Risk Reduction of Marine Oil Spill using Clusters of Fruit Peel Pellets

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Abstract. Globalization has led to massive rise in cross border trade. Increase in E-commerce business has contributed to this too. As a result, a continuous and complex logistics network of supply chains operate across the globe round the clock. Transportation of goods is the most essential activity of this network. Statistics reveals that approximately 90 percent of world’s goods are transported via sea route. This intense network of shipment poses a huge threat to marine ecosystem in numerous ways. One of the most dangerous events for marine ecosystem is oil spill. Oil spill from vessels and pipelines are a major reason behind mortality of marine wildlife. The present work focuses on developing a cost-effective sustainable solution for mitigation of marine oil spill. It was found from existing literature that peels of some fruits have substantial oil absorbing capacity. This fact was experimentally validated and a reduced scale prototype was designed aiming for the task of deployment in case of oil spill in marine waters. The experimental results show that the proposed model floats on water after absorbing oil up to its saturation value. It was also found that through appropriate mechanical setup, absorbed oil can be extracted for reuse or processing.

1. Introduction

Maritime activities have substantial contribution towards development and growth of economies across the world. In this era of globalization, spontaneous transportation of goods is essential for smooth operations of supply chains. Statistics show that more than 90 percent of world’s goods are transported via sea route. Apart from this, globally entire transportation system depends on hydrocarbon-based fuels. Majority of modern products such as cosmetics and lubricants are processed by products of crude oil. The major extraction of this crude oil is executed on offshore platforms. This inevitable dependency on crude oil and maritime logistics leads to a high probability of accidents in marine waters. The threat of accidents in marine waters can be directly related to the growing number of commercial and maritime activities [1].

One of the most adverse effects of these accidents is devastation caused by oil spill in oceanic waters. There are a number of oil spill remediation methods available in market. These can be classified into physical, chemical, thermal and biological classes[2]. Different types of methods are used depending upon variety of factors such as availability, cost, type of oil spill. In case of oil spill, the first response time is very essential. Generally, in case of oil spill in offshore locations far from coast, first response team takes time to reach the site. Consequences of oil spill is depicted by Figure 1 [3].
During the initial hours after oil spill, the oil spreads out in the ocean. For effectively dealing with oil spill, curtailment of this spreading is very essential. The present study focuses on this particular aspect of oil spill.

2. Objective of the Study
The present study is focused towards development of a reduced scale prototype which can be deployed in case of oil spill due to maritime accidents. As mentioned in Section 1, there are a number of technologies available for post disaster risk reduction and mitigation in case of marine oil spill. The major drawbacks of the existing technologies are their low-cost effectiveness and environmental implications. The primary objective of the present study is to design a cost-effective solution. It must be affordable to such an extent that even fisherman involved in small scale business can use it in case of oil leakage from small fishing trawlers.

The secondary objective of the present study is that the proposed model must be environment friendly with minimal environmental footprint.

3. Proposed Model
3.1. Methodology
Influx of crude oil into marine waters from sea bed seepage accounts to more than 6,00,000 tons/years. Marine organisms such as bacteria and phytoplankton also produce tons of hydrocarbons every year. These sources do not disturb the marine ecology. The reason behind this is the time frame. In case of artificial sources such as accidental oil spills, this huge incursion within a very small-time span leads to excessively high concentrations of hydrocarbons which is detrimental for marine ecology.

Crude oil is a complex agglomeration of many organic substances. Upon exposure to sea water, it breaks down into many states of aggregation. These includes slicks, emulsions, dissolved and suspended forms, precipitates. During the initial hours after oil spill, slicks have the major contribution. The behavior of oil in sea water is controlled by a number of interrelated processes, such as physical transport, evaporation, dissolution, emulsification, sedimentation, biodegradation and oxidation [4]. As per the study of Swan et al., processes acting on an oil slick can be represented as function of time [5]. Figure 2 illustrates the same.

The line thickness in Figure 2 represents the relative magnitude of each process. As clearly visible from the figure, during the initial hours after the oil spill, spreading contributes the most. As in case of open waters offshore, wind and ocean currents are very dominant. These factors catalyse the spreading. In case of oil spill in offshore locations, it takes a quite long time for the first response team to reach the site. For reducing the risk of the oil spill in such scenario, deployable devices can be very efficient which can help in sorption of oil and curtail the spreading in oceanic waters to a considerable extent. As mentioned in section 1, there a number of treatments available for oil spill clean up but out all the
options, adsorption is considered to be the most viable option due to low cost and environmental friendliness [6].

![Figure 2. Processes acting on an oil slick as a function of time following a spill [5]](image_url)

Now a days, agricultural wastes and related by products are utilized as sorbents because of its low cost and biodegradability [7]. Zubaidi et al. investigated the remediation of oil polluted water from waste lubricating oil by adsorption using pomegranate peels powder. The study revealed that the natural sorbent had excellent retention time and adsorption capacity [8]. Aliyu et al. performed a column study to investigate the suitability of banana peel as a sorbent. The experimental results confirmed its suitability as a low-cost sorbent [9]. Gheriany et al. evaluated the sorption capacity of the dried orange peel and thermally treated orange peel. Both the types of orange peel performed very well. Thermally treated peels were more efficient in comparison to dried [10]. Abdullah et. al. performed an experimental study with hybrid peel waste consisting of orange and banana peels with lubrication oil and petrol. Results showed that different ratios resulted in enhanced adsorption [11]. In the present study orange peels were used as sorbent.

3.2. System/Model
In the present study a reduced scale model of a floating cluster of orange peel pellets was designed. The objective was that it can be deployed in case of oil spill for oil sorption while floating at water surface. The schematic diagram of the same is illustrated by Figure 3.

The dried orange pellets were filled inside a fine net and was sealed. This net was attached to four hollow spherical balls via elastic cords. These hollow balls increase the floatability of the prototype. As illustrated in Figure 4, these balls can even be interconnected with hollow pipes to form rigid frame to increase its durability and floatability.

![Figure 3. Schematic Diagram of proposed Model](image_url)
4. Experimental Scheme
The proposed system was tested in a glass container of length 450 mm and breadth 244 mm. Around 60% of the container was filled with salt water. The container was filled with an oil layer of 7 mm above water. The oil has physio chemical properties as illustrated in Table 1.

| Characteristics          | Method       | Value    |
|--------------------------|--------------|----------|
| SAE Viscosity Grade      | SAE J306     | 90       |
| Colour                   | Visual       | Brown    |
| Appearance               | Visual       | Clear and Bright |
| Density @15°C, g/cc      | ASTM D1298   | 0.8992   |
| Kinematic Viscosity @40°C, cSt | ASTM D445 | 176.6    |
| Kinematic Viscosity @100°C, cSt | ASTM D445 | 16.6     |
| Viscosity Index          | ASTM D2270   | 98       |
| Copper Corrosion, 100°C, 3 hrs. | ASTM D130 | 1b       |

Figure 5. Test Setup

The layer thickness was measured at gradually increasing random time intervals. The observations are as presented in Table 2.
Table 2. Experimental Data

| Time  | Time Elapsed (min) | Thickness of Oil Layer (mm) | Volume of Oil (ml) | Oil Absorbed (ml) |
|-------|--------------------|------------------------------|-------------------|------------------|
| 03:40 | 0                  | 7                            | 768.6             | 0                |
| 03:50 | 10                 | 6.75                         | 741.15            | 27.45            |
| 04:16 | 36                 | 6.5                          | 713.7             | 54.9             |
| 04:28 | 48                 | 6                            | 658.8             | 109.8            |
| 04:38 | 58                 | 5.75                         | 631.35            | 137.25           |
| 05:19 | 98                 | 5.75                         | 631.35            | 137.25           |
| 05:40 | 119                | 6                            | 658.8             | 109.8            |
| 06:00 | 139                | 6                            | 658.8             | 109.8            |
| 06:20 | 159                | 6                            | 658.8             | 109.8            |
| 06:40 | 180                | 6                            | 658.8             | 109.8            |
| 1170  | 5.5                |                              | 603.9             | 164.7            |

Figure 6. Oil extraction

5. Results & Discussion

The experimental results reveal that for the first hour of the experiment, the proposed system operates admirably. As previously stated, the suggested technology is intended for immediate deployment in the event of an oil leak. These preliminary findings support its potential for such uses.

Figure 7. Oil absorption rate
The proposed model absorbed oil at a rate of nearly 3 times the weight of the orange peel pellets. The initial results were really encouraging. For the real-time applications, the rate of absorption within the first hour after deployment is appropriate. In the event of oil leakage, quick action is required to prevent the spread of the oil. At roughly 120 minutes, the system reaches its initial saturation point. For an accidental event, this amount of time is usually sufficient for the first reaction team to arrive. Authors also believe that multiple units of the proposed model must be interconnected while deployment in marine waters which will ultimately result in better floatability of the entire cluster along with ease during recollection of the cluster. Such clusters will lead to better curtailment of the spreading. It is also seen from Figure 7 that absorbed oil can be extracted from the proposed model, which could be processed for usage.

6. Conclusion
A deployable risk reduction technique was developed in this study to mitigate maritime oil spills from boats and pipelines in the event of an accident. Experiments were conducted on a reduced scale model, and substantial effectiveness was discovered. The current system's initial absorption rate was judged to be adequate for the real-world scenario. For improved efficacy in terms of work action as well as ease of deployment and collection, a network of such deployable systems would be coupled to form a deployable cluster. During the experimental examination, it was also discovered that the oil may be recovered from the proposed model for further processing.

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