DETERMINATION OF DYNAMIC WIPING EFFICIENCY OF COTTON-BASED NONWOVEN TEXTILE SUBSTRATES FOR TOXIC CHEMICAL DECONTAMINATION

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Abstract

Recently, human health issues are surfacing up in the Gulf of Mexico due to the toxic oil associated with the deepwater horizon rig explosion. It is extremely necessary to quickly remove oil from the contaminated surfaces, skin and protective equipment used by the volunteers. Utilization of absorbent/adsorbent textiles in from of wipes and vapor adsorbent masks can reduce such health hazards posed by oil, associated polycyclic aromatic hydrocarbons (PAHs) and volatile organic compound (VOC) vapors. It is very important to evaluate various clean-up materials for their dynamic wiping efficiency and practicality of application. The cotton-based three layered wipe Fibertect® can hold toxic chemical vapors and toxic gases associated with the oil. Evaluation of the dynamic wiping efficiency of various wiping materials including cotton-based Fibertect®, shall build a platform for a comparative analysis for such materials and wipe designs. This paper shall focus on elaborating an experimental procedure to determine the dynamic wiping efficiency of various cotton-based nonwoven textile substrates for different chemical spills including oil. Detailed design & fabrication of the dynamic wiping efficiency apparatus was carried out based on ASTM standards D 6702-01 and D 6650 – 01. The results also report the dynamic wiping efficiencies for different chemicals such as water, p-xylene and motor oil. Dynamic Wiping efficiency of cotton-based nonwoven composite wipe for 50 % capacity motor oil challenge was 63.4 %. 1 m^2 of cotton-carbon nonwoven composite absorbs up to 5.94 liters of motor oil. The results have proven extremely useful in optimizing the performance of the cotton-carbon based textile substrates.

Introduction

The Gulf of Mexico oil spill has been categorized as one of the largest oil spills the world has witnessed so far. Execution of a collaborative strategy to contain, isolate, incinerate and remove the oil from wildlife, ecosystem and other contaminated terrains has been a humongous challenge for all governmental and non-governmental organizations involved. Oil booms are used to contain oil in localized water zones. Addition of dispersants and burning of oil are commonly used for remediation purposes. However, there is no standard method practiced to wipe the oil from the already contaminated surfaces of vessels, boats, oil-rig platforms, etc. There have been 143 health related cases in Louisiana due to the oil spill exposure. It is extremely necessary to remove oil from the skin and protective equipment used by the volunteers. Utilization of absorbent/adsorbent textiles in from of wipes and masks can reduce such health hazards posed by sticky oil and associated PAH vapors.

Experimental results from the nonwovens and advanced materials lab at Texas Tech University have shown that each gram of cotton-carbon composite is able to absorb 15 grams of motor oil. This result matches with the oil absorption capacity of commercially available polypropylene sorbents. (Singh V. 2010). However, there is a need to evaluate the dynamic wiping efficiency of various existing and novel textile substrates (including Fibertect®) which have a potential to be used in such an application.

This paper presents a comparative analysis of dynamic wiping efficiency of various nonwoven wipes for cleaning polar/non-polar chemicals including oil. This work is a foundation towards elaborating a technical data chart for cotton-based nonwoven composites, and optimize their wiping efficiency for an oil spill.

Materials and Methods

The first part of this project involves manufacturing of a cotton and activated carbon fiber based nonwoven composite substrate. The later part of this work consists of design & fabrication of the dynamic wiping efficiency apparatus based on ASTM standards (D6702-01; D 6650 – 01).

The manufacturing of the three layered cotton-based composite material was carried out using H1 technology needleloom. In order to maximize the chemical absorptive and adsorptive capabilities of the decontamination wipe, and to ensure next-to-skin comfort, the protective composite substrate was designed in a way that it is composed of at least three layers:

1. Pre-filter layer (cotton) 2. Middle adsorbent layer (nonwoven activated carbon) 3. Next-to-skin layer (cotton)

Discounted cotton (micronaire:4.9; maturity ratio:0.71; length: 0.364) was used to manufacture the composite wipe. Polyester (type: 40 Å; denier: 1.2 – 1.3; dtex 1.5 in – 38 mm) composite containing nonwoven activate carbon was obtained from Hobbs Bonded Fibers, Waco TX, for comparative evaluation. Activated carbon is a known sorbent because of its high porosity and surface area (Sata and Ramkumar 2006).

For the dynamic wiping apparatus a stainless steel sled of a 4.63 in x 4.63 in base dimensions, 0.375 in thickness, a curved leading edge of 0.50 in radius, and 1kg ± 10g weight, was fabricated. The apparatus design was slightly modified in a way that a nonwoven wipes can be easily attached at the bottom of the steel sled which was dragged at a constant speed (25cm/s; 5 cm/s) using a nylon string.

Experimental Method:

The Dynamic Wiping Efficiency (DWE) method requires measurements of both the dry and wet weight of a fabric. At first, the dry mass of the specimen was recorded to the nearest 0.001 g. The specimen was then clipped at the bottom of the steel sled. Using the dispenser, liquid chemical was dispensed onto a steel plate. The free end of the nylon string which was used for pulling the sled, was held by the person conducting the experiment. After applying tension on the string, it was pulled at a constant pace which results in the movement of the sled at a constant speed (25cm/s; 5 cm/s) over 1m distance. Each time when the sled reached the 1m, tension on the string was released. The test specimen was removed and its wet mass was recorded to the nearest 0.001g.

The fabric specimens (5 inch x 4.5 inch) were subjected to liquid volume challenges of 10 ml, and 50 % capacity challenge. Here, 50 % capacity challenge is nothing but half of the maximum volume of challenge liquid (p-xylene, water, motor oil, etc.) sorbed by the 5 inch x 4.5 inch ply of the wipe. The dynamic wiping efficiency (DWE) was calculated as percentage ratio of the volume of liquid sorbed (v_s) to the volume of the liquid challenged (v_c). Also, the extrinsic sorbency was calculated as the maximum volume of motor oil (density: 0.861g/ml) sorbed by $1m^2$ of the wipe fabric.

Figures and Tables:

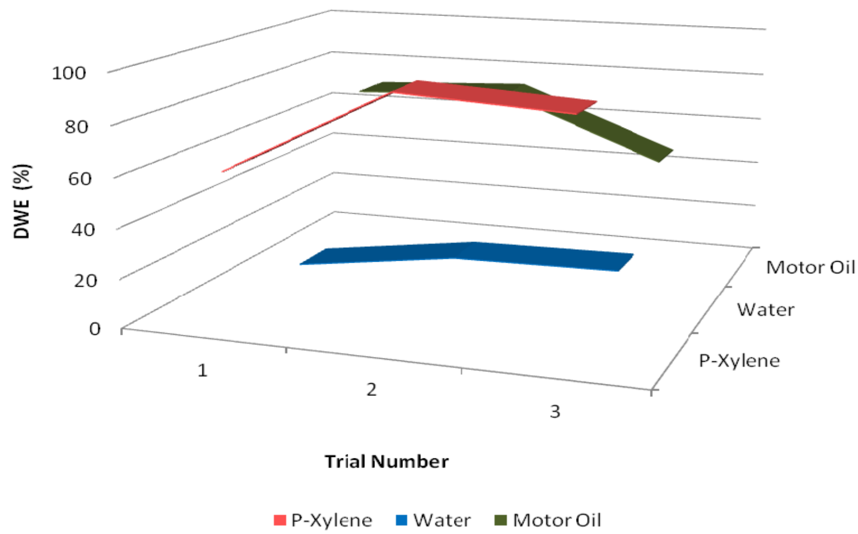
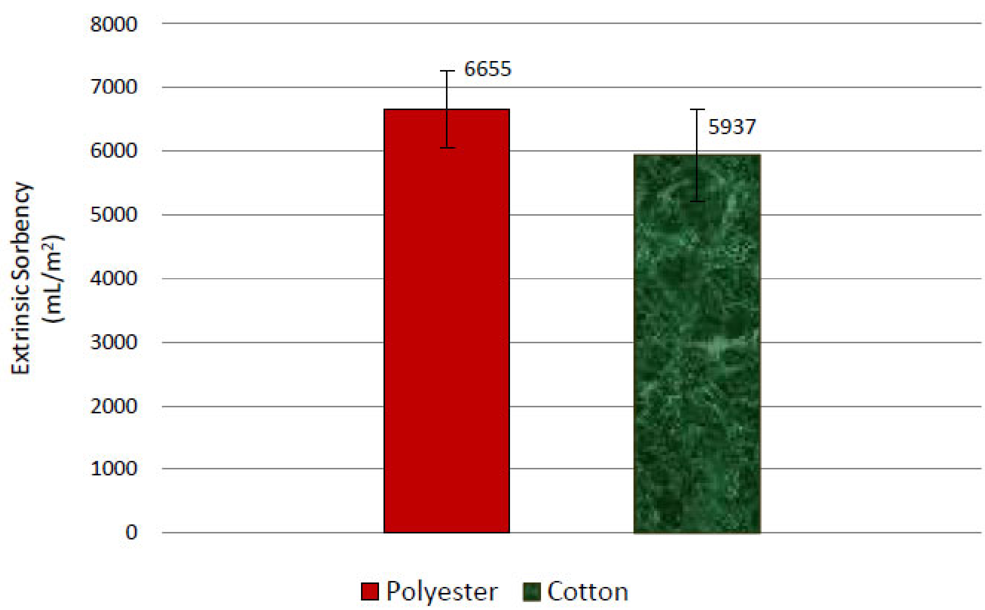


Figure 1. Dynamic Wiping Efficiency for all three trials in case of 50% capacity challenge (p-xylene;



water; motor-oil) for cotton Fibertect® ply (5 in x 4.5 in).

Figure 2. Extrinsic Sorbency for Fibertect® (polyester v/s cotton) for motor-oil challenge. No significant difference between mean values was observed ($p=0.49$; $\alpha=0.05$).

Results and Discussion

The results report the dynamic wiping efficiencies of cotton-carbon wipe Fibertect® for chemicals varying in their polarity. Highly polar chemical such as water, and non-polar chemicals such as p-xylene or motor oil, were used to investigate. It was found that cotton Fibertect® was highly selective towards sorption of non-polar chemicals such as motor oil and p-xylene. Therefore, in case of an oil-spill over water cotton Fibertect® would selectively sorb the oil over water. This also has been verified by initial testing of Fibertect® in the Gulf oil-spill region.

Unlike some previous studies which report the maximum absorption capacity of synthetic and natural fibers on a unit mass basis, this study focuses on the dynamic wiping efficiency of the wipe, which resembles a more realistic field-use scenario. DWE of cotton-based nonwoven composite wipe for 50 % capacity motor oil challenge at 25cm/s wiping speed was 63.4 %; and for 10 ml challenge the DWE was 80.1 %. When the wiping speed was lowered from 25cm/s to 5 cm/s ($p=0.73$; $\alpha=0.05$), for 10 ml motor-oil challenge, the DWE was reported to be 80.1% and 84% respectively. However, there was no significant different between the DWE mean values.

Summary

In an actual oil-spill situation, the oil may not only spread out on the water column but also on the oil rigs platforms, tankers, vessels and across various terrains, The DWE calculation represents a realistic and practical approach which takes into consideration the fact that a fabric wipe's overall performance and its DWE could vary depending on the material of the fabric and wiping speed. The DWE also varies based on the inherent properties of the chemicals involved in the spill eg: polarity, specific gravity, nature, volumetric amount etc.

Dynamic Wiping efficiency of cotton-based nonwoven composite wipe for 50 % capacity motor oil challenge was reported to be 63.4 %. 1 m^2 of cotton-carbon nonwoven composite absorbs up to 5.94 liters of motor oil. The results have proven extremely useful in optimizing the performance of the cotton-carbon based textile substrates.

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