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Effectivity of a Novel Trichloro(octadecyl)silane (TCODS) Coated Human Hair Composite Material as a Natural Oil Spill Sorbent

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Abstract

Oil spills are frequent accidents that have detrimental effects on the environment and health of organisms. To minimize environmental damage, oil spills require immediate cleanup, however pre-existing methods such as booms and skimmers have limited abilities. Natural sorbents are environmentally friendly, higher in sorption capacities, and inexpensive compared to conventional synthetic methods, but many tested possibilities lack hydrophobicity. The potential of human hair was investigated using adsorption experiments in kerosene and petroleum ether respectively. Human hair was transformed into a novel composite material coated with trichloro(octadecyl)silane (TCODS), a hydrophilizing agent shown to increase oil-water separation. Curly and straight hair were compared in both composite and loose form along with the presence of TCODS to test the sorption ability of the composite material given its greater surface area. The order of highest efficacy in oil removal to least performing sorbent modification was the loose with TCODS, loose itself, composite with TCODS, and composite itself. Decreased sorption capacities of the composite material can be attributed to decreased buoyancy of the starch solution, which resulted in a nonuniform, blocked cuticle. On average, curly hair adsorbed significantly more oil than straight hair due to its greater natural porosity. Comparison of sorption rates showed that a short contact time is required to attain a majority of total oil adsorbed. Reusability test demonstrated that human hair can be utilized several times without deterioration in sorption characteristics. Overall, this study supports the potential of human hair as a low-cost sorbent for oil spill cleanup.

Keywords: Oil spill, Sorption capacity, Human hair, Hydrophobicity, Sorbents

1. Introduction

1.1 Oil Spill Ubiquity

Each year, about 20 million tons of oil are spilled into the environment (Vlaev et al. 2011). The hazards of oil spills have been increasing in oceanic environments due to the increased production, transportation, and storage of crude oil globally (Oliveira et al. 2020). Oil spills can also occur from mishaps from tanks and pipelines, making them unpredictable accidents (Asadu al. 2021). Oil is composed of several types of hydrocarbons that are classified into paraffinic, naphthenic, aromatic, asphaltene, and polycyclic aromatic hydrocarbons (PAHs), as well as aliphatic compounds. When oil is spilled into these oceanic environments, toxic chemicals such as PAHs are released putting human and animal health at risk (Abdelwahab et al. 2016). Oil spills are problematic to the immediate and long-term health of organisms such as marine wildlife and birds due to ingestion (ulcers, diarrhea, gastrointestinal irritation, etc.), direct contact (liver/kidney damage, reproductive failure, death, etc.), and inhalation (respiratory inflammation, emphysema, pneumonia, etc.) of oil (Ober 2010). The Deepwater Horizon Oil Spill is currently known as the largest marine oil spill which significantly decreased biodiversity due to the decreased population of several organisms such as sea turtles and birds (Al-Majed 2012). Marine organisms are posed with severe health effects including alteration of metabolic and cardiac functions and impeded growth when in contact with substantial amounts of oil (Paganucco and Phillips 2018). Oil spills are environmentally detrimental, polluting water sources, and destroying natural resources (Ifelbuegu et al. 2015).

1.2 Pre-existing Remediation Shortcomings

Spilled oil transforms by spreading, evaporation, emulsification, photo-oxidation, dispersion, sinking, resurfacing, tarball formation, and biodegradation, which all make clean-up multi-faceted and complex (Al-Majed et al., 2012). Variables such as waves, tides, temperature, and wind conditions easily spread the oil onto the surfaces of water, making cleanup much more challenging (Al-Majed 2012). Some mechanical methods of cleanup include booms, floatable physical barriers to contain and slow the spread of oil which conglomerate the oil to one place, and skimmers, which pick up the conglomerated oil. However, these methods are expensive and inefficient due to low oil separation efficiencies caused by inherent hydrophilic property and low absorption selectivity (Zhang et al. 2018). Booms are also only efficient in calm waters. Bioremediation, which introduces naturally microbes and biological agents such as bacteria and fungi to aid oil spill cleanup, is also ineffective in cleaning large spills or submerged spilled oil (Al-Majed 2012). This is due to abiotic environmental factors such as low levels of nutrients and fixed forms of nitrogen, low temperatures, and insufficient oxygen which hinder the growth and multiplication of necessary microorganisms (Al-Majed 2012). In-situ burning*,* which removes oil slick on the surface of waters, can produce toxic compounds such as carbon monoxide and sulfur dioxide when the burning occurs on the water (Al-Majed 2012). Dispersants consist of surfactants which break down the oil into smaller droplets that can mix more easily with the water, but they contain compounds toxic to the environment and work better cleaning oils with larger viscosities (Trannum and Bakke 2012). Existing remedy technologies have disadvantages such as low efficiency, limited application abilities, and high cost (Zhang et al., 2018).

1.3 Sorbents

Sorbents are materials that have the capacity to adsorb oil in large capacities and possess hydrophobic and oleophilic properties, meaning they tend to repel water and adsorb the oil. Properties that determine a sorbent's efficiency include the amount of oil adsorbed per unit of sorbent, buoyancy, and recyclability (Paganucco and Phillips 2018). An ideal sorbent does not recover any water (Fingas 2011). An advantage of using sorbents is that they can perform well, no matter the sea conditions (Al-Majed 2012). The capacity of a sorbent depends on the amount of surface area available so that the oil can easily adhere onto the surface of the sorbent (Fingas 2011). Synthetic sorbents such as polyethylene, polyurethane, and other polymeric sorbents are widely used because they can be engineered to be hydrophobic and oleophilic (Paganucco and Phillips 2018). Synthetic sorbents, however, lack biodegradability, adding extra waste to the environment. These pre-existing adsorption methods fail to meet cost efficiency and environmental compatibility. Natural sorbents have become an increasingly attractive option for oil spill cleanup due to its cheap cost, abundance, and eco-friendliness. These materials primarily come from agricultural products such as kapok, palm fibers, cotton, straw, rice husks, etc. (Zamparas et al. 2020). Natural sorbents tend to uptake hefty amounts of water in addition to oil, causing them to sink (Fingas 2011). Unfortunately, these tested natural materials have poor oleophilic and hydrophobic properties. In order to improve these characteristics, natural sorbents can be modified using mechanical, thermal, and chemical methods (Zamparas et al. 2020).

1.4 Human Hair

Human hair is an abundant material that is overlooked as a waste material, so it could be repurposed for cleaning oil spills (Boulos et al. 2013). The structure of human hair consists of the medulla, cortex, and cuticle (Boulos et al. 2013) as depicted in Figure 1. The cuticle's inner layers consist of keratin proteins, making the hair water repellent due to the insolubility of keratinocytes which synthesize into keratin proteins (Ifelbuegu et al. 2015). Hairstylist Phil McCory was the first to utilize hair as a practical solution in cleaning the Exxon Valdez oil spill (Ukotije-Ikwut et al. 2016). Human hair is coated with the lipid 18-methyl eicosanoic acid (18-MEA), giving it hydrophobic properties, something that many previously tested natural sorbents lack (Zamparas et al. 2020). Hair follicles, contributing to its porous nature, have a large surface area, allowing oil to slip into the capillaries and stick onto the hair's surface (Boulos et al. 2013). Human hair's tensile strength also provides good stability if presented with environmental obstacles (Chenxi et al. 2022). Human hair, a cheap, sustainable, and natural waste product will not have any negative effects when in contact with water (Chenxi et al. 2022). Booms made from recycled human hair waste were significantly better at adsorbing crude oil in a simulated oceanic spill compared to commercial sorbents such as polypropylene ($p<0.001$). Hair booms also performed better than natural sorbents such as cotton ($p<0.001$) and recycled cellulose ($p<0.001$) (Paganucco and Phillips 2018). Compared to synthetic materials, hair sorbents are environmentally favorable in that they float on the surface of water, whereas synthetics sink and are hard to recover.

Table 1. Physical properties of studied oils

Parameters	Petroleum either	Kerosene
Viscosity* (cp)	0.3	1.64
Density (g/cm^3)	0.64	0.82

* at 15°C

1.5 Objectives

One of the objectives of this study is to assess different textures of human hair and their effectiveness in cleaning oil. To further enhance sorption performance, the hair will be coated with TCODS to test the hydrophobic characteristics and examine if the coating significantly increases sorption capacities. The trichlorosilyl group allows the compound to bind strongly to surfaces and the long alkyl chain is non polar and repels water from coming onto the surface of the sorbent (Chandrasekaran et al. 2021). Another objective is to determine whether transforming the human hair into a composite material to enhance surface area will increase sorption efficiency. Our study aims to determine whether the hair as the composite material with the TCODS coating will be a successful, novel solution in cleaning up oceanic oil spills.

2. Materials and Methods

2.1 Materials

Human hair was collected from haircuts as donations from local salons including Lemon Tree, Bam Style, Lakeville Hair Studio, and Angelo & Co Hair Stylists. Hair color was not scrutinized in the collection process. The donated hair came from people of different ages and genders in a variety of cut lengths, ranging from around 3 to 15 centimeters. The oils employed in this study were kerosene and petroleum ether, the characteristics of which are outlined in Table 1. Kerosene was purchased from Carolina Biological. Petroleum ether and toluene were purchased from Fisher Scientific. Trichloro(octadecyl)silane was purchased from Sigma Aldrich. All salts for the artificial seawater and other materials were obtained from William A. Shine Great Neck South Laboratory.

2.2 Hair Preparation

Hair collected from local salons was categorized based on texture (straight or curly). The gathered human hair was cleaned in detergent and warm water, then air-dried with exposure to moderate natural sunlight for 48 hours (Ifelbuegu et al. 2015). Each hair texture was divided into 6 grams portions.

2.3 Composite Material Creation

Cleaned and dried hair of varying lengths were combined with a starch solution in a three to one ratio of starch solution to hair (Thompson, 2010). The starch solution served as a structural additive and consisted of 30 milliliters of a water based detergent and 18 grams of cornstarch. Detergent was first massaged in hair groups until fully coated and absorbed. The starch mixture was then incorporated into the hair groups. The hair was flattened and formed into uniform configurations, approximately 3.5 inches in diameter to generate greater surface area. The final product is outlined in Figure 1.

Figure 1. Human hair engineered into a composite material and pressed into mats.

2.4 TCODS Coating

TCODS solution was created by adding 0.5 mL of trichloro(octadecyl)silane to 20 mL of toluene (Chenxi et al. 2022). Toluene hydrolyzes the TCODS which hinders severe reactions when TCODS comes in contact with water. The human hair was submerged in the solution for 15 minutes. After removal from solution, the coated human hair was left to cure at room temperature for 48 hours under natural sunlight to obtain the completed TCODS coated human hair groups.

2.5 Microscopic Analysis

A strand of each of the following samples were examined under a compound microscope: loose hair, loose hair coated with TCODS, composite hair, and the composite hair coated with TCODS. Hair was placed on a glass slide under the microscope. Photographs were taken using an iPhone 12 to examine qualitative differences between each of the samples' cuticles.

2.6 Sorption Experiments

Sorption tests were performed in an ocean mesocosm using artificial seawater. Artificial seawater was prepared as described in Kester et al. Table 2 outlines all the salts for the preparation of the artificial seawater. All the salts were combined and thoroughly stirred until fully dissolved in 1000 mL of distilled water. 20 g of petroleum ether and 20 g of kerosene were poured into 500 mL containers with 200 mL of the artificial seawater. Hair coated with TCODS or transformed into a composite were weighted for an initial weight due to the addition of added substances. For loose hair sorbents, 6 g were used. Hair sorbents were employed into the ocean mesocosm for a 60 minute contact period following the ASTM F 726-99 standard method of testing oil spill sorbents as outlined in Figure 2. After undergoing adsorption, the sorbent was drained for 30 seconds before placed on a weighing pan for measurement of final weight. Oil adsorption capacities were measured using the following equation: (Xo-Xs)/Xs (Ifelbuegu et al. 2015). Xo represents the total mass after adsorption and Xs represents the total mass before adsorption. All sorption experiments were performed at room temperature (25°C+/-2°C) and repeated for two trials with the average standard deviation and means calculated.

Table 2. Composition of salts in artificial seawater

Gravimetric salts	g Solution
Sodium chloride (NaCl)	23.926
Sodium sulphate (NaSO4)	4.008
Potassium chloride (KCl)	0.667
Sodium bicarbonate (NaHCO3)	0.196
Ascorbic acid (C6H8O6)	0.098
Boric acid (H3BO3)	0.026

$$\text{Sorption capacity} = \frac{X_0 - X_S}{X_S}$$

Equation 1. Xo (g) is the mass of the sorbent directly after oil adsorption. Xs (g) is the mass of the dry sorbent, before adsorption. All experiments were conducted at room temperature and performed in duplicate, with the average value and standard deviation (SD) calculated.

2.7 Reusability Test

The used hair sorbent was washed with water then and remaining oil was extracted using n-hexane, a solvent that requires little energy to extract oil without producing toxic fumes. The hair was left to dry for 48 hours before proceeding to be reused for sorption tests in three additional reuse trials after each desorption (Ifelbuegu et al. 2015).

2.8 Statistical Analysis

Data were first stratified by modification of hair and texture. Microsoft Excel was used to calculate averages, standard deviation, and standard error of all hair sorbent modifications for both straight and curly textures. Percent differences between final averages of sorption capacities for all groups in kerosene and petroleum ether respectively were calculated for all experimental groups. Significance between groups between each hair texture and type of modification were determined via a two tailed t-test, assuming statistically independent values, normally distributed data and equal variances, where significance was determined by $p<0.05$. All graphs were constructed in Excel.

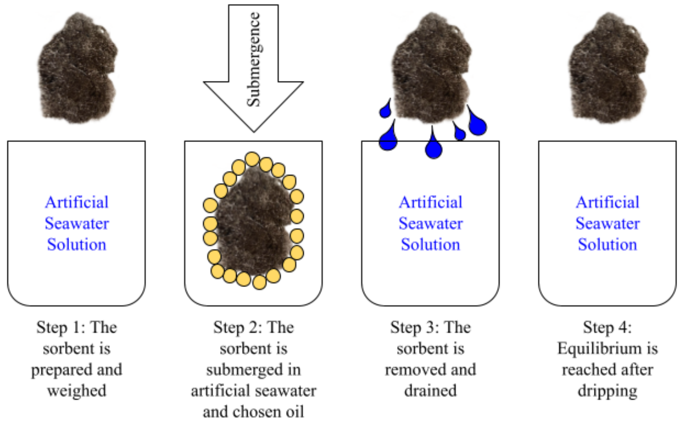

Figure 2. Methodology for measuring oil uptake for oil spill sorbent (adapted from Oliveira et al. 2021). Step 2 illustrates oil adsorption.

3. Results

3.1 Effects of contact time on adsorption

The effects of contact time on the adsorption of human hair were determined by adsorption tests at varying contact times of 5, 10, 20, 30, 40, 60, and 80 minutes with all other experimental values kept constant. Between each time increment, sorption capacities were measured and average values were plotted. In Figure 5, there was a rapid increase within the first five minutes for both oils. 93% and 78% of the total oil adsorbed occurred within the first 5 minutes of contact time, indicating that a short period of contact is required to attain a majority of oil adsorbed. As time progressed, the sorption rate decreased and remained relatively constant. The amount of kerosene adsorbed at varying contact times was significantly higher than the amount of petroleum ether adsorbed ($p<0.001$).

3.2 Effects of hair texture

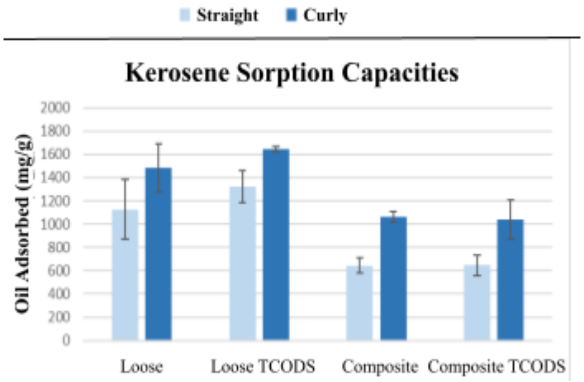

Figure 3. Kerosene sorption capacities of straight and curly hair groups. Sorption capacities for straight and curly hair in various modified forms were measured in kerosene for 60 minutes at 25°C+/-2°C. All hair sorbent groups were tested for two trials. Error bars represent ±1SEM.

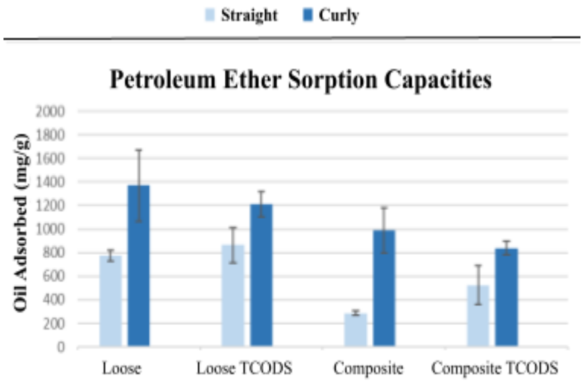

Figure 4. Petroleum ether sorption capacities of straight and curly hair groups. Sorption capacities for straight and curly hair in various modified forms were measured in petroleum ether for 60 minutes at 25°C+/-2°C. All hair sorbent groups were tested for two trials. Error bars represent ±1SEM.

Adsorption capacities for both straight and curly hair was compared in kerosene and petroleum ether from sorption tests. The adsorption capacities of both hair textures are shown on Figures 3 and 4 for kerosene and petroleum ether respectively. Curly hair groups had an average sorption capacity of 1327 mg/g and 1099 mg/g for kerosene and petroleum ether respectively. Straight hair groups had an average sorption capacity of 933 mg/g and 612 mg/g for kerosene and petroleum ether respectively. Across both oil types, curly hair sorbents adsorbed significantly more oil than straight hair sorbents (p=0.01). Curly hair sorbents adsorbed significantly more kerosene than straight hair sorbents (p=0.03). However, there was no significant difference between the amount of petroleum ether adsorbed by curly hair compared to the amount adsorbed by straight hair (p=0.12). Curly hair sorbents adsorbed 52% more oil than straight hair sorbents.

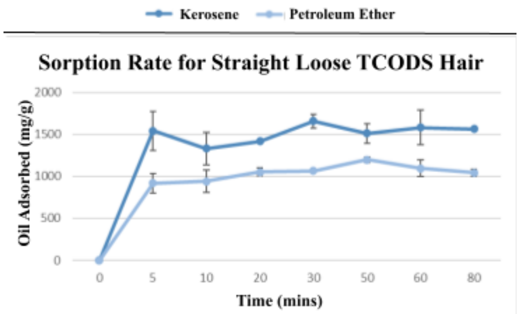

Figure 5. Sorption rate for straight loose TCODS coated hair. Sorption rate of straight loose hair coated with TCODS in kerosene and petroleum ether at 25°C+/-2°C. Sorbents were tested at varying contact times for two trials. Sorption capacities were calculated for each timestamp and averaged for each group. Error bars represent ±1SEM. Kerosene was adsorbed significantly more than the amount of petroleum ether adsorbed (p=0.0003).

3.3 Effect of hair sorbent type (modifications)

Adsorption capacities for all four sorbent types (loose, loose coated with TCODS, composite, and composite coated with TCODS) were compared in kerosene and petroleum ether as shown in Figures 3 and 4. The composite material lowered the sorption capacity of the hair sorbent compared to the loose hair sorbent. Figure 6A and 6B are examples of the hair sorbent that weren't transformed into the composite material. Figure 6C and 6D are examples of the hair sorbent that were transformed into the composite. Figures 6C and 8D have an uneven distribution on their cuticle surface whereas in Figures 6A and 6B the cuticle is evenly distributed. Composite hair groups had an average sorption capacity of 875 mg/g and 626 m/g compared to loose hair groups that had an average sorption capacity of 1304 mg/g and 1071 mg/g for kerosene and petroleum ether respectively. There was no significant difference between the composite hair sorbent groups compared to the loose hair sorbent groups (p=0.12). The loose hair group coated with TCODS adsorbed significantly more oil than the composite hair coated with TCODS (p<=0.05). TCODS coated groups on average had sorption capacities of 1171 mg/g and 862 mg/g while the groups without TCODS coating had averages of 1089 mg/g and 848 mg/g for kerosene and petroleum ether respectively. The sorbents coated with TCODS had overall higher average sorption capacities than the sorbents without the TCODS, but there was no significant difference (p>0.05). The loose hair coated with TCODS was the best performing group for efficiency, adsorbing 6%, 50% and 51% more oil than the loose hair itself, the composite coated with TCODS, and the composite itself, respectively.

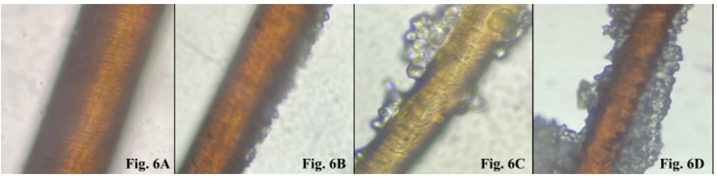

Figure 6. Bright field microscopic analysis of different straight hair groups. 6A) Straight loose hair; note the uniformity of the cuticle surface, which is consistent given the untreated nature. 6B) Straight loose TCODS hair; the TCODS coating formed a thin layer above one side of the cuticle, however less severe than as seen in 6C) straight composite hair and 6D) straight composite TCODS hair. The composite coating is thought to have created thicker coating on hair strands due to the greater viscosity of starch versus TCODS.

3.4 Reusability of human hair sorbent

Between each trial of reuse, the hair sorbent was cleaned and oil was extracted from before retesting for sorption capacities in kerosene. Reusability of the straight loose TCODS coated hair sorbent is shown in Figure 7. Between each trial of reuse, there was no significant decrease in sorption capacity (p>0.05).

4. Discussion

The objective of this study was to evaluate the effectiveness of different sorbent types and different hair textures in adsorbing oil. We were specifically testing whether transforming the loose hair into a novel composite material would increase sorption capacity and whether TCODS would serve as an effective hydrophobic coating to enhance sorption ability of the sorbent.

The creation of the composite material was initially formulated by the idea presented in Gan et al. 2022 and Thompson 2010 which stated that a greater surface area would allow adsorption to occur more spontaneously due to there being more room for adsorption to occur. The composite material ended up producing lower sorption capacities than the loose hair. In Figures 6C and 6D, after the hair was combined with the starch solution to create the composite, the cuticle became blocked compared to Figure 6A and the starch solution was unevenly distributed to the entire surface of the hair. This potentially minimized the true effectivity of the composite material's performance. The blockage of the cuticle in the composite material sorbents most likely made it harder for oil to seep through the cuticle surface which aligned with the qualitative results from Figure 6. In the creation of a composite carbon fiber for oil spill cleanup, Gan et al. 2022 found that the composite was successful because in a SEM microscope analysis, the morphology was shown to have a uniform distribution and the nanoparticles weren't in clusters. The addition of the starch solution added additional weight to the sorbent itself, increasing the initial weight of the sorbent. Pagnucco and Phillips in 2018 found that the hair sorbent was the least buoyant compared to polypropylene, cotton, and recycled cellulose. Since human hair is naturally less buoyant due to low surface tension and increased porosity, further decreasing the buoyancy with the starch solution would be bound to lower adsorption ability. TCODS coating was slightly more effective in improving sorption ability for kerosene in comparison to the non-coated counterparts, however it was less effective in petroleum ether adsorption as shown in Figure 3 and 4. These results slightly differ from those found by Chenxi et al 2022, which found that TCODS coating improved oil absorption capacity, more specifically for petroleum ether. As shown in Figure 6B is the loose hair coated with TCODS where the surface of the cuticle is evenly distributed and smooth on a large scale, however, close up, the TCODS coating is rough. In a study done by Chenxi et al 2022, hair modified with the TCODS successfully adhered to the surface of the cuticle which synergistically improved oil affinity and the oil adsorption ability of the human hair fiber. This probably attributes to the loose TCODS group being the best performing sorbent type compared to the other sorbent types in our study because not only does the roughness of the TCODS have hydrophobic and lipophilic properties, preventing water to reach the sorbent surface, but similarly to Figure 6A with the loose hair itself, they both have an evenly distributed cuticle, allowing oil to easily diffuse onto the surface. The superior performance of curly hair textured sorbents compared to straight hair textured sorbents can be attributed to its natural greater porosity compared to the porosity of straight hair. In highly porous hair, the layer of the cuticle becomes opened, allowing oil to easily attract onto the surface. This is similar to the findings from Ifelbuegu et al. 2015 where hair type C, which had a tight, rough, coarse, and spongy nature with larger macropores, had twice the sorption capacities of type A and B hairs which were less coarse.

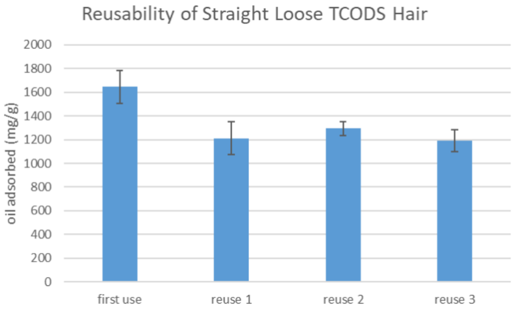

Figure 7. Reusability of straight loose TCODS hair. Reusability of human hair sorbent was tested by re-testing the sorption capacity of the hair sorbent after oil extraction and cleaning of the sorbent between each reuse. Kerosene sorption capacities of straight loose TCODS coated hair were measured after several reuses. Two trials were performed. Error bars represent ±1SEM. No significant difference between each trial of reuse ($p>0.05$).

The initial high rate of oil sorption within the first five minutes of contact time as shown in Figure 5 may be attributed to the sites on the surface of the sorbent being unoccupied and bare. As time progresses, those sites become increasingly infiltrated with oil molecules which saturates the surface of the sorbent and decreases the sorption rate. This is similar to the findings from Ifelbuegu et al. 2015 where there was a rapid increase within the first five minutes and the sorption rate slowed until it reached equilibrium. In the context of adsorption, equilibrium is when the rate of adsorption—when the molecules adhere to the surface— is equal to the rate of desorption—when the molecules are released from the surface. During the five minutes, more than 90% of the total oil adsorbed was adsorbed, reinforcing the idea that a short amount of contact time is required for a majority of total oil adsorbed to be adsorbed. The higher sorption capacities for kerosene for all hair types can be attributed to the higher viscosity of kerosene compared to petroleum ether as outlined in table 1. The thickness of the kerosene probably enhanced the adherence of the kerosene onto the surface of the hair sorbent compared to the petroleum ether which is less thick and viscous. This aligns with findings in both Chenxi et al. 2022 and Ifelbuegu et al. 2015 where the oil that had the highest viscosity was shown to have the higher sorption capacities across all experimental groups out of all the other oils tested that had lower viscosities. The insignificant difference found between trials of reuse for testing reusability for the hair sorbent also matches with findings in Ifelbuegu et al. 2015 and Ukotije-Ikwut et al. 2016 where human hair was tested for reusability and in both studies, there were no significant decreases after the multiple cycles of reuse.

The approach for creating the composite material via the starch solution created an uneven distribution throughout the surface of the hair sorbent, which may have accounted for the infectivity of the composite material. Other approaches in the creation of the composite hair sorbent with materials to increase buoyancy and uniformity should be taken in order to justify whether the composite material is a preferable option opposed to the loose hair itself. When coated with TCODS, the hair is not biodegradable due to the nature of the coating, so it would need to be disposed of as hazardous waste. TCODS is moderately toxic to aquatic organisms and can increase the acidity of aquatic environments, so implementing this on a large scale would not be preferred. The TCODS' hydrophobic mechanisms weren't directly established due to the insignificance between the groups with the TCODS coating and the groups without the TCODS coating, so other hydrophobic/oleophilic coatings such as ethyl 2-cyanoacrylate or octadecylphosphonic acid should be tested on human hair sorbents to see whether there are other environmentally friendly coating options that would statistically increase sorption capacities. Since porosity played a role in increased sorption capacities as shown from the curly hair adsorbing significantly more oil than the straight hair, other hair textures with higher porosities than curly hair such as kinky hair should be tested. Furthermore, sea surface pH depends on the location of the ocean, and since oil spills occur in various oceanic environments, the durability of the human hair sorbent should be tested in different oceanic conditions with varying pH such as alkyl or acid solutions. Studies on adsorption isotherms and kinetics should be implemented in the future to get a sense on the relationship between the adsorbent and adsorbate. This would be done in environments of varying temperatures.

In a real world oil spill, both curly and straight hair have shown potential in effectively adsorbing oil in their loose form. The abundance, reusability, and biodegradability of these materials strengthen the practicality of this solution. Only 500 grams of hair is required to create a 2x2 foot 1 inch thick mat that can soak up 1.5 gallons of oil. Since there was no significance between the loose hair and the loose hair with TCODS, coating the hair with TCODS would not have to be necessary for using this in an oil spill cleanup.

5. Conclusion

Human hair sorbents in various forms and textures were studied to determine the effectiveness in hair sorbents for cleaning up oil spills. The hair sorbents made out of curly hair were found to be significantly better in adsorbing oil than hair sorbents made from straight hair. Hair sorbents transformed into a composite diminished sorption abilities. The implementation of the TCODS coating had no significant effects in increasing sorption capacities and the sorbents transformed into the composite material decreased sorption capacity. These findings reveal the importance of examining other hydrophobic coatings and different approaches for the creation of the composite. All hair types had a higher affinity towards kerosene due to its larger viscosity compared to petroleum ether. The loose hair coated with TCODS was the best performing group followed by the loose hair itself, the composite with TCODS, and the composite being the worst performing sorbent type. The findings implicate that human hair sorbents in an unmodified form has potential use as a low cost sorbent in cleaning up oil spills and can efficiently be used several times without severe deterioration in sorption abilities for a short amount of contact time.

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