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A study on water hyacinth *Eichhornia crassipes* as oil sorbent

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Abstract: The sorption of diesel, lubricant and castor oils onto different parts (root, stem and leaf) of the dry biomass water hyacinth was studied at the laboratory scale. The parts of the aquapyte water hyacinth (*Eichhornia Crassipes*) were characterized by physico-chemical methods and the characteristics were used to elucidate the oil sorption process. Hydrophobicity, wettability (capillarity), buoyancy and sorption capacity of oils in the presence/ absence of water were studied to evaluate the suitability of the sorbent for application. In all the three sorbents, the oil sorption capacity increases with the increase of oil film thickness. However of the three parts, the stem has a greater sorption capacity of 9.3, 7.8 and 11.08 g/g for the three oils such as diesel, lubricant and castor oils respectively, even though the root of water hyacinth showed a higher hydrophobicity and surface area. These sorption capacities are comparable with widely used commercial oil sorbent such as nonwoven polypropylene which has a sorption capacity in the range of 10-16 g/g.

Keywords: Buoyancy, *Eichhornia* ***c****rassipes*, Hydrophobicity, Oil spillage, Sorption, Wettability

INTRODUCTION

Oil spillage and chemical leakage frequently occur during extraction, transportation, transfer and storage. They cause a loss of energy source and have a major negative effect on natural flora and fauna and on human health (Zhu *et al*., 2011a,b; Rebeiro *et al*., 2000). The conventional methods for the removal of oil spillage are oil skimming by oil skimming vessels, combustion and sorption. Among these methods the sorption process is desirable due to easy handling and availability of variety of adsorbents (Ceylan *et al*., 2009). Some of the adsorbents widely used in practical applications (Zhu *et al.*, 2011b) are sponges, wool-based nonwoven materials, polyvinyl chloride/ polystyrene fibres, butyl rubber, zeolite, activated carbon, organo clay, hair, wool, straws (Sun *et al*., 2002), wood (Choi and Cloud, 1992), cotton grass fibre (Suni *et al*., 2004), pine bark (Haussard *et al*., 2003), pith bagasse (Hussein *et al*., 2008), coconut shell (Amuda and Ibrahim, 2006) etc. It has also been shown that some agricultural products such as straws, cellulosic fibre, milk weed, and cotton fiber significantly absorb more oil than the synthetic organic materials used commercially (Sun *et al*., 2002). However, these products are not given adequate attention in the oil industry.

The present study concerns the sorption (absorption/ adsorption) of organic oils onto the dry biomass water hyacinth (*Eichhornia crassipes*) (a freshwater aquaphyte) which has good hydrophobicity, high uptake capacity, buoyancy and biodegradability essential for oil sorption. It is found in rivers and ponds. It grows and reproduces at a very high rate and is considered the worst aquatic plant (El-Sayed, 2003). The dense mats of water hyacinth float on the water surface, blocking navigation and interfere with irrigation, fishing, recreation, and power generation. These mats also prevent sunlight penetration and reduce the aeration of water, leading to oxygen deficiency. They competitively exclude submerged plants and reduce biological diversity. The control of water hyacinth invasion, mainly by mechanical collection and dumping is expensive and presents a solid waste problem to get rid of the water hyacinth dumps. Much research has been carried out for the best utility of dumped water hyacinth. The potential of the aquaphyte as a low cost alternative for the treatment of oil effluents and spills has been attempted in this study.

MATERIALS AND METHODS

Water hyacinth (*E. crassipes)* was collected locally from the Tamirabarani river bed. It was washed several times with tap water and finally with double distilled water to remove sand and other coarse impurities. Then it was dried in sunlight for 5 days. The root, the stem and the leaves of the dried plant were powdered separately and later sieved to get particles' the size of

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75 microns ASTM (American Standard for Testing of Materials). Kept intact in polyethylene containers, the root, the stem and the leaf portion were used for adsorption study as such in the native state without further processing. The surface area of the root, the stem and the leaf of the biomass water hyacinth was determined by the Methylene blue method (Palit and Moulik, 2000).

Tested oils: Three types of oils namely diesel oil, lubricant oil and castor oil were used to investigate the sorption characteristics of root, stem and leaves of the biomass. Physical characteristics of the oils used in sorption study are given (Table 1).

Methodologies of oil sorption experiments

Buoyancy test: The sorbents that are used for water spills should undergo the buoyancy test (Rebeiro *et al.*, 2000). The buoyancy test was carried out using literature procedure (Radetic *et al.*, 2008) by static system. 1g of the sorbent was gently and evenly placed on the surface of 250 mL water in a 500 mL beaker for 15 min. Then the floated sorbent mass was measured to calculate the buoyancy percentage.

Hydrophobicity: The tendency of the leaf, the stem and the root of the biomass water hyacinth to be removed from the water phase into a non-polar phase was determined by testing the partition of the biomass between aqueous and hexane phases (Rebeiro *et al.*, 2000). In this experimentation, a sample of approximately 1.0 g was placed in a beaker and was stirred for 3 min. The mixture was then let stand for 5 min, the time necessary for the separation of the phases. The quantity of material transferred to the organic phases was determined by filtration followed by subsequent drying and weighing. The results are expressed in terms of the proportion of material transferred to the organic phase or remained at the interface. This value is an estimation of the degree of hydrophobicity of the biomass.

Wettability: The wettability of biomass by both oil and water, as expressed in terms of capillary rise, was determined by using an experimental procedure (Rebeiro *et al.*, 2000) based on the rate and amount of liquid rise in a packed bed of particle size 75 microns of the leaf, the stem and the root biomass of water hyacinth. The 75 micron powder prepared by grinding and screening, was manually packed in a glass tube (1cm inner diameter and 40 cm long) and closed at its lower end with a cotton frit. This column was then dipped in a beaker containing the liquid (hexane or water) and the liquid rise was measured as a function of time. The time t = 0 was taken when the levels in the tube and in the beaker was the same.

Sorption capacities of the oils onto the biomass in the absence of water: For the determination of the sorption capacity of the oils onto the biomass in the absence of water following the procedure (Rebeiro *et al.*, 2000; Radetic *et al.*, 2008). All the tests were performed at 27 ± 4^{0}C. In order to analyze the oil sorption capacity of leaf, stem and root of biomass water hyacinth sorbent in oil without water, 1.0 g of sorbent was placed on top of 100 ml of oil in a glass beaker. After 60 min of sorption, the oil was drained for 2 min and the wet sorbent was weighed. The oil sorption capacity (Choi and Cloud, 1992) of the sorbent was determined by the following equation (1)

$$q = [m_f - (m_o + m_w)]/ m_o \qquad (1)$$

Where, q is the sorption capacity (g/g), m_f is the weight of the sorbent after 2 min of drainage (g), m_o is the initial weight of the sorbent (g), and m_w is the weight of the water (g). It is found that oil without any water is a medium where m_w is equal to zero.

Sorption capacities of the oils onto the biomass in the presence of water: For determination of the relations between oil/water selectivity and oil thickness in the water surface, different volumes of the oil (lubricant oil, castor oil and diesel) were poured onto 100 ml of sea water in a series of 250 ml glass beakers. The oil thicknesses were found to be 0.5, 1.3, 1.5, 2.6 and 2.8 cm respectively. After attaining a steady state, 1.0 g water hyacinth biomass was placed in the beakers. After 60 min of sorption, the wet sorbent was removed, drained for 2 min, and weighed. The saturated sorbent was squeezed. Then the liquids recovered from the sorbent were centrifuged according to the standard method D4007-8I. The oil capacity of the sorbent was determined by equation (1).

RESULTS AND DISCUSSION

Characterisation of water hyacinth (*E. crassipes*): Table 2 presents the results of the physico-chemical characterization of the root, the stem and the leaf of the biomass water hyacinth. The root of water hyacinth had a higher surface area than the stem and the leaf. The surface morphologies of the root, the stem and the leaf of water hyacinth are shown in Fig. 1. It can be seen that the surface morphologies displayed a smooth surface caused by different micro structures without

Table 1. Characteristics of oils used in sorption study.

Oil	Density (g/ml)	Viscosity (pa/sec)
Diesel	0.844	4.401
Lubricant oil	0.850	5.153
Castor oil	0.961	2.420

Table 2. Characteristics of the parts of the adsorbent water hyacinth (75 micron).

Parameter	Stem	Leaf	Root
Bulk density (g/cc)	0.0139	0.0278	0.031
Particle density (g/cc)	0.0078	0.0125	0.023
Pore space volume (ml)	3.2	4.0	2.200
Surface area (m^2/g)	5.4	10.2	77.88
Pore volume (cm^3)	17.78	22.22	13.75
Buoyancy (%)	40.1	12.5	37.9
Hydrophobicity (%)	22	2.1	15.1

Table 3. Oil sorption capacity of the parts of water hyacinth in the absence of water.

Oil	Sorption Capacity (g/g)		
	Root	**Stem**	**Leaf**
Diesel	3.105	9.010	4.401
Lubricant oil	4.643	9.289	5.153
Castor oil	6.300	11.08	4.92

Table 4. Oil sorption capacity of the parts of water hyacinth in the presence of water.

Oil	Sorption Capacity (g/g)		
	Root	**Stem**	**Leaf**
Diesel	3.058	8.066	3.466
Lubricant oil	4.434	8.560	3.631
Castor oil	6.004	10.310	4.120

any ripple due to the coverage of plant wax.

Buoyancy test: The buoyancy test showed that the stem had higher percentage of buoyancy than the leaf and the root of biomass water hyacinth. The hydrophilicity test showed that the root part had higher percentage of hydrophilicity than the stem and the leaf of biomass water hyacinth.

Capillary rise: Figs. 2 and 3 showed the water and hexane capillary rise respectively through the stem, the leaf and the root of the biomass water hyacinth. The water capillary rise showed that the root part was more hydrophilic than the stem and the leaf of biomass water hyacinth. The hexane capillary rise showed that leaf was more hydrophobic than the stem and the root of biomass water hyacinth.

Oil sorption capacity of parts of the biomass water hyacinth in the absence of water: Table 3 presents the results of the sorption of diesel, castor oil and lubricant oils onto the root, stem and leaf of water hyacinth biomass in the absence of water. The sorption capacity of castor oil was greater than the lubricant and diesel oils onto the biomass stem, leaf and root of water hyacinth. This may be due to the increased viscosity of the pollutant which decreases the rate of sorption (Ceylan *et al*., 2009). The sorption capacity of the stem part was higher than the root and the leaf parts for all the three oils.

Oil sorption capacity of parts of the biomass water hyacinth in the presence of water: Sorption selectivity between oils and water is an important parameter for oil sorbent used in the spill cleanup on the water surface. The oil sorption capacities of the three parts, the root, the stem and the leaf of biomass water hyacinth in the presence of oil over water baths containing different thicknesses of oil film for diesel oil, castor oil and lubricant oil are given in figs. 4-6. The amount of

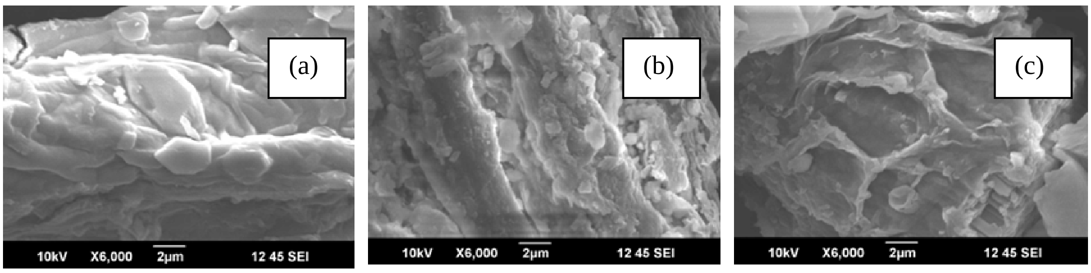

Fig. 1. *SEM images of (a) leaf (b) root (c) stem of the biomass water hyacinth.*

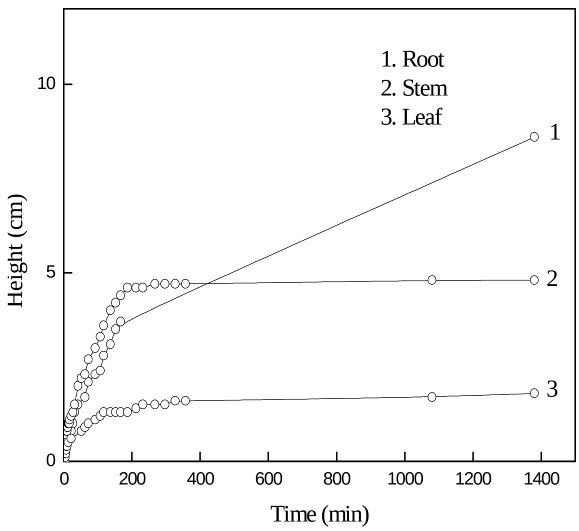

Fig.2. *Water capillary rise of the root, the stem and the leaf of the biomass water hyacinth.*

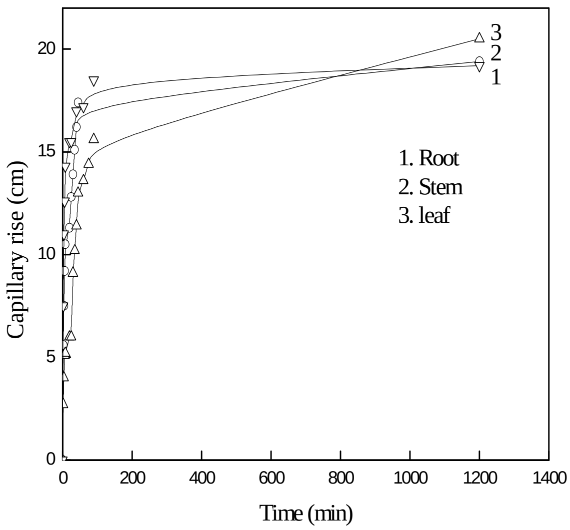

Fig.3. *Hexane capillary rise of the root, the stem and the leaf of the biomass water hyacinth.*

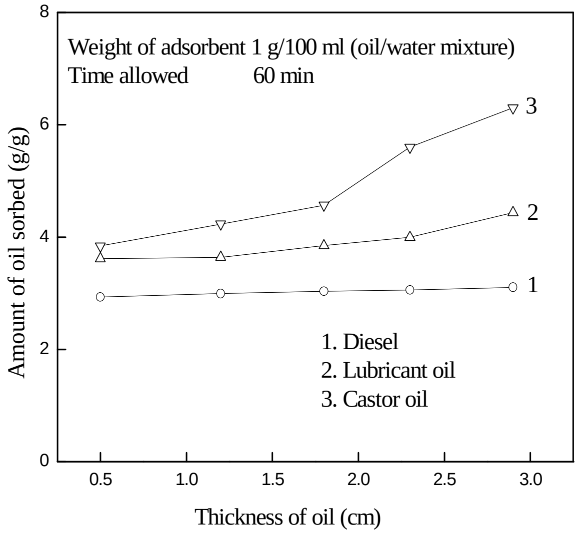

Fig. 4. *Oil sorption capacity of the root of biomass water hyacinth in the presence of water.*

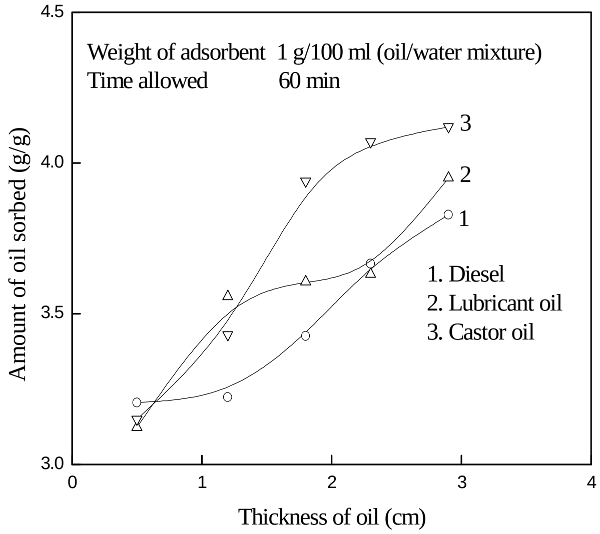

Fig. 5. *Oil sorption capacity of the leaf of the biomass water hyacinth in the presence of water.*

water pickup is low, which allows the indication of sorbent selectivity between oil and water. As shown in these figures the oil sorption capacity of the sorbents increases with the increase of oil film thickness until the sorbent is saturated with oil. At low thickness of oil spilled over water, almost the entire amount of added oil can be picked up by the sorbent. In oil/water mixture systems, the maximum oil capacity of the biomass stem of water hyacinth onto the diesel oil, lubricant oil and castor oil is given in Table 4. The sorption capacity of the stem part is higher than the root and the leaf parts for all the three oils. There is a difference in oil sorption capacities for pure oil and oil/water mixture system. This may be due to the absorption of water over oil in the pores of the leaf, the stem and the root.

Oil sorption mechanisms: The mechanism of oil sorption by sorbents can be adsorption, absorption, capillary action, or a combination of these (Radetic *et al*., 2008). The adsorption is based on the specific surface area of the adsorbent and the hydrophobic interaction between the adsorbate. This mechanism is a function of the hydrophobicity of the sorbent, the porosity of the sorbent and the volume of the sorbent. In many cases the sorption of non polar hydrocarbons occurs through a combination of both mechanisms. Thus, both the capillarity and the hydrophobicity of the leaf, the stem and the root of biomass water hyacinth, contribute to the total oil sorption. The relative significance of these mechanisms depends on the properties of the sorbent and sorbate.

Conclusion

The results obtained in this study showed the stem, the leaf and the root of the biomass water hyacinth, have a good oil sorption capacity. The parts of the bio material showed a rapid oil sorption and a high sorption capacity, high degree of hydrophobicity and low water uptake make water hyacinth a suitable alternative to traditional synthetic oil sorbents applied

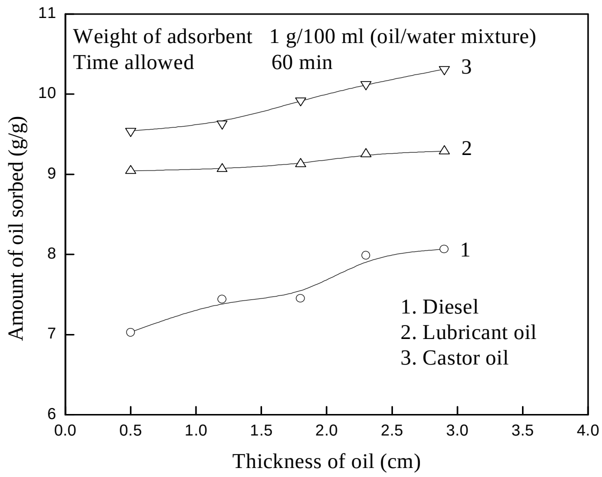

Fig. 6. *Oil sorption capacity of the stem of the biomass water hyacinth in the presence of water.*

to the oil recovery in the absence/presence of water. The material is inexpensive and abundantly available in tropical regions but the expensive control of water hyacinth invasion by mechanical collection, dumping and solid waste problems can be reduced by using it as an oil sorbent. Thus the findings project the inference that the stem, the leaf and the root of the biomass water hyacinth can be deemed low cost yet efficient oil sorbent.

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