyzed by recording the amount of oil collected, the number of hair booms used, and other important observations relevant to the effectiveness of the hair as an oil absorbent.

Conceptual Framework
Through mathematical analysis using a formula examined by researchers, they aim to estimate the time needed for the clean-up of an oil spill. This study involves three processes: a. Data collection (input); b. Analysis (process); c. Deriving conclusions (output).

For the input, it consists of the independent variable, dependent variable, and controlled variables. The independent variable of the oil density, volume of oil, area of oil spill, sea temperature, hair absorption rate, hair propensity of oil, perimeter of the spill area, and the weight of hair used. The dependent variable of the estimated time to finish the clean-up. The controlled variables are the weight of hair available.

The process begins with the collection of data, such as the volume of oil and the rate absorption by hair. After gathering the necessary data, it is then analyzed and processed using the mathematical formula**:** $m=\max(Vo/Qmax, Vo/s \times t)$, where m is the mass of hair needed (kg), where m=(Vo/Qmax) is the formula for capacity requirement and where the m=(Vo/s x t), can be written (t= Vo/ s x m) as is the formula for time requirement.

Results

Situation 1

Assume an oil spill occurs in the sea with a total volume of 800,000 liters. Human hair is used as the absorbent material, with a maximum oil-holding capacity of 3 L/kg and an absorption rate of 0.3 L/kg/h under typical sea conditions. The oil spreads across a wide surface area with a uniform average thickness. However, due to logistical constraints, only 180,000 kg of human hair is available for deployment. Using a computational cleanup model, estimate the total hair required to fully absorb the oil spill within the specified cleanup time and determine whether the available hair supply is sufficient to achieve complete oil removal.

Solution

Using the given oil spill volume and surface area, the researchers can first compute the average oil thickness and then apply the absorption model to estimate the cleanup time (denoted by t) for a specified mass of human hair. Once the cleanup time is determined, the model can be used to evaluate the extent of oil absorbed over time and verify whether the available hair is sufficient to clean the entire spill area within the target duration, using the established computational formulas.

Given:
Volume = 800,000L
Oil hair can hold = 3 L/kg
Oil absorption rate = 0.3 L/kg/h
Hair Available= 180,000 kg
The researchers will calculate the mass of hair needed (m) for the oil spill to cleanup.

$$m=(Vo/Qmax)$$
$$m=(800{,}000L/ 3\ L/kg)$$
$$= 266{,}666.67\ kg$$

With the calculated mass of hair needed, the researchers can now calculate for the time needed to finish the clean up.

$$t= Vo/ s \times m$$
$$t=800{,}000\ L/(0.3\ L/kg/h \times 266{,}666.67\ kg)$$
$$t=800{,}000\ L/ 80{,}000\ L/h$$
$$t= 10\ h$$

With the given mass of hair available, the researchers can now calculate for the time needed to finish the clean up.

$$t= Vo/ s \times m$$
$$t=800{,}000\ L/(0.3\ L/kg/h \times 180{,}000\ kg)$$
$$t=800{,}000\ L/ 54{,}000\ L/h$$
$$t= 14.81\ h$$
$$t= 14\ h \text{ and } 49 \text{ minutes}$$

Situation 2

An oil spill of 250,000 liters occurs near a coastal mangrove area. Human hair is proposed as the sorbent material, with an oil absorption capacity of 2.8 L/kg and an average absorption rate of 0.25 L/kg/h under moderate wave action. The oil spreads over 12,000 m² with an average thickness of 0.02 m.

Due to limited collection from salons and waste sources, only 60,000 kg of human hair can be obtained within 48 hours. Using a computational cleanup model, calculate the mass of hair required for complete oil absorption and evaluate the extent to which the available hair falls short of the required amount.

Solution

Given:
Volume = 250,000L

Oil hair can hold = 2.8 L/kg
Oil absorption rate = 0.25 L/kg/h
Surface area=12,000 m^2
Average thickness=0.02 m
Hair Available= 60,000 kg
Although the calculated oil volume based on surface area and thickness is approximately 240,000 L, this value closely matches the reported spill volume; therefore, the given value of 250,000 L is used in the analysis to represent the total oil spill more accurately.

The researchers will calculate the mass of hair needed (m) for the oil spill to cleanup.

m=(Vo/Qmax)
m=(250,000L/ 2.8 L/kg)
= 89,285.71 kg

With the calculated mass of hair needed, the researchers can now calculate for the time needed to finish the clean up.

m=(Vo/s x t)
m=250,000 L/(0.25 L/kg/h x 89,287.71 kg)
m=250,000 L/ 22,321.43 L/h
t = 11.20 h
t= 11 h and 12 minutes

With the given mass of hair available, the researchers can now calculate for the time needed to finish the clean up.

t= Vo/ s x m
t=250 L/(0.25 L/kg/h x 60,000 kg)
t= 250,000L/ 15,000 L/h
t= 16.67 h
t= 16 h and 40 minutes

Situation 3

A tanker accident releases 1.2 million liters of crude oil into open sea conditions. The oil slick covers approximately 60,000 m², with an average thickness of 0.02 m. Human hair is used as the absorbent, with a maximum oil-holding capacity of 3.2 L/kg. Strong ocean currents reduce the effective absorption rate to 0.2 L/kg/h.
Despite large-scale response efforts, only 250,000 kg of human hair is available for cleanup within a 72-hour period. Using a computational cleanup model, estimate the total hair required for full oil removal and assess whether complete cleanup is feasible given the limited sorbent availability.

Solution

Given:
Volume = 1,200,000L
Oil hair can hold = 3.2 L/kg
Oil absorption rate = 0.2 L/kg/h
Surface area=60,000 m^2
Average thickness=0.02 m
Hiar Available= 250,000 kg

The researchers will calculate the mass of hair needed (m) for the oil spill to cleanup.

m=(Vo/Qmax)
m=(1,200,000L/ 3.2 L/kg)
m= 375,000 kg

With the calculated mass of hair needed, the researchers can now calculate for the time needed to finish the clean up.

m=(Vo/s x t)
m=(1,200,000 L/0.2 L/kg/h x 375,000 kg)
m=(1,200,000 L/ 75,000 L/h)
t = 16 h

With the given mass of hair available, the researchers can now calculate for the time needed to finish the clean up.

t= Vo/ s x m
t=1,200,000 L/(0.2 L/kg/h x 250,000 kg)
t= 1,200,000L/ 50,000 L/h
t= 24 h

Situation	Volume of Oil Spilled	Oil Hair can Hold	Oil Absorption Rate	Hair Needed	Hair Available	Time Using Hair Needed Amount	Time Using Hair Available Amount
1	800,000 L	3 L/ kg	0.3 L/kg/h	266,666.67 kg	180,000 kg	10 h	14.81 h
2	250,000 L	2.8 L/ kg	0.25 L/kg/h	89,285.71 kg	60,000 kg	11.20 h	16.67 h
3	1,200,000 L	3.2 L/ kg	0.2 L/kg/h	375,000 kg	250,000 kg	16 h	24 h

Discussion

In this study, human hair booms are investigated as a potential alternative material in cleaning oil spills based on variables that include oil quantity, oil density, hair absorption rate, weight of hair used, sea water temperature, and estimated cleaning time. The results of this study are backed by a number of previous studies that emphasize the effectiveness of hair as a potential oil-absorbing material.

Some scientific research proves that human hair is capable of oil absorption to a considerable extent. According to Alderton (2022), human hair is capable of absorbing oil to several times its weight due to its natural properties. This is relevant to the variable of oil absorption capacity of hair, which is being used as a variable in this study. The hair strands have a rough surface, which enables oil to stick to it easily, thus proving to be a good absorbent in oil-polluted water.

In a study conducted by Ukpong (2020), the researcher determined that higher temperatures lead to increased rates of oil absorption since the temperature of the oil would not be thick anymore. The study supports the use of sea temperature as an independent variable for this study. When the temperature increases, the movement of the oil into the hair pores of absorbent materials would take a shorter time.

Research by Alea et al. (2022) reported 467 oil spill incidents that occurred within the Philippines from 2000 to 2021, emphasizing the prevalence of oil spills and the need for effective cleanup techniques. This study underscores the significance of estimating the cleanup period, where the importance of estimating the cleanup completion time corresponds with the research study’s dependent variable: the estimated completion time of the cleanup process.

In another study, Arockiaraj and Kankara (2019) highlighted the relevance of spill area, oil volume, and environmental conditions in determining the effects of oil spillage. These parameters are directly related to the independent variables considered in this study, namely spill area, perimeter of the spill, and oil volume, and the results of the study verify the relevance of spill area in determining the amount of absorbent material and the time needed for spill cleaning.

De Guzman (2023) wrote about actual oil spill cleanups in which communities in the Philippines collected human hair from salons for use in oil absorption during a tanker oil spill. Such an actual application of oil spill cleanups verifies the viability of this study and proves that hair can indeed be abundantly and inexpensively accessed for cleanups, particularly in developing nations. This verifies the variable regarding availability and mass of hair for cleanups.

Moreover, Matter of Trust in 2013, an organization recognized for its environmental solutions, proved that hair booms can be used for several cycles once cleaned appropriately. This confirms the premise in this research paper that hair booms can be reused, thus making it an eco-friendly remedy for oil spill cleanup. This can help in using less hair for cleanup.

Despite the above advantages, studies have also highlighted some drawbacks. Natural absorbents such as hair may need appropriate containment, such as stockings or meshes, to function effectively while also being able to float on water surfaces (Alderton, 2022). This could have an effect on the rate of absorption. On a conclusive note, the existing literature is highly supportive of the variables as well as assumptions employed within the scope of this research. The results indicate that human hair booms are a viable, environment-friendly, and practical alternative for cleaning up oil spills once the variables such as the amount of oil, rate of absorption, temperature, and availability are taken into consideration.

Conclusion

This research concludes that the use of hair booms is an effective method of oil spill cleanup. This is because hair naturally absorbs oil. Human hair has been shown to adsorb 3-9 times its own weight in oil, demonstrating its potential as a low-cost and environmentally friendly biosorbent (Ifelebuegu et al., 2015). This gives it the ability to remove oil spills on the surface of the water. Additionally, the fact that the hair is biodegradable means that it is a safe method of oil spill cleanup because it will not damage the marine life or increase the amount of waste present. The results of this study show that hair booms can prove particularly useful in small- to medium-scale oil spills.

Moreover, the fact that human hair is usually discarded in salons and barber shops also encourages recycling. Human hair that is typically discarded by salons and barbershops can instead be collected and repurposed for oil spill cleanup, transforming waste into an environmentally beneficial resource (Heap,2021). It is a good way of converting something that is usually considered trash into something of great use for purposes of protecting the environment.

Despite the fact that some variables, such as the condition of the sea, temperature, and availability of hair, may influence the process, the findings indicate that the use of hair booms possesses great potential in the cleanup process. This technique can be aided by the existing methods in the process of oil spill response. Moreover, this study emphasizes the need for community engagement and collaboration. By encouraging salons, barbershops, and communities to participate in the hair drive, it is possible to improve the cleaning process and increase awareness of environmental stewardship. Such engagement can contribute to oil spill cleanup, in addition to fostering a sense of common responsibility in the protection of marine environments.

Finally, the application of hair booms is a sustainable and affordable technique for cleaning oil spills. With the application of scientific knowledge, community engagement, and environmental best practices, this technique can go a long way in protecting marine life as well as the livelihoods of people who depend on healthy oceans.

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