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Optimization of Crude Oil Sorption by Particle Size Variation of a Composite Constituent

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Abstract

Crude oil spills globally and especially in the Niger Delta region of Nigeria have caused a lot of environmental problems resulting to severe health issues. Exploring ways of increasing the efficiency of clean up processes will result to optimized effects. The optimization of a clean-up process was explored by varying the particle size of a constituent of the absorbing composites. The composites were prepared using wastes- wood saw dust, high density polyethylene and egg shell combined in two different ratios, 1:1:1 and 2:1:1 by mass with different particle sizes of the wood saw dust (0.180mm, 0.300mm & 0.600mm). They were put into an extruding machine, a Jombo Extruder 300, at a temperature of 250°C to bind the components together and the products (in molten form) were collected in receiving molds of the same dimensions; length of 29cm, width of 14cm and thickness of 1.5cm. The prepared composites were immersed in simulated crude oil spill in water over a period of time to determine the amount of crude oil absorbed. Though there was an attenuation in the absorption of the crude oil over a time period, but the biggest particle size of 0.600mm absorbed the highest amount of crude oil in the two different composites ratios, 0.18kg and 0.13kg respectively while the particle size of 0.300mm absorbed the least amount of crude oil, 0.08kg and 0.03kg respectively.

Keywords: Oil spill, Composite, Absorption, Optimization, Particle size

1. Introduction

The sources of water pollution are varied, involving almost every significant human activity. Most generally done is the direct dumping of wastes; sewage, and industrial effluents. In areas of crude oil exploration and exploitation, oil spillage is known to be a major environmental problem.

In Nigeria, most especially in the Niger Delta, oil spillage is rampant. It is reported that oil spillage has caused constant threat to farmlands, crop plants and forest tree species (Ogri, 2001). Oil spills cause epidemics of many diseases because spilled oils contain many toxic substances (Liao et al., 2015), which could be injurious to human health. The direct effect on the ecosystem includes damage of fur and feathers of birds, making them prone to death by freezing. It also hampers movement of vessels on water, thereby impairing economic activities.

As a result of these effects on the ecosystem, the release of oil into the environment has caused serious environmental concern and attracted public attention (Retallack et al., 2016). In order to contain crude oil spillage, physical, chemical and biological methods have been employed. Efforts such as the application of chemical dispersants, skimming of the surface oils, application of biological oil agents and inoculating the spilled areas with relevant microbes, adsorption of the oil on a recoverable medium are the outcomes of intensive research. The latter is one of the less expensive methods of oil spill containment measures because its bulk is made from waste materials. The waste materials mostly used are wood saw dust, egg shell and polyethylene materials.

Sawdust or wood dust is a byproduct of cutting, grinding or otherwise pulverizing wood with a saw or other tools; it is composed of fine particles of wood. It contains various organic compounds (lignin, cellulose and hemicelluloses) with polyphenolic groups that could bind materials through different mechanisms. Bryant et al;1992 showed that some adsorption processes by red fire sawdust take place primarily on components such as lignin or tannin rather than onto the cellulose backbone of the sawdust. Further studies by Sabadell and Krack 1975 investigated several wood types for adsorption.

The egg-shell is constituted of a number of layers of calcium carbonate. The top layer is the vertical layer that is about 5-8µm and is enclosed by the organic cuticle (Chojnacka, 2005). The porosity of eggshell as elucidated by scanning electron microscope (Carvalho et al., 2011), renders it as a remarkable material that could find use in the making of adsorption materials(Koumanova et al., 2002, Rohaizar et al., 2013, , Zulfikar and Setiyanto 2013, Putra et al., 2014 and Kumaraswamy et al; 2015.

Polyethylene, $[-CH_2-CH_2-]_n$ consists of linear or branched chain molecule having strong intramolecular bond but weak intermolecular bonds. It can be reshaped by application of heat and pressure and is either semi crystalline or amorphous in structure. They are mostly used as binders because of the two free bonds and ability to form a cross-link (Moore, 1963)

These materials which were hitherto, wastes of little or no economic values had been harnessed in the formulation of composites for crude oil adsorption and absorption with sorption capacity of about 21.0 %(Ibe and Otanocha, 2017). Therefore, increasing its sorption capacity will ultimately lead to an optimised efficiency in crude oil spill containment.

The aim of this work therefore is to explore some structural adjustments in the sorbent matrix (composite) and the resulting effects on crude oil sorption.

2. Materials and Methods

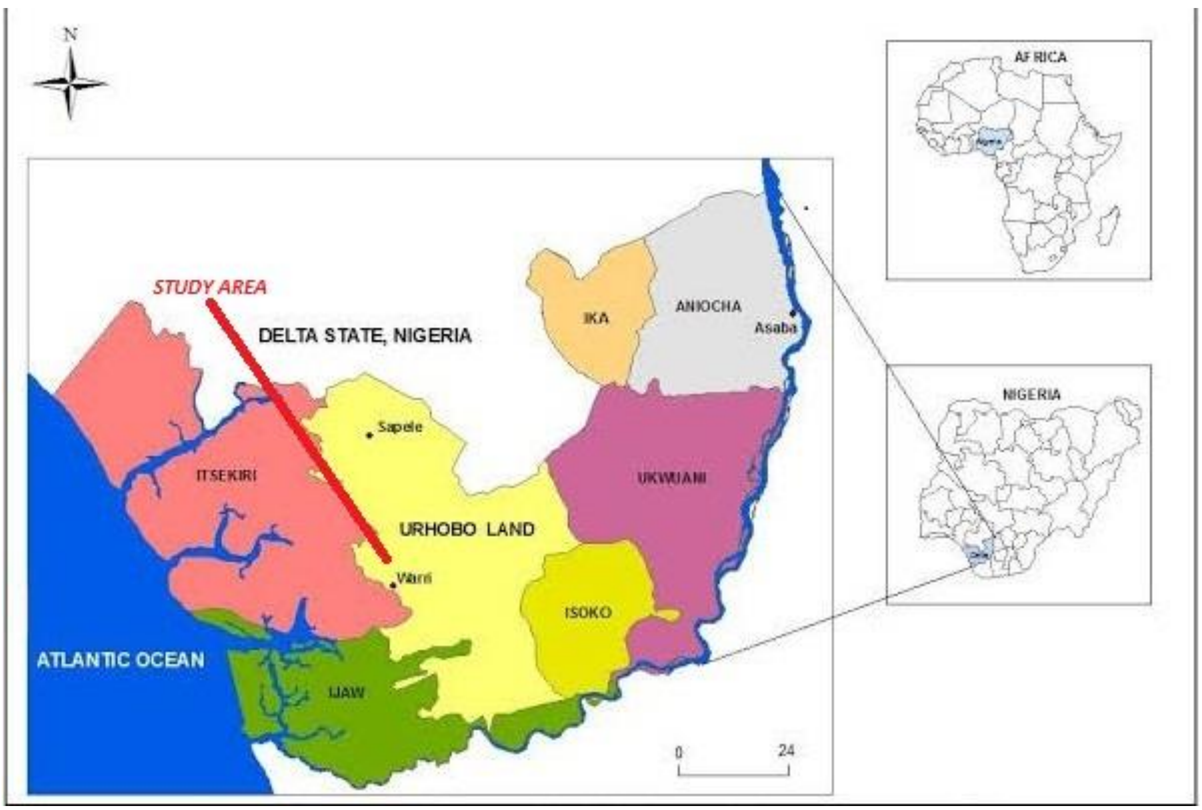

Fig 1: Map showing sample location

2.1 Sampling of WastesThe waste high density polyethylene (HDPE) bags were sourced from waste dump sites within the premises of Federal University of Petroleum

Resources, Effurun (FUPRE) , Delta State, Nigeria while the wood saw dust was obtained from the saw dust dune of Udu saw mill in Udu Local Government Area of Delta State , and the egg shells obtained from a grilled meat(Suya) seller at FUPRE Junction all in Urhobo Land within the coordinates, 5°34“23'N and 5°50“38'E.

Fig. 2: FUPRE Waste Dump Site

Fig. 3: Udu Saw Dust Dune

2.2 Sample Preparation

Waste high density polyethylene bag

The collected waste polythene bags were washed with ordinary water and rinsed with distilled water before air drying to remove moisture (Brigden et al., 2018). They were later shredded.

Woodsawdust

The saw dust samples were hand-picked to remove unwanted particles, air dried and oven dried at 50°C to remove associated moisture. The particle sizes were further reduced before sieving with sieves of different mesh sizes.

Egg shell

The egg shells were washed with tap water several times and later rinsed with distilled water to remove contaminants. They were air-dried and incubated in hot air oven at 40°C for 30 minutes (because protein component in egg shell can denature at high temperature greater than 40^{o}C). They were ground, and sieved to obtain particle size, 0.15-1.18mm (Singh and Gupta, 2016).

2. 3 Methods

2.3.1 Preparation of Composite Absorbent

The sieved sawdust (SD), eggshell powder (ESP), and high density polyethylene (HDPE) composites were combined in two different ratios by mass(1:1:1) and (2:1:1) but with various mesh sizes(0.150mm, 0.300mm, 0.425mm, 0.600mm) of saw dust. The mix was loaded in an extruder machine, a Jombo Extruder 300, at a temperature of 250°C to bind the components together and the products (in molten form) were collected in receiving molds of the same dimensions; length, 29cm; width, 14cm and thickness or height, 1.5cm.

2.3.2 Crude oil absorption by the composite absorbent

A crude oil spill in water was simulated by putting 750mL of crude in 3L of water contained in a 7L plastic trough. The composite(sorbents) of different particle sizes (0.150mm, 0.300mm, 0.425mm, 0.600mm) were weighed before immersion in the simulated oil spill medium and held on clamps of retort stands

After 24hours, the composites were removed from the medium and allowed to drain inside a beaker, and later washed with 300ml of hexane in a different beaker. The hexane was evaporated at room temperature. The combined weights made up the weight of sorbed crude oil. The composites were reweighed after drying. The procedure was repeated for another 24hours.

3. Results and Discussion

3.1 Results

Table1: Amount of crude Oil sorbed by composites (SD: HDPE: ESP) 1:1:1 after 24hours

Composites Particle size	Mass of composite before immersion (kg)	Mass of composite after immersion(kg)	Mass of crude oil extracted from the composite (g)	Total mass of the crude oil sorbed by the composite (kg)
0.300mm	0.550	0.555	27.460	0.032660
0.600mm	0.650	0.700	36..976	0.086976
1.18mm	0.800	0.850	65.298	0.115298

SD- Saw Dust; HDPE- High Density Polyethylene; ESP – Egg Shell Powder

Table2: Amount of crude Oil sorbed by composites (SD: HDPE: ESP) 1:1:1 after the 2nd 24hours

Composites Particle size	Mass of composite before immersion (kg)	Mass of composite after immersion (kg)	Mass of crude oil extracted from the composite	Mass of the crude oil sorbed by the composite (kg)
0.300mm	0.555	0.555	16.00	0.01600
0.600mm	0.700	0.710	10.97	0.02097
1.18mm	0.850	0.900	23.77	0.07377

SD- Saw Dust; HDPE- High Density Polyethylene; ESP – Egg Shell Powder

Table3: Amount of crude oil sorbed by composites (SD: HDPE: ESP) 2:1:1 after 24hours

Composites Particle size	Mass of composite before immersion (kg)	Mass of composite after immersion (kg)	Mass of crude oil extracted from the composite (g)	Mass of the crude oil sorbed by the composite (kg)
0.300mm	0.600	0.650	33.5720	0.0835720
0.600mm	0.600	0.700	33.9352	0.1339352
1.18mm	0.600	0.750	32.9030	0.1829030

SD- Saw Dust; HDPE- High Density Polyethylene; ESP – Egg Shell Powder

Table4: Amount of crude oil sorbed by composites (SD: HDPE: ESP) 2:1:1 after the 2nd 24hours

Composites Particle size	Mass of composite before immersion (kg)	Mass of composite after immersion (kg)	Mass of crude oil extracted from the composite	Mass of the crude oil sorbed by the composite (kg)
0.300mm	0.650	0.700	21.86	0.07186
0.600mm	0.700	0.750	35.24	0.08524
1.18mm	0.750	0.80	49.17	0.09917

SD- Saw Dust; HDPE- High Density Polyethylene; ESP – Egg Shell Powder

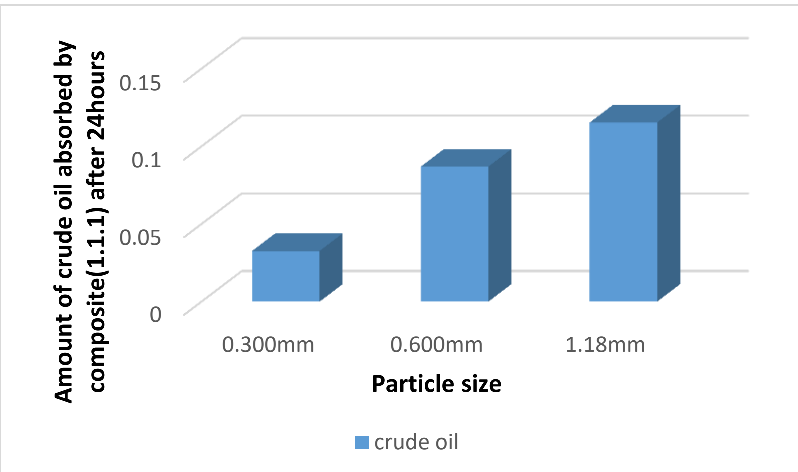

Fig.4: Plot of amount of crude oil sorbed by composite (1:1:1) against particle size after 24hours

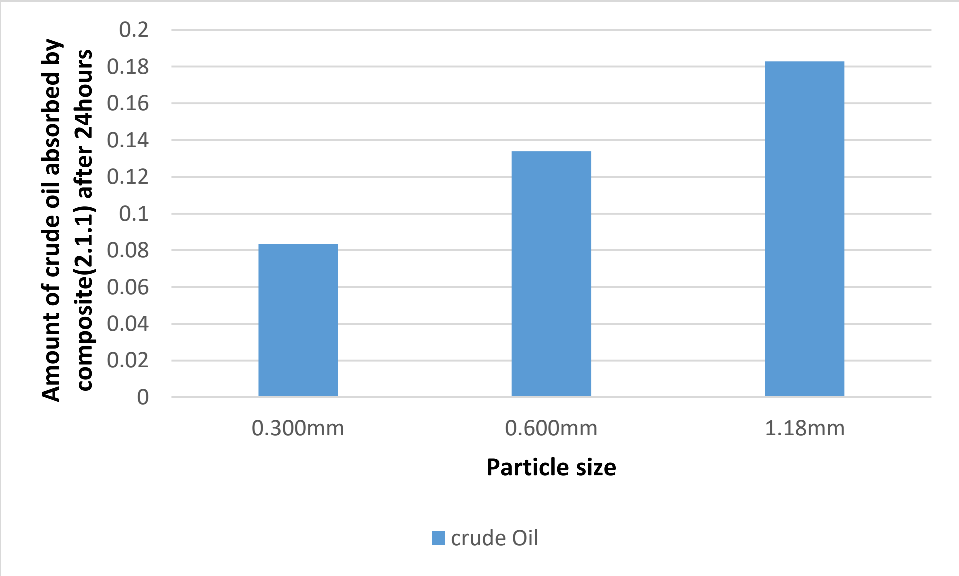

Fig.5: Plot of amount of crude oil sorbed by composite (2:1:1) against Particle size after 24hours

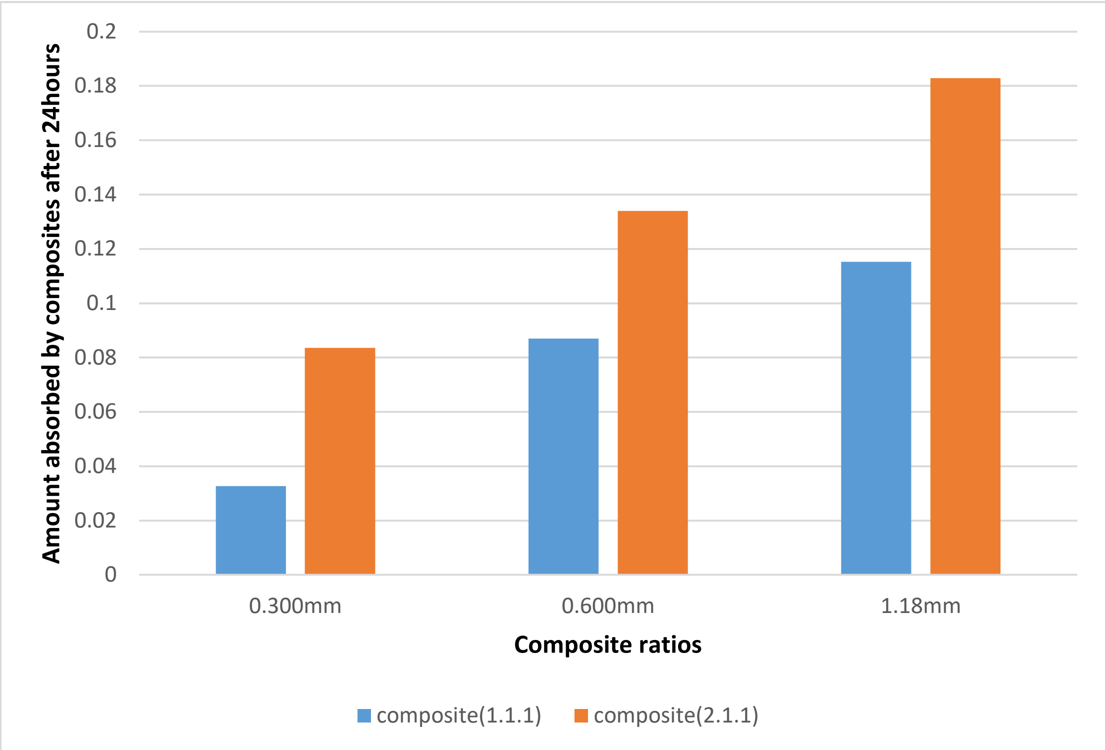

Fig 6: Plot of amount of crude oil sorbed by composites against composite ratios after 24hours

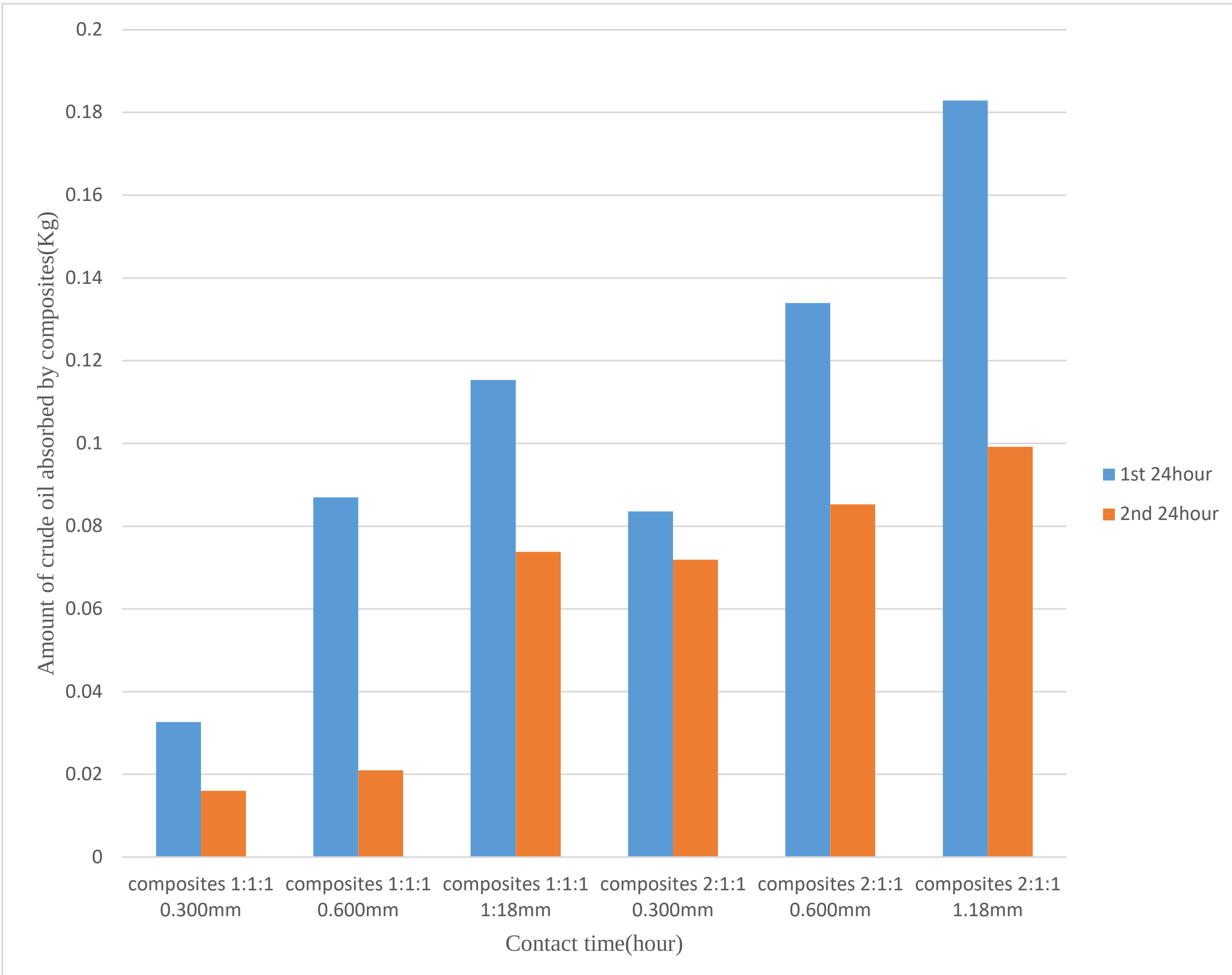

Fig 7: Plot of amount of crude oil sorbed by composite against contact time

3.2 Discussion

3.2.1 Variation of the amount of Crude Oil Sorbed against Particle Size

The increase in particle size of one of the constituents of the composite, sawdust in the composite 2:1:1, resulted in increase in the amount of crude oil absorbed, 0.18kg for particle size 1.18mm; 0.15kg for particle size 0.60mm and 0.08kg for particle size 0.30mm while the composite 1:1:1, gave the following variation, 0.13kg for particle size 1.18mm; 0.08kg for particle size 0.600mm and 0.03kg for particle size 0.30mm as shown in figures 4-6 and tables 1-4. Even though the composite 2:1:1 comparatively absorbed more crude oil than composite 1:1:1, it is clearly evident that the particle size of the saw dust, 1.18mm absorbed the highest amount of crude oil in each of them, 0.18kg and 0.13kg respectively while the particle size 0.30mm absorbed the least amount of crude oil in each of them, 0.08kg and 0.03kg respectively. These are contrary to results of the study of Kumarasywamy *et al.*, 2015 where increase in the particle size of eggshell powder resulted in the decrease in the adsorption of chromium. The phenomenon exhibited here by the composites is also contrary to one of the known laws of adsorption of Languimir and Freudenlich where reduction in particle sizes is said to result in increased number of pores and resultantly increased adsorption, though in liquid and gaseous media(Israel & Inam, 2014; Okafor *et al.*, 2013). It could be concluded that bigger micro pores were created by the larger saw dust particles in the waste high density polyethylene waste matrix during the extrusion process. The smaller particle sizes though could have create more micro pores. However, the summation of the overall space size may not be up to the summation of the overall space size of the larger particles.

The effect of composite ratios on crude oil sorption had earlier been investigated by Ibe and Otanocha, 2017 and Ibe, 2019. The effects of the two composites, 2:1:1 and 1:1:1 used in the current investigation are in consonance with the results the previous works by the authors

3.2.2 Variation of Crude Oil Absorbed with Contact Time The absorption process was monitored in two segments of twenty four hours each. The amounts of crude oil absorbed in each segment are shown in figures 6 and 7 and tables 1-4. In the first twenty four hours, higher amounts of crude oil were sorbed, after which there was attenuation. The attenuation could be as a result of decreased sorption sites by oil particle fills in the pores. Even though efforts were made to desorb the crude oil sorbed in the first twenty four hours before re-immersion, yet there was attenuation. The de-sorption process could not free all the entrapped oil particles within the sorption sites

Conclusion

The optimization of crude oil sorption by composites of saw dust, egg shell and high density polyethylene wastes was achieved by varying the particle size of saw dust from smaller to larger particle sizes in the composite matrix. The sorption process attained attenuation point after a period of time.

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