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# Sorption Efficiency of Various Biodegradable Wastes in Crude Oil Spill Cleanup in Igbokoda, Ilaje LG, Ondo State

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## Abstract

This study examined the efficiency of various biodegradable wastes in crude oil spill cleanup in Igbokoda, Ilaje, Ondo state using biodegradable waste made from melon shaft, groundnut shell, maize corn cob, yam peel, potatoes peel and sugarcane bagasse. They were subjected to natural modification using Crude and Groundnut oil as pollutant and their oil efficiencies were compared. The effectiveness of these modifications was determined by comparing oil sorption results with unmodified biodegradable sorbent. The work is pure scientific in nature with laboratory experimentation. The results show that sugarcane bagasse has the highest oil sorption rate of 10.76g Seconded by Maize corn cob with sorption rate of 3.69g, groundnut peel 3.359g potatoes peel 2.165, coconut fruit extract 2.058, melon shaft 1.614, while the waste with the least sorption rate is yam peel with 1.470g using 1g of biodegradable waste as absorbent. The wastes also show good buoyancy for retention capacity, reusability and oil recovery rate and so these materials should be developed for oil spill cleanup in the study area, especially the use of sugarcane bagasse which has the highest sorption rate in the study, seconded by maize corn cob and groundnut peel. This research however discourages the use of synthetic sorbent in the cleanup of oil spill due to their non-biodegradability issue. The prepared sorbent is a better alternative of the commercial polypropylene sorbent which are being used nowadays.

**Keywords:** Sorption efficiency, Biodegradable waste, Crude oil, Oil spill.

## Introduction

Oil exploration and exploitation in the Nigerian's oil producing region has produced many environmental concerns like contaminated soil, groundwater and surface water contamination, destruction of existing vegetation and aquatic organisms and the socio-economics of the built-up area around the facilities. The oil industry located within Niger Delta region has contributed immensely to the growth and development of the country, but unsustainable oil exploration activities has rendered the Niger Delta region one of the five most severely petroleum damaged ecosystems in the world with significant environmental and ecological problems (Ayuba 2012).

It has become imperative globally that we build a more sustainable society. Part of the drive towards achieving this includes finding an environmentally friendly solution to materials we use in oil spill clean-up.

There are various effective methods used in the cleaning of oil spill around the world today, some of the methods commonly used to remove oil include; oil booms, dispersants, skimmers, oil pumping, in-situ burning, bioremediation, solidifier and sorbents (Muhammad et *al.*, 2015).

Oil boom is a containment with temporary floating barrier used to contain an oil spill in order to make the oil recovery easier and prevent it from spreading further after the oil is spilled. With the use of Booms, the oil spill is concentrated in thicker surface layers so that other collection methods can be used more effectively. This is commonly used in the United states of America and is known as an environmental friendly technique in oil spill clean-up. This method is effective in calm water surface; it is not suitable in turbulent water scenario.

Dispersal method is used when the oil spill cannot be contained, the options left available is to speed up the natural breakdown of oil components by adding dispersal chemical to the spillage medium thereby allowing the oil to bond with water chemically and later scooped up by skimmers. The disadvantage of using dispersant in oil spill cleanup is that, they are often inflammable and cause health hazards to the operators and potential damage to fish, and marine mammals. It also results in the creation of tar balls.

Oil spill containment and skimming is the most common of the oil spill cleanup methods that involves trying to contain the spill within few hours of the spill with floating booms that prevent the spill from going out of control. Floats are equipped with skirts that hang beneath them so oil does not get pushed under the booms by the ocean waves. Once the floats are installed, skimmers or oil scoops is mobilized to remove the containment from the surface of the water. The method is not effective if the wind is strong.

Another effective oil spill method being used is In-situ burning. In-situ burning involves the burning of concentrated oil spillage floating on the sea. In situ burning has the potential to remove large amount of oil spillage from the sea. A factor necessary for consideration when opting in in-situ burning is for the oil spill on the sea be thick for at least 2mm and above so as to combat the cooling effect of the wind and maintain its fuel source for the burning. This process of burning oil slick is disadvantaged with thick smoke and environmental pollution which poised risk to human health. Aquatic organism living close to the sea surface are also endangered.

Bioremediation on the other hand, is an effective cleanup method used in mopping up of oil spill after the heavy oil is removed. It is a series of processes used to quicken natural biodegradation though the use is limited to spillages on land, further research is being carried out for its use on the sea surface. It is one of the best way to clean oil spill with less cost using biological agent to break down the oil into carbon dioxide and fatty acid.

Lastly, Sorbent are large sponges specially designed for larger oil slicks designed to pull oil from water surface in areas that cannot be reached by the skimmers. To be useful in dealing with oil spill sorbents need to be oleophilic / hydrophobic. Although sorbents may be used as the only cleanup method in small spills, it is often used to remove final traces of oil as a

complement for other cleanup methods. The United States Environmental Protection Agency categorise sorbents into natural inorganic, natural organic and synthetic absorbent Sorbents are materials with high attractions for oil and repellent for water. Sorbent materials remove oil by two mechanisms. These can either be done by adsorption or absorption. Adsorption involves the adherence of oil to the sorbent material which is dependent upon the viscosity of the oil. The more viscous the oil, the thicker the layer that will adhere to a given material (Idris et el, 2014). On the other hand, absorption relies on capillary attraction; oil fills the pores within the material and moves upward (uptake) into the material due to capillary force. Removal of oil by sorption has been observed to be one of the most effective techniques for complete removal of spilled oil under ambient conditions. Most commonly used commercial sorbents are synthetic sorbents made of polypropylene or polyurethane (Teas *et al.,* 2001; Wu et al, 2014). They have good hydrophobic and oleophilic properties, but their non-biodegradability is a major disadvantage (Deschamps *et al.,* 2003).

The use of sorbents is of great interest, as it allows the collection and complete removal of oil by achieving a change from liquid to semi-solid phase. Use of sorbents is one of the physical methods and has been applied in the industry for several years. Commercial sorbents are extensively used in oil spill clean-up. The most commonly applied are synthetic sorbents like polystyrene, polypropylene, and polyester foams. They have high hydrophobic and oleophilic properties and can sorb up to 70 times their weight in oil. They can also be used several times after recovery in some instances (Aboul-Gheit et al, 2006). Sorbent can be grouped as inorganic minerals and synthetic, organic, and organic (agricultural) products. However, efficiency is dependent on sorption capacity, density, wettability, retention rate and recyclability and examples are cotton, straws, corn cobs, coconut shells, kenaf, kapok fibres, rice husk, and silkworm cocoon, hay, sawdust, bagasses, gorse, and dried palm fronds (Sun *et. al,* 2002). It is therefore desirable using sorbent that are cheap, efficient, environmentally friendly and easy to deploy biodegradable waste in the cleanup of oil spill. This study was conducted to evaluate the efficiency of some selected biodegradable wastes in the cleanup of crude oil spill in the Igbokoda area of Ondo state, Nigeria.

**Statement of the Research Problem**

This study has become very imperative due to the environmental degradation occasioned by hydrocarbon oil spill in the Niger delta area of Igbokoda, Ilaje, Ondo State of Nigeria. There has been series of conflicts between the indigenous people and the major oil companies operating within the region over the years due to occasion of oil spillages both on water bodies and land. The activities of the oil companies instead of improving the region have impoverished its people by causing a serious decline in their marine and agricultural resources, which constitute their economic mainstay of the study area.

Some of the agitation of the oil spills in Igbokoda, Ilaje, Ondo state include; sabotage and theft through siphoning. The reason that sabotage accounts for majority of the spills is that there is an extensive network of pipelines between oil fields, also there are many small networks of flow lines that carry oil from wellheads to flow stations- most of the pipelines are on land and swamps and in very difficult terrain, leaving a large portion unmanned by the various security personnel's. Corrosion also accounts for a large portion of the spills in the Niger Delta; this is because most of the facilities belonging to the major multinationals were constructed before the early eighties according to the prevailing standards. There is drastic decline in the region's biodiversity and ecological resources, which are the main sources of their income and the people's mode of survival (Asthon *et al*, 1999).

Another problem encountered by the inhabitants in Igbokoda, Ilaje, Ondo state is health hazards resulting from pollution of oil spill in the environment. Hence, there are environmental challenges as well as socio-economic problems emanated from adverse effects of oil mining in the area, which has culminated into low agricultural productivity and poor farm yields sufficient enough to threaten the food security of the Ilaje people of Ondo state of Nigeria.

Adverse impacts on the ecology have also resulted from oil drilling; the dredging of the swamp waters by oil multinationals for access to pipelines and facilities; and natural gas flares that occur in the course of oil production. After many years, during which these adverse effects either received little attention or were simply ignored, fresh efforts have been mounted in recent years by Government, environmentalist, non-governmental organisations (NGOs) and oil multinationals to remedy the situation. Agitation by the Niger Delta communities especially the Ogonis' has received attention of Government and this has led to the inauguration of Hydrocarbon Pollution Remediation Project (HYPREP) which was commissioned for the cleanup of Ogoni land oil spill.

Lastly, the use of commercial synthetic product such as polypropelene in oil spill cleanup though effective but disadvantaged with non-biodegradability issue and high cost of production. Synthetic product is also known to cause secondary pollution after it is used in cleaning up an oil site. Synthetic sorbents are chemically modified and this has dangerous effect on the marine organism, the chemical used in preparing absorbent for oil spill cleanup are not without their consequences on aquatic animals. Based on these identified problems, the study intends to conduct an alternative way of cleaning oil spill using biodegradable waste without chemical modification in oil spill clean-up in Igbokoda, Ilaje Local Government area of Ondo state.

**The Study Area**

**Location of the Study Area**

The study area is located in Ilaje Local Government Area of Nigeria in Ondo State, Nigeria. The study area lies between latitudes 6°00′ 00″ N and 6°20′ 00″ N and longitude 4°45′ 00″ E and 5°45′ 00″ E. It is bounded to the north by Ikale and Arogbo-Ijaw in the Okitipupa and

Ese-Odo Local Government Areas of Ondo State. In the southern boundary is the Atlantic Ocean whereas it is bordered in the west by Ijebu in Ogun State, the eastern boundary is the Itsekiri land in Warri, Delta State. It has a coastline of about 180km thus making Ondo state, the state with the longest coastline in Nigeria. The major occupation of the Ilaje people are fishing, canoe and boats building, commercial water transport etc. The administrative nerve centre of Ilaje at Igbokoda is primarily mangrove swamp forest.

Major rivers into which secondary watercourses from swamp areas flow dominate the entire area (ERA 1999). Crude oil is concentrated in the Ugbo subgroup area, while some communities in the Mahin and Aheri subgroups feel the impact of oil exploitation but are not oil producing. The region is endowed with hydrocarbon resources, which are the mainstay of Nigeria's economy. Since the discovery of crude oil in commercial quantities in the area in the late1950s, the region has witnessed major infrastructural development resulting from oil and gas exploration, upstream damming of the Niger River, and construction of ports for crude oil and gas export.

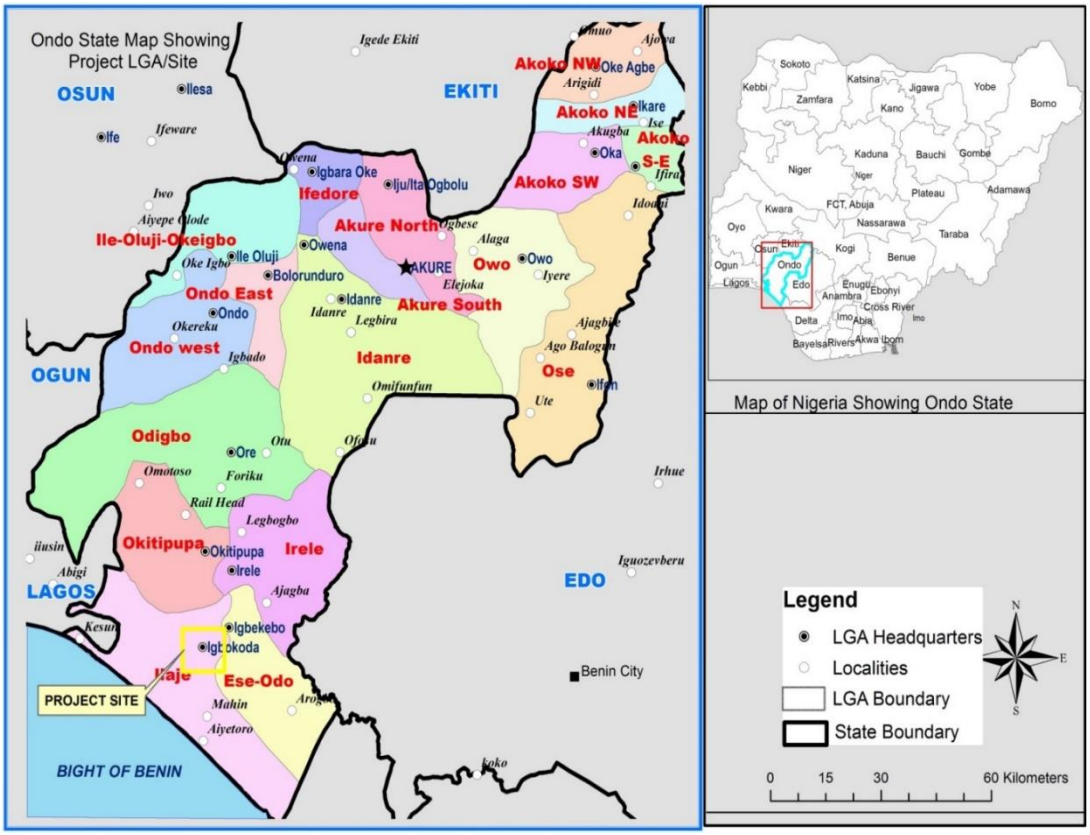


**Fig 1.** Map of the Study Area (Inakwu O.A, 2012).

**Relief of the Study Area**

Igbokoda is situated on an elevation of between 1.0 and 1.5 meters above sea level. It is plain with no presence of hill. Ondo state is composed of lowlands and rugged hills with granitic outcrops in several places. The land rises from the coastal part of Ilaje/eseodo (less

than 15 above sea level) in the south; to the rugged hills of the north eastern portion in Akoko area.

Ondo state comprised of two geologic formations. The first region is sedimentary rocks in the south, these sedimentary rocks are mainly of the most Cretaceous sediments and the cretaceous Abeokuta formation while the second is the region of Precambrian basement complex which is mainly of the medium grained gneisses. These are foliated rocks occurring as outcrops. In the surface of these outcrops; severely contorted alternating bands dark and light coloured minerals can be seen. These bands of light coloured minerals are essentially feldspar and quartz; while the dark colour bands contain abundant biotic mica. A small proportion of the state; especially to the north.

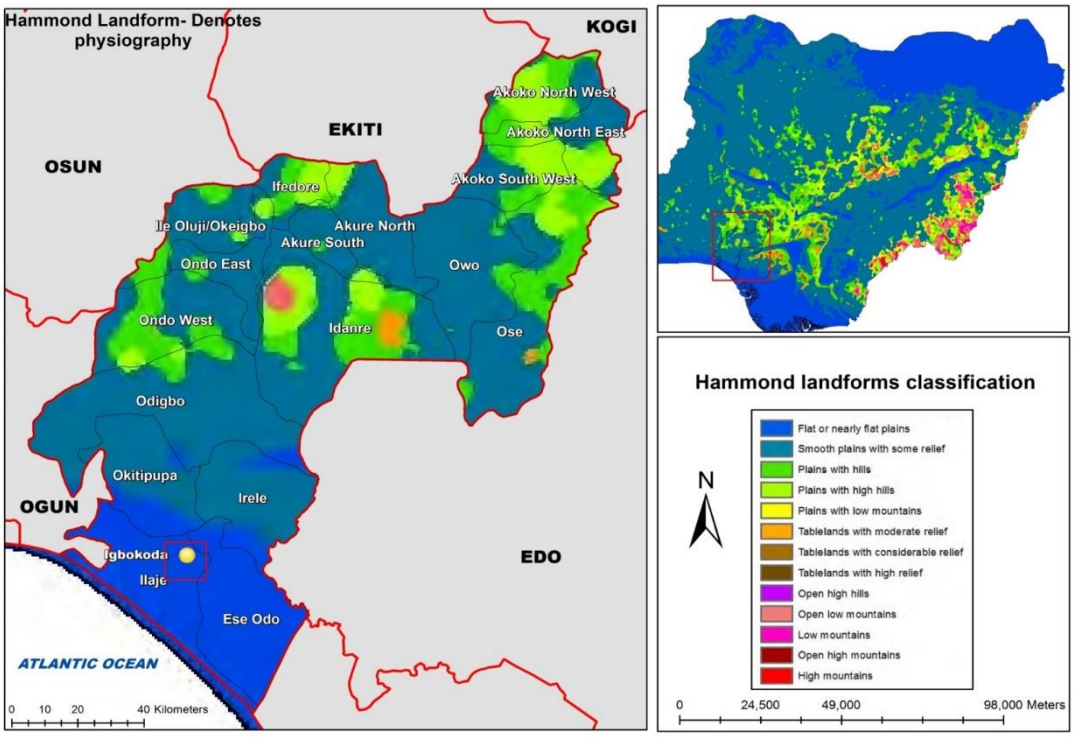


**Fig 2.** Relief Map of the Study Area (Inakwu O.A, 2012)

**Vegetation Type of the Study Area**

The natural vegetation is the composed of many varieties of hardwood timber such as Melicia excelsa, Antaris africana, Terminalia superba, Lophira procera and Symphonia globulifera. In the northern districts of the study area, the vegetation consists of woody savanna featuring such tree species such as Blighia sapida. The swamp flats are the domain of the fresh water swamp forests in the interior and the units of mangrove vegetation near the coast. The sand ridges are characterized by savanna and stunted rain forests. Over most of the state, the natural vegetation has been very much degraded as a result of human activities, the chief of which is based on the rotation of bush fallow system. As a result, the original forest is now restricted to forest reserves. An important aspect of the vegetation of

the state is the prevalence of tree crops. The major tree crops include cocoa, kola, coffee, rubber, oil palms and citrus, cocoa being the most prevalent. It is also important to note that rubber and oil palms have been cultivated in large plantations in Odigbo, Okitipupa and Irele Local Government Areas. Trees that are not native have also been introduced as forest plantations. These exotics have been used to re-vegetate large portions of harvested old forest reserves in Omo and Owo. They include mainly Tectona grandis (teak) and Gmelina arborea pulp wood (Daramola *et al*, 2009).

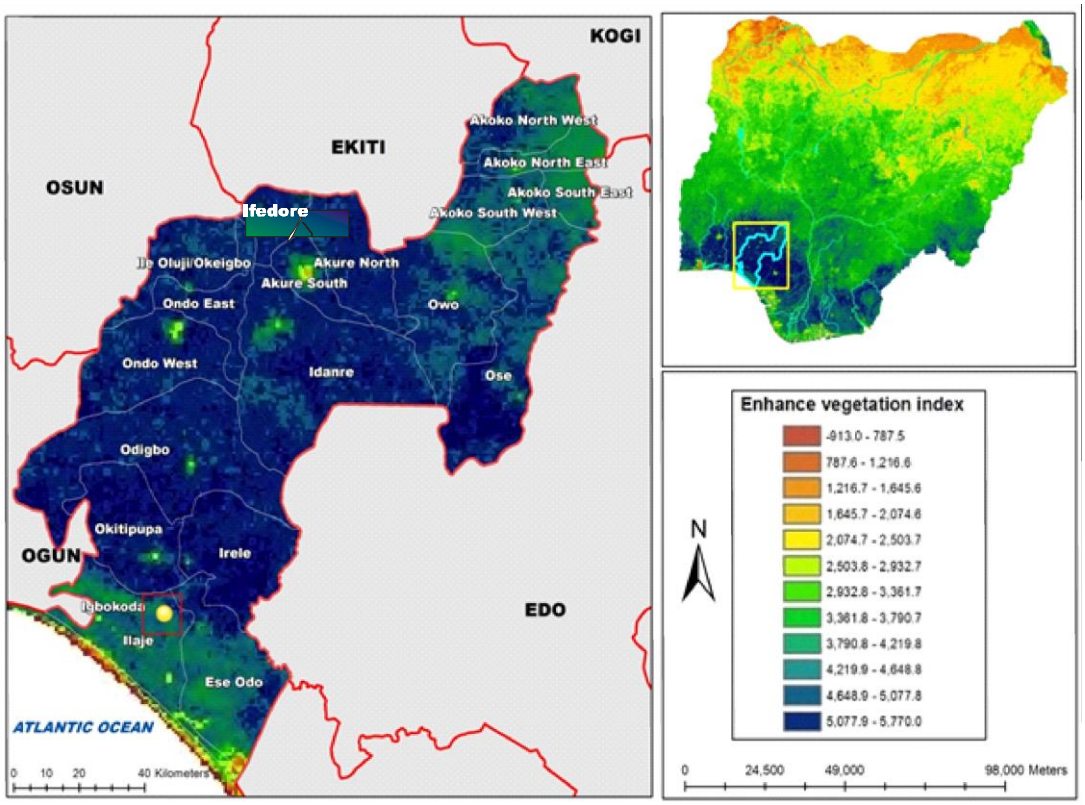


**Fig 3.** Vegetation Map of the Study Area (Inakwu O.A, 2012).

## Materials and Methods

### Preparation of Absorbent and Laboratory Process Description

Seven household biodegradable wastes materials were selected, they include coconut fruit extract, sugarcane baggase, groundnut peel, melon shaft, maize corn cob, potatoes peel and yam peel. They were washed and dried before broken into smaller sizes. They were dried under a constant temperature at 40 degrees centigrade and then grinded to a uniform size distribution of between 0.400 and 0.800mm using blender.

### Equipment and Materials Used for Laboratory Experimentation

Equipment and material which will be used include:

i. Biodegradable waste used for absorbents- melon shaft, groundnut shell, maize corn cob, coconut fruit extract, yam peel, potatoes peel, and sugarcane bagasse.

ii. Equipment- Water bath, rollers, Magnetic stirrer, oven (dryer), sustainer, glass beakers, filter paper, UV sensor.
iii. Magnetic bar
iv. Crude oil and Groundnut oil.

**Oil Sorption Experiment**

A 250mL sample of sea water was placed in a 500ml glass beaker, 20ml oil was added to the beaker thus making it 270ml mixture of crude and water, the mixture was then shaken using magnetic stirrer. The dried fibre sample (1 g) was weighed using filter paper on weighing machine and then poured into the beaker containing the oil/water mixture. The mixture Shaking time is approximately 15 minutes at 105 cycles/min using magnetic stirrer and bar. Thereafter, the wetted fibre was filtered into a measuring cylinder using filter net tied with rubber to the beaker to drain and then taken to the oven for 5 min at 105degrees. The test was repeated three times in order to obtain the average values. The same method was used for the 3g and also the modification using groundnut oil instead of crude.

The oil sorption of the sample was evaluated by weighing the samples before and after the absorption and determined by the formula:

Oil sorption capacity (OSC): $\frac{(S_{st} - S_o)}{S_o}$ (1)

Where $S_o$ is the initial dry sorbent weight, $S_{st}$ the weight of sorbent with oil at the end of the sorption test, and the quantity ($S_{st} - S_o$) the net oil sorbed. All weights are measured in grams. (Vinitkumar et al, 2013).

The reusability test was carried out using the residue of the absorbent used, dried in the oven for 24hours at 105degree and the same method was repeated.

**Laboratory Experiment in Real Life Situation**

The sea water used in the laboratory denotes the ocean body on which the spill occurs, the reason water volume is higher compared with the crude. Due to the massive nature of the ocean, no matter the magnitude of the spillage it cannot measure 5% of water in the ocean. The crude oil represents the oil spill on water body (ocean); the 20g of oil used represents the volume of oil spill depending on the magnitude of the spillage. The stirring on the magnetic stirrer also represents the turbulence (turbulence is the pattern of fluid flow motion characterized by chaotic changes in pressure and flow velocity of the ocean in the presence of the oil spilled).

**Data Analysis**

Household biodegradable waste were selected and subject to laboratory experimentation. Data collected from the laboratory were subjected to descriptive statistics, bar graph was designed to present the data obtained from the laboratory experiment using excel statistical software.

## Results and Discussion

**Table 1**. Oil Sorption Capacity (OSC) data of the variation of the liquid test volume (Crude oil)

| S/N | Biodegradable waste | Sst (g) | So(g) | OSC |
|---|---|---|---|---|
| 1. | Coconut Fruit Extract | 3.058 | 1.0 | 2.058 |
| 2. | Sugarcane Bagasse | 11.760 | 1.0 | 10.760 |
| 3. | Groundnut Peel | 4.359 | 1.0 | 3.359 |
| 4. | Melon Shaft | 2.614 | 1.0 | 1.614 |
| 5. | Maize corn Cob | 4.690 | 1.0 | 3.690 |
| 6. | Potatoes Peel | 3.165 | 1.0 | 2.165 |
| 7. | Yam Peel | 2.470 | 1.0 | 1.470 |

**Table 2**. Oil Sorption Capacity (OSC) data of the variation of the liquid test volume (Groundnut Oil)

| S/N | Materials | Sst (g) | So(g) | OSC |
|---|---|---|---|---|
| 1. | Coconut Fruit Extract | 4.757 | 1.0 | 3.757 |
| 2. | Sugarcane Bagasse | 10.356 | 1.0 | 9.356 |
| 3. | Groundnut Peel | 3.132 | 1.0 | 2.132 |
| 4. | Melon Shaft | 3.855 | 1.0 | 2.855 |
| 5. | Maize Corn Cob | 5.221 | 1.0 | 4.221 |
| 6. | Potatoes Peel | 2.962 | 1.0 | 1.962 |
| 7. | Yam Peel | 2.788 | 1.0 | 1.788 |

The absorption efficiency results of various biodegradable waste used in the study are as shown in table 1,2 and figure 1. Sugarcane bagasse as seen in the table has the highest sorption capacity of 10.760g using crude oil and 9.354g using groundnut oil. From the experimentation result, it could be deduced that using sugarcane bagasse as sorbent material would absorb crude oil eleven times the absorbent and nine times using groundnut oil. The result further show that in comparison, the sorbent absorbed crude oil more than the groundnut oil used as pollutant in the study. The sugarcane bagasse showed a rapid oil pickup with very high sorption capacity of approximately 11g using 1g of bio-sorbent (in 15minutes at 105 circle per minutes), high degree of hydrophobic and oleophilic property with low water uptake. The best performing material amongst the seven biodegradable waste is proven to be sugarcane bagasse.

Subsequent to Sugarcane bagasse is Maize corn cob, having the second sorption buoyancy of 3.7g approximately using crude oil and 4.221g using groundnut oil. Differences in the absorption rate of oil absorbed between crude and groundnut oil with the same sorbent quantity (1gram) used is the oil viscosity. It was deduced from the experimentation that using different crude with different viscosities would produce different absorption result as

seen in the table and graph. The result further shows that, using maize corn corb as sorbent material for oil spill cleanup would absorb crude oil of 400% or more the sorbent materials used. This means that for every increase in the quantity of absorbent made of maize corn cob, the absorbent would absorb four times the absorbent used. i.e for every 4g of absorbent made of maize corn cob, the absorption rate would be four times or more the absorbent used.

Groundnut peel according to the laboratory experiment has the third sorption capacity amongst the seven materials used. With 1gram of groundnut peel as absorbent, the result shows crude oil absorption rate of 3.359g and 2.132g of groundnut oil absorbed. Groundnut peel also shows a good buoyancy rate for oil sorption efficiency with 3.359g using crude oil and 2.132g using groundnut oil. This however reveals that 1g of groundnut peel would absorb 3g of crude oil spill naturally without chemical modification.

According to the performances of the biodegradable waste used in the study as shown in the figure 1. below, sugarcane bagasse and maize corn cob show a reassuring result and can be regarded as useful waste which can be channelled into the production of absorbent for oil spill cleanup with little or no cost of procurement due to the waste they are. It is also noteworthy that groundnut peel a waste could also be channelled into the production of absorbent for oil spill cleanup. Groundnut is a seasonal agricultural product always in abundance in rainy season especially in the tropical region.

Both Yam and Potatoes peel have the least hydrophobic and oleophilic properties when compared to the other biodegradable waste used in the study. Potatoes peel settles in the mixture with small quantities of oil absorbed, it is however known to have poor buoyancy for oil sorption.

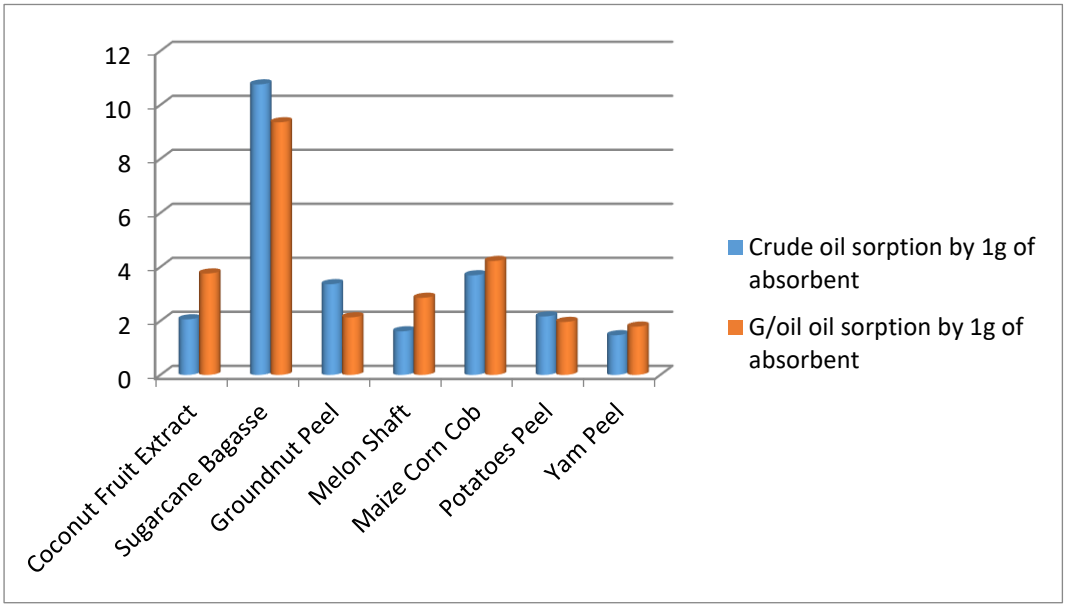


**Figure 1.** Graph showing absorption efficiencies of the seven biodegradable waste used in the study, using crude and groundnut oil as pollutant.

**Source:** Authors Field Work (2022).

**Applications of Biodegradable Waste Sorbent to Real Life Oil Spill Situations in Igbokoda, Ilaje Local Government**

Biodegradable waste degrades easily naturally on its own. It requires little or no cost in acquiring it. One way by which it can be made available in good quantity is to have a waste bin particularly for biodegradable sorting in each location for the households to keep their biodegradable waste, some industries also have these waste in large quantity after which they have extracted the useful product and thus remain the waste. From the research laboratory work carried out, some waste can be reused with higher sorption rate; they have advantages over the industrial standard commercial synthetic sorbent like polypropylene, polyurethane and polyethylene with non-biodegradability and non-reusability issue.

Lesego et al, 2016, reported that in 2007/08 and 2009/10, about 80,000 and 100,000 tonnes of sugarcane were produced, respectively. Nigeria contributes only 1.9% to the production capacity of sugarcane in sub-Sahara Africa valued at $30,155,345 (Choice et al, 2015). However, this is expected to increase due to the establishment of Nigeria's first sugarcane bio-refinery in Zaria in 2015 (Punch Newspaper, 2015). The factory was established to increase sugar and ethanol production. The recent interest shown by the government in expanding the sugar industry and establishing policies to develop biofuels from local feedstock has necessitated the expansion of sugarcane production in Nigeria. Despite the plans to increase sugarcane production in Nigeria, strategies to manage the residues such as straw and bagasse are not in place. Ogwo et al, 2012 reported that 1 ton of sugarcane generates about 270 kilogram of bagasse.

This indicates that if 50% of the demand for sugarcane production in Nigeria is met; sugarcane bagasse would constitute a massive waste if efforts are not in place to beneficiate it. One major ways by which such waste could be harnessed is to make them useful by converting them to raw materials for the production of absorbent for oil spill cleanup. If the sugarcane production is put at 90,000 tonnes, then the bagasse generated would be 24,300,000kg. From the laboratory experiment, fig 1. result shows 1g of sugarcane bagasse absorbs 10.760g crude oil without any chemical modification. This means that 24,300,000kg waste of sugarcane can be used to clean 261,468,000litres (1,644,584.3 barrels) of crude oil spill which is more than the oil spill of five years put together according to NOSDRA.

The abundance of corn in Nigeria has made its residues to pose serious threat to the environment. Between 2010 and 2015, the average production of corn in Nigeria was 8.18 million metric tons (Lesego et al, 2016). Corn cob is an agricultural waste which is left after which the grains were extracted. It is sold as snacks on every street of Nigeria during the raining season when it is harvested, after eating the corn, the corn cob is thrown on the street. Also, some industries like cereal make use of corn as raw materials for the production of flakes (corn flakes, popcorn, cereals etc.) and as such they do in abundance piled up waste of corn cob after which the grains were extracted. According to Muchlisyam, 2014; it is estimated that 40-50% of corn is corn cob. Going by corn production according to Lesego

et al, 2016 that Nigeria produced 818,000,000 metric tons of corn in 2016 and the corn cob is estimated to be 40-50% of the corn.

Taking an average of 45% as an estimated corn cob production of 818,000,000 metric tonnes corn production as at the year 2015, that means Nigeria produced 368,100,000 metric tons' corn cob yearly. This could be channeled into the production of absorbent for oil spill cleanup instead of allowing it to cause nuisance and littering the environment. Therefore, if 1g of corn cob could absorb 3.690g crude oil from the laboratory experiment, this means that corn cob could clean 1,104,300 barrels of oil spilled. The analysis shows that the potential capacity of corn cob production in a year when channeled to absorbent production is more than what could be used in cleaning oil spill in three consecutive years considering the spill statistics put at 7,672,886litres per year according to NOSDRA.

Groundnut shell is another major waste used in this study. It has been estimated that Nigeria produced 1, 917, 000 tons of groundnuts (Nautiyal, 2002). Groundnut shell is known to be a major waste of groundnut which constitute nuisance in the environment after which the groundnut seed was extracted. With the production volume of 1,917,000 tons (1,917,000,000 kg) of groundnut produced in the year 2002. Although this is likely to have increased, groundnut shell constitutes about 30% of the total groundnut. If Nigeria produced 1,917,000 tons of groundnuts in the year 2002, which means Nigeria produces 575100 (57,510,000kg) tons waste of groundnut shell and this can be channeled to absorbent production for oil spill cleanup. It could be assumed that if 1g of groundnut shell could absorb 3.359g of crude oil used in the laboratory and 575,100 groundnut peels which were generated in the year 2002 would clean 193,176,090 kg of crude oil which is 193,176,090 litres (16, 461, 81.4 barrels). So with oil spill statistics put at 7,672,886 litres/year in the last four years, groundnut shell could be developed to clean up these spills with excess absorbent left for future use.

There is therefore two major ways we can employ these materials for cleaning up real life oil spills in the magnitude that frequently occur in the study area. One way is to pack the absorbent powder obtained from crushing and after modification into other materials that will serve as containers. The properties of these containers will be such that will allow oil pass through its pores while also keeping the absorbent materials from pouring out while cleaning. Secondly, the powdery absorbent could be coagulated/compacted and used as sponges for oil spill cleanups. After cleaning up the oil could be wriggled out of the absorbents and reused again.

## Conclusion

Based on the findings on efficiency of various biodegradable wastes in crude oil spill cleanup, we examined efficiency of seven various household biodegradable wastes which are in abundance in Nigerian environment, these are; coconut fruit extract, sugarcane bagasse, groundnut peel, melon shaft, maize corn cob, potatoes peel and yam peel in two types of oil to determine their potential use in the oil spill cleanup.

The various sorption capacity of the biodegradable waste using crude oil as pollutant followed the general trend using crude oil: sugarcane bagasse > maize corn cob > groundnut peels > potatoes peel > coconut fruit extract > yam peel while sorption capacity of the same material using groundnut oil also followed the trend; sugarcane bagasse > maize corn cob > coconut fruit extract > melon shaft > groundnut peel > potatoes peel > yam peel. Residues and the sorption capacity may be further increased by reducing granulometry or chemical modification such as acetylating and esterification.

The use of sugarcane bagasse, maize corn cob and groundnut peels is environmental friendly, sustainable and economical in oil spill cleanup. Generally, sugarcane bagasse, maize corn cob and groundnut peel show reassuring potential for oil spill cleanup without the issue of non-biodegradability and secondary pollution which are the disadvantages of synthetic product, being used on commercial scale. The understanding of oil sorption mechanism obtained in the current work is significant to the research and design of new oil sorbent using biodegradable waste. The sorbent can be recovered with simple squeezing process and reused for more than 15 time, though the capacity gradually reduces at every reuse. Utilizing biodegradable waste in the production of absorbent would help in fulfilling zero waste theory and circular economy theory of reduce, reuse and recycle.

**Recommendation**

In line with the findings on the study, the following recommendations are made;

- To achieve a sustainable and environmental friendly cleanup of oil spill, Government and oil multinational companies need to pay attention to the new area of research of oil spill clean-up using biodegradable waste. Biodegradable waste such as sugarcane bagasse from the study has the highest and excellent sorption capacity; 1 gram of it has the efficiency to absorb 10-11 grams of crude oil spill, which could compete with the commercially used synthetic sorbent such as polypropelene, polyurethane and polyethylene which are disadvantaged with the issue of non-biodegradability.
- Government and oil multinationals should make funds available to the researchers in the area of oil spill cleanup using biodegradable waste. This will help to reduce the rate of waste generation in the environment. Many researches which should benefit the environment in the area of oil spill cleanup dies due to inability to fund them.
- Government and other stake holders in oil sector (NOSDRA and NESREA), should discourage the use of synthetic sorbent and encourage the use of biodegradable sorbent. This would help in the implementation of Zero waste and Circular Economy theory and prevent the environment from secondary pollution caused by synthetic sorbent used in oil spill cleanup globally.
- Area of biodegradable waste for oil spill clean-up should be explored and encouraged, particularly the use of sugarcane bagasse which has the highest sorption capacity amongst the seven waste used in the study.

- Government should make effort to legislate on creating a purse or pull of fund for the cleaning project at intervals.

## Competing Interests

Authors have declared that no competing interest exist.

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