Miscanthus sinensis (Silver Grass) Fiber as a Component of an Eco-friendly Sorbent Bag for Oil Spill Clean-up

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ABSTRACT: Oil spills are one of the most serious global, environmental problems; however, synthetic sorbents used to manage oil spills have significant environmental drawbacks due to low biodegradability. This study was conducted to determine the potential of *Miscanthus sinensis* (silver grass) as a component of an eco-friendly sorbent bag for oil spill clean-up. Randomized complete block design, a standard in agricultural experiments, was used in the study. *Miscanthus sinensis* fibers were sorted into different sizes (595 μm, 841 μm, and 2000 μm), and sorbent bags were prepared. Scanning electron microscope (SEM) was used to characterize morphology, and samples were subjected to dry and oil layer systems to measure diesel and kerosene oil sorption capacities. *Miscanthus sinensis* fiber was found to be stable and porous, exhibiting a unique bamboo-shaped structure which was sunken in the middle and protruding on both sides. No significant differences between diesel and kerosene sorption capacities were observed among the sorbent bags with *Miscanthus sinensis* fibers in dry and oil layer systems. Evaluating fiber size and sorption capacities in dry and oil layer systems, the highest diesel and kerosene oil sorption capacities were exhibited by the five hundred ninety-five micrometer *Miscanthus sinensis* fibers, followed by 841 μm and 2000 μm *Miscanthus sinensis* fibers. These results demonstrate the possibility of using *Miscanthus sinensis* as a component of eco-friendly sorbent bags. Additional research should be conducted to determine the sorption capacities of sorbent bags with Miscanthus sinensis on the other types of oil.
KEYWORDS: Oil spill; Sorbent bag; *Miscanthus sinensis*; Fiber; Sorption capacity.

INTRODUCTION

Demand for oil has increased over recent decades with oil serving as one of the most important sources of energy for modern society. Oil is used to create synthetic polymers and chemicals, and used to run vehicles, industrial plantations, and factories worldwide.[1]

Nevertheless, recent events have demonstrated that oil storage, transportation from production to consumers, and consumption entail risks of accidental oil spills in natural waterways and bodies of water.[2] The greatest contributing factors include tanker disaster, wars, equipment breakdown, natural disasters and routine operations during the transportation phase.[3] Data shows that oil spills in the last decade resulted in 24,000 tons of oil being leaked from tankers worldwide per annum.[3] In Korea in 2007, an oil spill was recorded where the tanker spilled 11,000 tons of oil.[4] In the Philippines in 2006, 500,000 L of oil leaked into the southern coastal region of Guimaras that produced damage estimated at 352 million pesos.[5] These oil spills resulted in pollution with detrimental effects on marine ecosystems and human health.[6]

The public is conscious of the environmental problems caused by oil spills. Several studies have recently been carried out to evaluate the use of booms and skimmers, oil pumping, *in-situ* burning, bioremediation, chemical dispersant and solidifier agents,[3] and synthetic sorbents like polypropylene and polyurethane foams.[7] Despite the superior sorption qualities of synthetic sorbents, they have low biodegradability. As a result, several researchers have investigated the use of organic materials as alternative sorbents to remediate oil spills with a number of studies showing the importance of plant fibers as alternative sorbent materials.[8,9] Abejero et al. (2013),[10] determined that natural kapok fibers packed in nylon nets have potential to be used as a sorbent for oil spills. With a limited amount of research dealing with oil spill management using natural fibers found in the Philippines, the authors of this paper wanted to address the challenge of exploiting local plants as possible sources of natural fibers for oil spill sorption.

Given this challenge, the research authors conducted a study that investigated the potential of *Miscanthus sinensis* (silver grass) fiber as an eco-friendly component of sorbent bags for oil spill clean-up. *Miscanthus sinensis* is a coarse perennial, herbaceous plant introduced to the Philippines during the early 20th century.[11] It contains cellulose, pentosans, extractives, ash and Klason lignin.[12] The research authors wanted to investigate and share a more practical and economical way to manage oil spills and to help the community by promoting green innovation to control oil spills using *Miscanthus sinensis*, a randomly distributed and not-widely-used weed in the Philippines. *Miscanthus sinensis* may provide considerable benefits as a natural plant with few side-effects and potentially no significant difference in sorption capacity compared to commercially used synthetic sorbents with negative impact on the environment as well as on non-target organisms.

The main objective of the study was to determine the potential of *Miscanthus sinensis* in an eco-friendly sorbent bag for oil spills. Specifically, the study determined the diesel and kerosene oil sorption capacities of different sizes (595 μm, 841 μm, and 2000 μm) of *Miscanthus sinensis* fibers in dry and oil

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layer systems. The authors also sought to determine the level of significance of the differences among the sorption capacities of all control and treatment samples used in each system.

RESULTS AND DISCUSSION

Morphological characterization analysis of *Miscanthus sinensis* (silver grass) fiber under scanning electron microscope (SEM) is shown in Figure 1. The study was limited to a magnification of 30 μm of the *Miscanthus sinensis*.

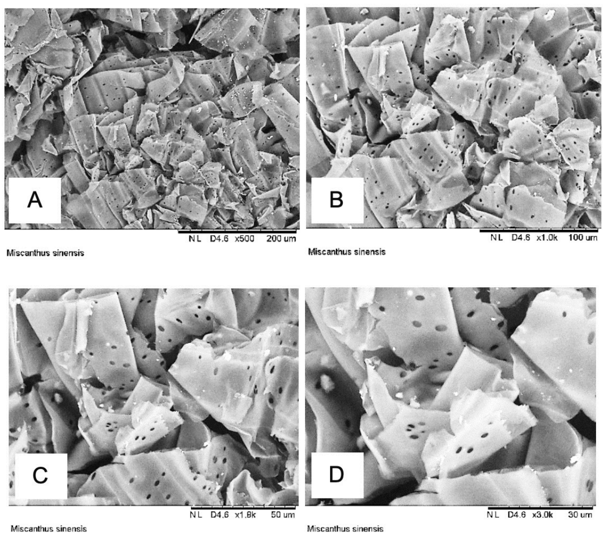

Figure 1. (A–D) Scanning electron microscope (SEM) images of Miscanthus sinensis (silver grass) fiber.

Table 1. Diesel oil sorption capacity of sorbent bags in dry systems.

Sorption Capacity (g/g)			
595 μm	841 μm	2000 μm	Polypropylene
3.91	3.29	2.00	4.14

Polypropylene also exhibited the highest diesel oil sorption capacity in oil layer system with 1.83 g/g, followed by 595 μm and 841 μm *Miscanthus sinensis* fibers with 1.33 g/g and 0.83 g/g, respectively. The least sorption capacity was found with 2000 μm *Miscanthus sinensis* fibers absorbing 0.27 g/g as shown in Table 2.

Table 2. Diesel oil sorption capacity of sorbent bags in oil layer systems.

Sorption Capacity (g/g)			
595 μm	841 μm	2000 μm	Polypropylene
1.33	0.83	0.27	1.83

Meanwhile, in the kerosene oil dry system, as shown in Table 3, results obtained showed that polypropylene had the highest sorption capacity with 4.48 g/g, followed by 595 μm, and 841 μm *Miscanthus sinensis* with 3.33 g/g and 2.81 g/g, respectively. Two thousand micrometer *Miscanthus sinensis* fibers was identified to have the least sorption capacity with 2.33 g/g

Table 3. Kerosene oil sorption capacity of sorbent bags in a dry system.

Sorption Capacity (g/g)			
595 μm	841 μm	2000 μm	Polypropylene
3.33	2.81	2.33	4.48

Polypropylene also registered the highest kerosene oil sorption capacity in the oil layer system with 1.33 g/g. It was followed by 595 μm and 841 μm *Miscanthus sinensis* fibers with 1.00 g/g and 0.83, respectively. The least sorption capacity was found in sorbent bag with 2000 μm fibers with 0.43 g/g. The results of kerosene oil sorption capacity of sorbent bags in oil layer system are shown in Table 4.

Table 4. Kerosene oil sorption capacity of sorbent bags in oil layer systems.

Sorption Capacity (g/g)			
595 μm	841 μm	2000 μm	Polypropylene
1.00	0.83	0.43	1.33

Bioactive components such as cellulose and lignocellulos have high potential for oil sorption. *Miscanthus sinensis* contains cellulose, one of the favorable components of an organic sorbent.[12] The sorption capacity of organic sorbents is attributed to its natural fiber that is mainly composed of cellulose. Through capillary action, these hollow tubular structures cause the oil to be adsorbed.[10] Furthermore, greater sorption capacities with smaller sizes of *Miscanthus sinensis* fiber was observed which corresponds to the improvement of sorption capacity when the particles size decrease due to increasing surface area.[13]

The significant variations in the oil sorption capacities among sorbent bags in each system were investigated using two-way Analysis of Variance (ANOVA)· The results of the ANOVA indicate that significant differences between the diesel and kerosene oil sorption capacities of sorbent bags used was observed in both dry and oil layer systems· The results of two-way ANOVA are shown in Tables 5 and 6·

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Table 5. Difference between the diesel and kerosene oil sorption capacities of *Miscanthus sinensis* (silver grass) fibers and standard sorbent agent used in dry systems using two–way ANOVA.

Source of Variation	SS	Df	Ms	F	P	F crit	Remarks
Total	20.19	23	-	-	-	-	-
Between Oils	0.05	1	0.05	0.21	0.66	4.49	**NOT SIGNIFICANT**
Among Sorbent Bags	13	3	4.33	16.56	3.66E-05	3.24	**SIGNIFICANT**
Oils x Sorbent Bags	2.94	3	0.98	3.75	0.03	3.24	**SIGNIFICANT**

Table 6. Difference between the diesel and kerosene oil sorption capacities of *Miscanthus sinensis* (silver grass) fibers and standard sorbent agent used in oil layer systems using two–way ANOVA.

Source of Variation	SS	Df	Ms	F	P	F crit	Remarks
Total	20.19	23	-	-	-	-	-
Between Oils	0.002	1	0.002	0.004	0.95	4.49	**NOT SIGNIFICANT**
Among Sorbent Bags	5.87	3	1.96	3.84	0.03	3.24	**SIGNIFICANT**
Oils x Sorbent Bags	1.12	3	0.37	0.73	0.55	3.24	**NOT SIGNIFICANT**

Since there are significant differences among the oil sorption capacities of sorbent bags in dry and oil layer systems, Tukey's HSD was employed to determine which among the sorbent bags had significant variations.

Table 7. Tukey's HSD test for the oil sorption capacities of sorbent bags A, B, C and D in dry systems.

Sorbent Bags	q_s	q'	Remarks
A vs B	7.14	4.49	**SIGNIFICANT**
A vs C	4.74		**SIGNIFICANT**
A vs D	4.05		**NOT SIGNIFICANT**
B vs C	2.40		**NOT SIGNIFICANT**
B vs D	11.19		**SIGNIFICANT**
C vs D	8.79		**SIGNIFICANT**

Legend

A - 595 µm *Miscanthus sinensis* (silver grass) fibers
B - 841 µm *Miscanthus sinensis* (silver grass) fibers
C - 2000 µm *Miscanthus sinensis* (silver grass) fibers
D – polypropylene

As indicated in Table 7, there was no significant difference between the diesel and kerosene oil sorption capacities of sorbent bags with 595 µm *Miscanthus sinensis* fibers and polypropylene, and between 841 µm and 2000 µm *Miscanthus sinensis* fibers. Nevertheless, results showed that there was a significant difference between the diesel and kerosene oil sorption capacities of 595 µm and 841 µm *Miscanthus sinensis* fibers; 595 µm and 2000 µm *Miscanthus sinensis* fibers; 841 µm *Miscanthus sinensis* fibers and polypropylene and; 2000 µm *Miscanthus sinensis* fibers and polypropylene.

Table 8. Tukey's HSD test for the oil sorption capacities of sorbent bags A, B, C and D in oil layer systems.

Sorbent Bags	q_s	q'	Remarks
A vs B	2.67	4.49	**NOT SIGNIFICANT**
A vs C	3.45		**NOT SIGNIFICANT**
A vs D	1.75		**NOT SIGNIFICANT**
B vs C	0.78		**NOT SIGNIFICANT**
B vs D	4.42		**NOT SIGNIFICANT**
C vs D	5.20		**SIGNIFICANT**

Legend

A - 595 µm *Miscanthus sinensis* (silver grass) fibers
B - 841 µm *Miscanthus sinensis* (silver grass) fibers
C - 2000 µm *Miscanthus sinensis* (silver grass) fibers
D – polypropylene

As shown in Table 8, there was no significant difference between the diesel and kerosene oil sorption capacities of 595 µm and 841 µm *Miscanthus sinensis* fibers; 595 µm and 2000 µm *Miscanthus sinensis* fibers; 595 µm *Miscanthus sinensis* fibers and polypropylene; 841 µm and 2000 µm *Miscanthus sinensis* fibers and; 841 µm *Miscanthus sinensis* fibers and polypropylene. Nevertheless, results showed that there was a significant difference between the diesel and kerosene oil sorption capacities of 2000 µm *Miscanthus sinensis* fibers and polypropylene.

CONCLUSION

Based from the results of the study, *Miscanthus sinensis* fibers can be used as eco-friendly sorbent bag for oil spill clean-up. It was noted that the smaller size of *Miscanthus sinensis* fiber was more effective in diesel and kerosene sorption in dry and oil layer systems. It was found that in diesel and kerosene sorption capacities in dry systems, 841 µm *Miscanthus sinensis* fiber is as good as 2000 µm *Miscanthus sinensis* fiber. It was also found that in diesel and kerosene sorption in oil layer systems, 549 µm *Miscanthus sinensis* fiber is as good as 841 µm and 2000 µm *Miscanthus* sinensis fiber.

The sorption capacities of *Miscanthus sinensis* fibers are attributed to its porous characteristics and its cellulose composition, good properties of an organic sorbent. The findings of the study have demonstrated the possibility of using *Miscanthus sinensis* fibers as a component of eco-friendly sorbent bags for use in oil spill remediation.

METHODS

A. Collection of Miscanthus sinensis *(silver grass)*. Three kilos of *Miscanthus sinensis* (silver grass) were collected from a vacant lot at Barangay Molino, Bacoor City. The collected leaves were placed in a plastic bag and prepared for laboratory use.

B. Preparation of Miscanthus sinensis *(silver grass) fibers.* Collected *Miscanthus sinensis* (silver grass) fibers were washed thoroughly using tap water to remove all debris, cut using scissors, and dried in an oven at 80°C for three hours. After drying, fibers were crushed using an electric blender and sieved into different sizes using 595 µm, 841 µm, 2000 µm sieves.

C. Morphological characterization analysis. Morphological structure of *Miscanthus sinensis* (silver grass) was analyzed by scanning electron microscope (Hitachi TM3000) with magnifications of 200 μm, 100 μm, 50 μm and 30 μm at the University of Santo Tomas, Manila. The samples were mounted onto round, stainless steel holders using double-sided, conductive adhesive tape.

D. Purchasing of materials and setting up of containers. Three liters of Petron diesel (density 0.86 g/cm^3) and kerosene oil (density 0.81 g/cm^3) were collected from Brgy. Gawaran, a mechanical shop in Bacoor City.[14] A one-meter nylon net was purchased in the market at Antonio S. Arnaiz Ave., Pasay City. The net was measured using a ruler, and thirty-six 6.5 cm x 12 cm x 1 cm nylon net bags were sewed. Forty-eight 250 mL beakers were set up to determine the oil sorption capacity of sorbent bags in each system.

E. Preparation of sorbent bag with Miscanthus sinensis (silver grass) fibers. Seven grams of different-sized (595 μm, 541 μm, 2000 μm), natural fibers from Miscanthus sinensis (silver grass) were weighed using a digital balance. Fibers were packed in nylon net bags with three replicates each per test. Polypropylene (The Liquidator), purchased in the market at Dona Soledad Ave., Parañaque City, was used as the positive control for the study.

F. Diesel oil sorption capacity of sorbent bags with Miscanthus sinensis (silver grass) fibers.

a. Dry system. Fifty milliliters of diesel oil were poured into a 250 mL beaker. Each sorbent bag was soaked in the container for 60 min. After the sorption time, the bag was lifted out and hung over the beaker for 15 minutes to allow unabsorbed diesel oil to separate.

b. Oil layer system. One hundred milliliters of artificial sea water (3.5% NaCl), prepared by dissolving 35 g NaCl in 1000 mL of distilled water, and 10 mL of diesel oil were poured in a 250 mL beaker. Each packed sorbent bag was soaked in the beaker for 60 min. After the sorption time, the bags were lifted out and hung over the beaker for 15 min to allow unabsorbed diesel oil to separate. Bags were then placed in a beaker filled with 50 mL n-hexane where the absorbed oil was dissolved, and the water sank to the bottom of graduated cylinder due to its higher density.

G. Kerosene oil sorption capacity of sorbent bags with Miscanthus sinensis (silver grass) fibers

a. Dry system. Fifty milliliters of kerosene oil were poured into a 250 mL beaker. Each sorbent bag was soaked in the container for 60 min. After the sorption time, it was lifted out and was hung over the beaker for 15 min to allow unabsorbed kerosene oil to separate.

b. Oil layer system. One hundred milliliters of artificial sea water (3.5% NaCl), prepared by dissolving 35 g NaCL in 1000 mL of distilled water, and 10 mL of kerosene oil were poured in a 250 mL beaker. Each packed sorbent bag was soaked in the beaker for 60 min. After the sorption time, it was lifted out and was hung over the beaker for 15 min to allow unabsorbed kerosene oil to separate. Bags were then placed in a beaker filled with 50 mL n-hexane where the absorbed oil was dissolved, and the water sank to the bottom of graduated cylinder due to its higher density.

H. Monitoring of the set-up and recording of the data. A digital balance was used to measure the mass of samples before sorption and the mass of oil containing samples (after dripping). The quantity of water absorbed by the sample (after dripping) was also measured using a beaker.

I. Statistical Analysis. The diesel and kerosene oil sorption capacities of sorbent bags in dry and oil layer systems were calculated according to the equations adapted from Dong, et al. (2015).[7]

where m_f is the sample mass before sorption (g), m_{f15} is the mass of the oil containing sample after 15 min of dripping (g), and m_{w15} is the mass of the water absorbed by the sample after 15 min of dripping.

Data were statistically analyzed using Two-way Analysis of Variance (ANOVA). Two-way ANOVA was used to determine the statistical significance among the sizes of *Miscanthus sinensis* (silver grass) fibers. Tukey's HSD test was used to determine the post-statistical difference between sorbent bags used in the study.

Equation 1. Sorption Capacity in Dry System

$$\text{Oil sorption capacity} = \frac{m_{f15} - m_f}{m_f}$$

Equation 2. Sorption Capacity in Oil Layer System

$$\text{Oil sorption capacity} = \frac{m_{f15} - m_f - m_{w15}}{m_{w15}}$$

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