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Research article

Deep Groundwater Remediation by means of Oil Skimmer in Baruwa Community, Lagos State.

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Abstract

A key feature to effectively recover spilled oil is the careful selection and proper use of the equipment and materials most suitable to the type of oil and the conditions at the spill site. Generally, this requires material selection based upon the absorption properties of the selected sorbent materials. These absorption properties are a function of the surface characterisation where hydrophobic and oleophilic properties are essential. The specific study site is Baruwa community in Alimosho Local government area of Lagos state, Nigeria. Earlier studies carried out by Adekunte (2008) and Balogun (2009) have revealed that the people of Baruwa community in Lagos state own about 350 hand dug wells for domestic water supply; more than 200 of these wells are under lock for the past twenty years because of the suspected oil seepage from leaking underground NNPC (Nigerian National Petroleum Corporation) pipeline. According to the United State of Environmental Protection Agency U.S EPA (1995), the cost for remediating sites with groundwater contamination can range from $100,000 to millions of dollars. However, to effectively remediate aquifer and subsurface contamination from petroleum hydrocarbons is a common problem facing many environmental managers, as decisions on how to clean-up the hydrocarbon contaminations in a timely and effective manner coupled with the availability of suitable devices and materials are required. To separate the mixed oil from the water, industrially designed various type of oil skimmers are getting used. Herewith, in this research work, efficiency studies of a belt type oil skimmer were conducted by testing six synthetic and six local belt materials in the laboratory and the results were correlated with the two prototype belt samples (light fuel oil fuzzy belt and standard poly belt) used at the recovery site. The belts absorbed the oil from water in the monitoring wells and was scooped out and collected into a vessel. The three laboratory tests that were conducted on the materials are: Oil sorption capacity, oil retention test and absorbent pick-up efficiency test. From the laboratory tests conducted, it was observed that light oil fuzzy belt (LFO) performed best out of the selected synthetic materials but some of the local materials such as cotton fibre, turkey feather, rug and Igala skin have exceptional performance over all the tested samples. Consequently, light fuel oil belt being the second belt material used at the spill site, has a better performance of the six synthetic belts when used on oil Grabber® Model 8 - Belt Skimmer and much more efficient than standard poly belt in recovering petrol from the wells. The depth to groundwater at the site varies from 23m to 25m.

Keywords: Groundwater, Contamination, Petroleum hydrocarbon, Remediation

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1.0 INTRODUCTION

Groundwater, which is a major source of drinking water around the world, plays a significant role in the development of the water resources in many countries. Quality deterioration of this important source is a significant problem that may lead to a sharp decrease in its value. Groundwater can be contaminated by various sources including ruptured oil pipelines and leaks from chemical storage tanks. Underground storage tanks (USTs) usually hold light non-aqueous-phase liquids (LNAPLs) such as common fuels. Serious contamination of groundwater as well as soil with hydrocarbon leakage can result from leakage through leakage in the tanks themselves or the associated pipeline. This problem, which is faced at many older gas stations, is complex because early detection of such leaks is rare. Once such a problem is discovered, questions related to estimating the extent of contamination, which will be used to plan for site remediation and restoration, will arise (Al-Suwaiyan, 2002).

Petroleum hydrocarbon liquids are generally less dense than water, which implies that such liquids are lighter than water, immiscible with water and would float on the water table of a groundwater aquifer. Accidental release of petroleum hydrocarbons to the subsurface causing groundwater contamination may occur through spills around refineries, leaking pipelines, storage tanks or other sources. Hydrocarbon liquids may eventually reach a water table and spread laterally in a pancake-like lens and if the spill is large, they will depress the water table. Hydrocarbons in the aquifer that exist as separate phases are termed free product or light non-aqueous phase liquids, LNAPL (Obigbesan, 2001).

Using contaminated ground water causes hazards to public health through poisoning or the spread of disease. Consequently, the practice of groundwater remediation has been developed to address these issues. Contaminants found in ground water cover a broad range of physical, inorganic, chemical, organic, bacteriological, and radioactive parameters. Pollutants and contaminants can be removed from ground water by applying various techniques thereby making it safe for use. Although there are different techniques employed to recover hydrocarbon contaminant from groundwater surface but oil skimming approach was used in this study.

A monitoring-well oil skimmer remediates various oils, ranging from light fuel oils such as petrol, diesel or kerosene to heavy products such as No. 6 oil, creosote and coal tar. The oil skimmer consists of a continuously moving belt that runs on a pulley system driven by an electric motor. The belt material has a strong affinity for hydrocarbon liquids and for shedding water. The belt, which can have a vertical drop of about one hundred feet (30m), is lowered into the monitoring well past the LNAPL/water interface. As the belt moves through this interface it picks up liquid hydrocarbon contaminant, which is removed and collected at ground level as the belt passes through a wiper mechanism (Parche, 1999).

2.0 METHODOLOGY

2.1 Description of the Study Area

The Baruwa area (Latitude 06˚ 35' 12" N, Longitude 03˚ 16' 21" E) is located in Ipaja, between the popular Iyana-Ipaja Bus-stop and the Ikotun Area of Alimosho Local Government Council of Lagos State, South West Nigeria. It is about 2.5km from Iyana-Ipaja Bus Terminal and is bounded by Gowon Estate and Abesan Estate to the right and left respectively while coming from Iyana-Ipaja Bus Terminal. It is accessible by a network of roads through Ipaja and Ayobo and is a densely populated residential area with a population of over 100,000 people living in the area. Its existence dates back to the early 20th Century but it became prominent in the 1970s due to population explosion witnessed in Lagos, which led to the development of satellite communities

(Adekunte, 2008). Figure 1a shows the map of Baruwa-Lagos indicating the position of the study area (Baruwa).The area has a few cottage industries and small scale enterprises and has fair to good supply of electricity, with a network of earth roads without a proper drainage system leading to impassability of some roads during the rainy season.

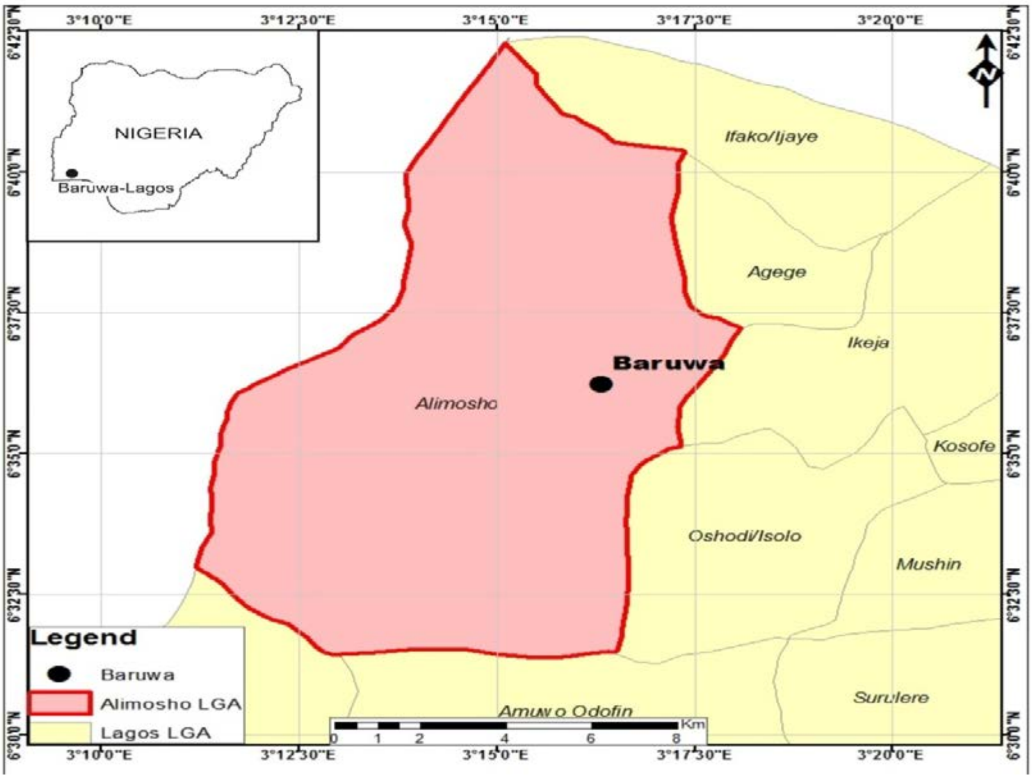

Fig. 1a: Map of Nigeria Indicating the Location of Baruwa-Lagos.

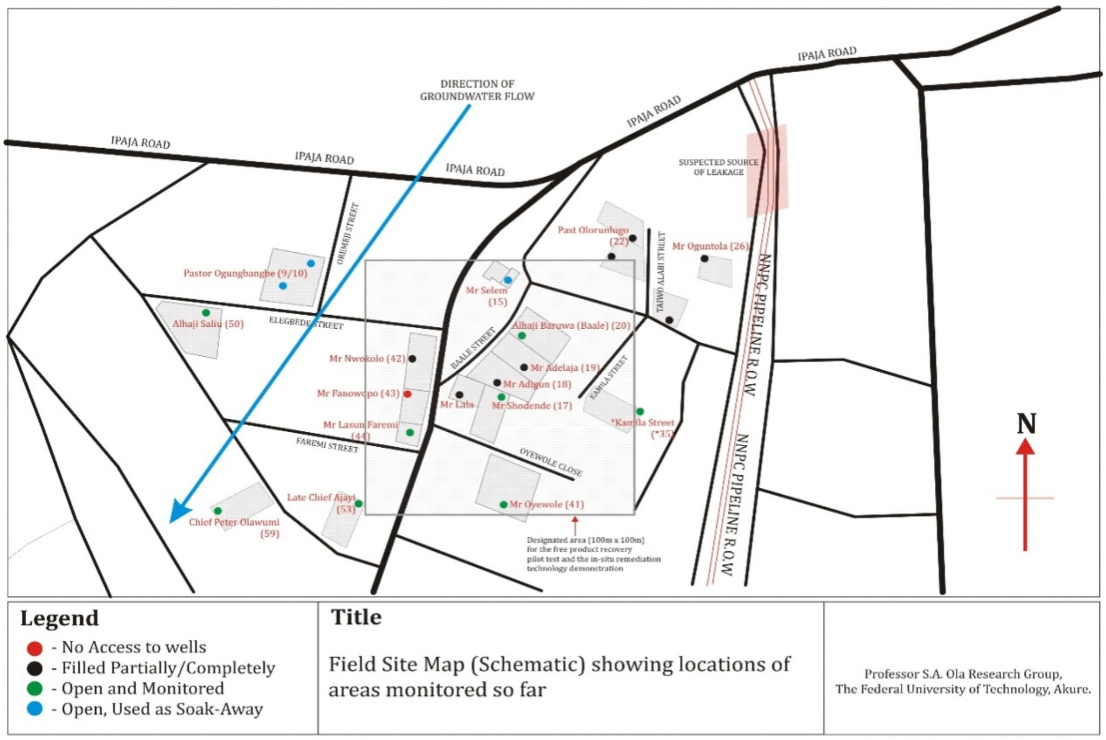

Fig 1b: Field Schematic showing Locations of Wells Monitored and Direction of Groundwater Flow (2014)

2.2 Research Approach

The two major aspects involved in this research work are: laboratory testing of imported and local belt samples of oil skimmer and monitoring of field (field work) performance of belt samples. In carrying out the laboratory test, a portion (3cm x10cm) of each of the six imported belt samples (Standard Poly Belt, Corrosion Resistant Steel Belt, Elastomeric Belt, XP Poly Belt, Light fuel oil, LFO Fuzzy Belt and Looped Fuzzy Belt) and six other local materials (Igala skin, cotton fibre, rug, turkey feather, palm tree fibre and bamboo fibre) were prepared and subjected to laboratory test and their results were thereafter compared to determine their rate of hydrocarbon recovery. The three hydrocarbons that were utilized in the laboratory are petrol, diesel and kerosene fuels sourced from NNPC filling station in Akure

The field work involved using Six (6) hydrocarbon recovery/existing contaminated water supply wells with identity W17, W20, W53, W44, W41, and W35 within 100m x 100m area for the pilot recovery test from the contaminated site in baruwa community, Lagos State.

Field Equipment

The two major equipment that were utilized in the field are; Model 8 - Belt Oil Skimmer which was used for effective recovery of liquid hydrocarbon and oil interface meter was used to measure the elevation of the product and groundwater in each of the selected monitoring wells

2.3 Research Methods

Three laboratory tests were carried out on the samples to determine their properties and ascertain their rate of hydrocarbon recovery. The tests include oil sorption capacity of belt samples, absorbent pick-up efficiency test and oil retention test on belt samples. A simple procedure as reported by *(*Karan *et al.,* 2011*)* was used to study the oil sorption capacity of the belt materials and oil retention capacities of the samples according to the American Standard Test Methods for sorbent performance, ASTM F 716-07: 2007.

Test for Oil Sorption Capacity

In this procedure, Sample fuel (50 g) was placed in a 500ml plastic cylinder; the weight of a measured sample, W_S at a dry was determined with the aid of digital weighing balance and then suspended in the oil bath after which each of the samples was allowed to soak for 20mins and the weight measures as W_{SO}. After shaking and draining, the amount of oil absorbed (g) per g of the sorbent (*S*) which is the oil sorption capacity was determined by weighing, using the relationship given in equation 1:

$$S = \frac{Wso - Ws}{Ws} = \frac{Wo}{Ws} \quad --------------- \quad (1)$$

Test for Oil Retention on Belt Samples

The sample (3cm x10cm) was placed in 500ml of each of the fuels separately for 15 min. while it is vertically hung on a calibrated spring balance. Where upon the adsorbed oil begun to drip from sorbent, the weight of the material was monitored and measured after 15, 30, 60, 90, and 120seconds of drainage. The amount of oil (W_R) retained was determined as a difference between the weight of the wet material (W_T) after drainage and the initial weight of the material, W_S *(*Winter, 2009*).* The weight of oil retained on each sample was computed by the relationship given in equation 2.

$$W_R = W_T - W_S \quad --- \quad (2)$$

Test for Absorbent Pick-up Efficiency

500ml of water was mixed with 200ml of each of the fuels for 15 min. The sample (3cm x10cm) with its weight when dry (W_S) was suspended in the bath for another 15mins on a calibrated spring balance. The weight of the sample and fuel (W_{SO}) was measured. The pick-up efficiency was then evaluated from the two parameters (Moses, 2013) as shown in equation 3.

$$\text{Efficiency (\%)} = \frac{Wo}{Wso} \times 100 \quad \text{------------------------------------- ---------} \quad (3)$$

Procedures for Field Test

The oil skimmer equipment was set up at proper levels in each well. Inspection of all mechanical and electrical components of the skimmer and collection system, and oil/water separator was made. The thickness of free product and water in the wells was measured using water level/ interface meters before and after operation of the equipment to ascertain the level of free product on groundwater surface. The interface meter contains a probe that senses the presence of both oil and water which is signalled by sound indications when in contact with each of the two immiscible liquids (petrol and water).The recovery rate of fluids was monitored by collecting samples at an interval of an hour (1hour) and the discharging rate of the oil skimmer was consequently determined.

3.0 RESULTS AND DISCUSSIONS

3.1 Computation of Oil Sorption Capacity of Belt Samples

Oil sorption capacity test was conducted on both the synthetic and local belt materials and the laboratory results are shown in Table1 and Figure 2. It is shown that light fuel oil fuzzy belt, looped fuzzy belt and standard poly belt have higher value of sorption capacity and hence their better performance over the remaining three imported samples. Similarly, cotton fibre, rug and red deer skin have higher sorption capacities than the remaining local materials (turkey feather, palm tree fibre and bamboo fibre) when soaked in diesel fuel. This shows that more oil is absorbed into their fibre matrix than the remaining three materials.

It is evident in Figure 2 that the oil sorption property varies for different oil densities and viscosities. The oil with higher density (diesel fuel) tends to have higher sorption capacity. The high viscosity of heavy oil significantly affects the capillary penetration of oil into the small pores of sorbent material. Figure 2 further reveals that the sorption behaviour of the three used fuels follows almost the same trend. Light oil tends to be absorbed by sorbent fast and hence the high release rate compared to the heavy oil. Therefore, the three of the six imported samples that performed better in the laboratory are light fuel oil fuzzy belt, looped fuzzy belt and standard poly belt. Besides, some local materials like cotton fibre, rug, Igala skin and turkey feather have exceptional performance over the synthetic materials.

Table 1: Sorption Capacities of Belt Samples in Three Sample Fuels

S/N	Name of sample	Diesel Fuel	Kerosene Fuel	Petrol Fuel
1	Cotton fibre	3.20	2.30	1.70
2	rug	2.43	1.85	1.55
3	Turkey feather	2.05	1.47	0.88
4	Red deer(Igala) skin	2.17	1.62	1.03
5	Light fuel oil (LFO) fuzzy belt	1.68	1.14	0.65
6	Looped fuzzy belt	0.95	0.75	0.47
7	Corrosion resistant (CR) belt	0.42	0.33	0.29
8	Standard poly belt	0.50	0.40	0.38
9	Palm tree fibre	0.20	0.18	0.12

10	XP Poly belt	0.24	0.17	0.16
11	Elastomeric belt	0.19	0.16	0.14
12	Bamboo fibre	0.12	0.10	0.04

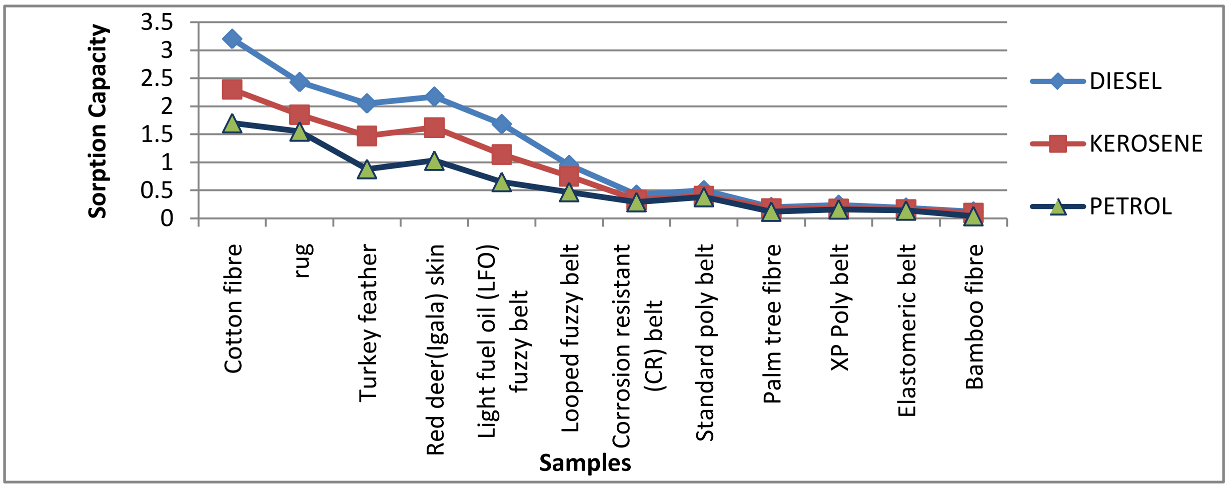

Figure 2: Sorption Capacities of All Samples in the Three Sample Oils

3.2 The Results of Oil Retention Test on Belt Samples

The rate of oil retention on each of the tested samples was investigated by soaking the samples in each of the three fuels used (diesel, kerosene and petrol) and weighing at an interval of time. The results of the weight of petrol retained on each of the materials at a particular time, T (0seconds, 15seconds, 30 seconds, 60 seconds, 90seconds and 120 seconds) are shown in Table 2 and Figure 3.

Higher absorption indicates that the fibres have greater sorption capacity to absorb and hold product of higher viscosities. Heavy product is known to be more viscous having a higher specific gravity; it goes on to the fibres and moves into the interior of the fibrous mass. In the case of low viscosity hydrocarbon (petrol) with low specific gravity (Table 2), the product quickly moves into the fibres mass as well as on to the surface but desorbs easily during the drainage period. This is evident in the decreasing value of the amount of oil retained from 15seconds to 120seconds (2minutes) in each of the materials as shown in Figure 3. It is therefore established that the three of the six imported belt samples that have better oil retention property are looped fuzzy belt, light fuel oil fuzzy belt and standard poly belt whereas some local samples like rug and red deer (Igala) skin showed better oil retention properties compared to other synthetic materials in petrol fuel.

Table 2: Weight of Petrol Fuel Retained at a Specified Time on All the Tested Samples

S/N	Name of sample	Weight of Petrol Fuel Retained w_0 (g)	Weight of Petrol Fuel Retained, w_{15} (g)	Weight of Petrol Fuel Retained, w_{30} (g)	Weight of Petrol Fuel Retained, w_{60} (g)	Weight of Petrol Fuel Retained, w_{90} (g)	Weight of Petrol Fuel Retained, w_{120} (g)
1	rug	6.20	5.00	4.00	3.50	3.00	2.30
2	Red deer (Igala) skin	2.70	1.90	1.70	1.40	1.20	0.95
3	Looped fuzzy belt	2.80	1.80	1.40	1.20	1.00	0.90

4	Light fuel oil (LFO) fuzzy belt	2.40	1.70	1.30	1.00	0.70	0.60
5	Standard poly belt	0.90	0.70	0.65	0.59	0.49	0.42
6	Cotton fibre	1.70	1.6	1.2	0.8	0.60	0.4
7	Elastomeric belt	0.67	0.32	0.27	0.22	0.20	0.17
8	Corrosion resistant (CR) belt	0.70	0.40	0.32	0.20	0.18	0.15
9	XP Poly belt	0.75	0.6	0.3	0.25	0.21	0.12
10	Palm tree fibre	0.30	0.27	0.22	0.17	0.12	0.10
11	Bamboo fibre	0.30	0.25	0.2	0.15	0.12	0.07
12	Turkey feather	0.15	0.13	0.08	0.05	0.03	0.02

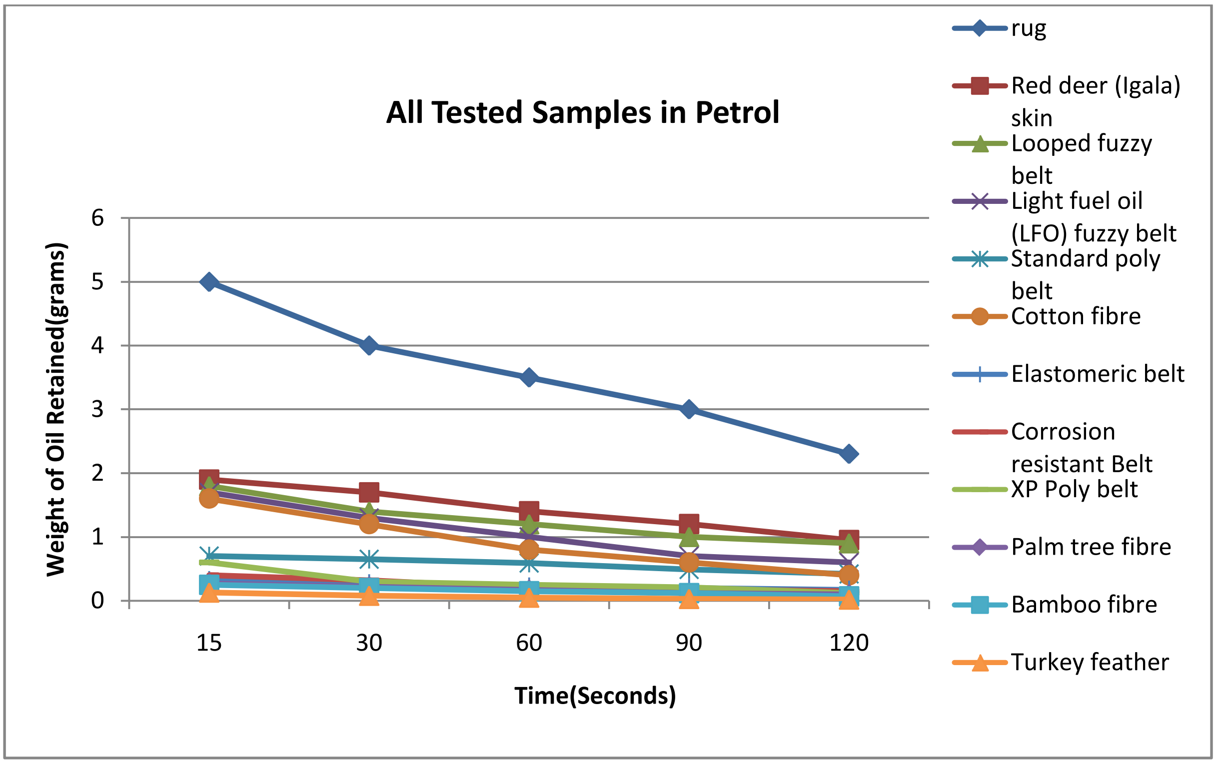

Figure 3: Variation of Weight of Petrol Fuel Retained with Time on All Tested Samples

3.3 The Result of Absorbent pick-up Efficiency Test

The result of pick-up efficiency of each of the tested samples in a mixture of water and each of the three fuels used is shown in Table 3 and Figure 4. From the result in Table 3, light fuel oil fuzzy belt, looped fuzzy belt, and standard poly belt have values of pick-up efficiency of 39.34%, 32.18% and 15.25% respectively in petrol fuel, the values being higher in other fuel samples (diesel and kerosene) due to their higher density. Cotton fibre, rug and Igala skin (local materials) have higher oil pick-up efficiency values in the three sample fuels. This then establishes their suitability in recovering oil from groundwater surface.

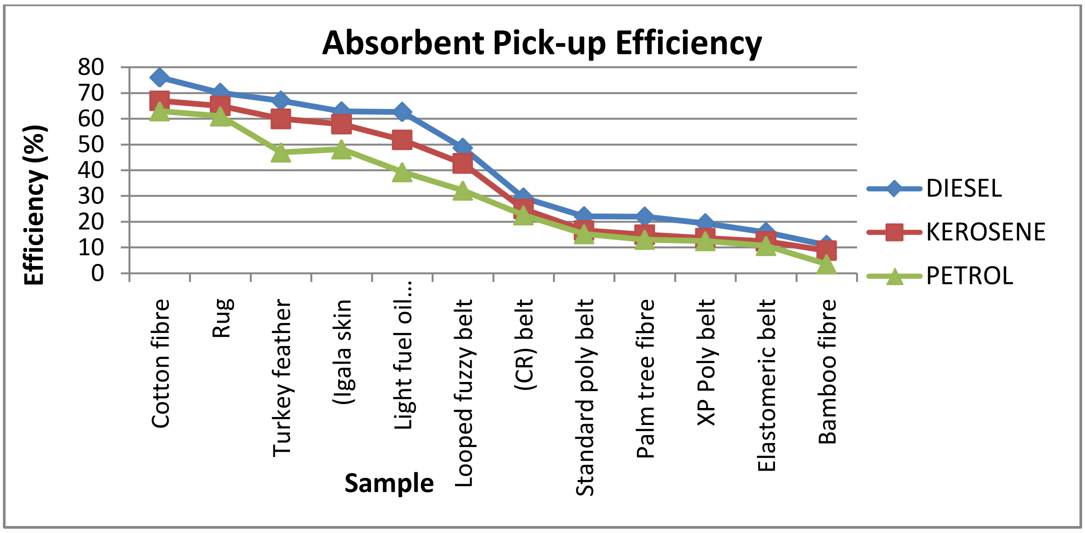

Figure 4: Comparisons of Pick-up Efficiencies of All Samples (Synthetic and Local) in a Mixture of Water and Fuel

Table 3: Summary of Pick-up Efficiencies of All Tested Samples in a Mixture of Water and Fuel

S/N	Size of Sample (cm× cm)	Name of Sample	Absorbent Pick-up Efficiency (%)		
			Diesel	Kerosene	Petrol
1	3 × 10	Cotton fibre	76.00	67.00	63.00
2	3 × 10	Rug	70.00	65	61.00
3	3 × 10	Turkey feather	67.00	60.00	47.00
4	3 × 10	(Igala skin)	62.82	57.97	48.21
5	3 × 10	Light fuel oil (LFO) fuzzy belt	62.63	51.85	39.34
6	3 × 10	Looped fuzzy belt	48.69	42.72	32.18
7	3 × 10	(CR) belt	29.40	25.00	22.58
8	3 × 10	Standard poly belt	22.12	16.67	15.25
9	3 × 10	Palm tree fibre	22.00	15.12	13.08
10	3 × 10	XP Poly belt	19.41	13.73	12.56
11	3 × 10	Elastomeric belt	16.00	12.50	10.68
12	3 × 10	Bamboo fibre	11.00	8.90	3.60

3.4 Field Tests

Initial Field Information of the Site Monitoring Wells

Table 4 shows the respective well information obtained on 26th May, 2014 from the wells monitored and where skimming operations were performed.

Table 4: Initial Hydrocarbon Thickness from the Monitored Wells (26th May, 2014.)

S/N	Well ID No.	Owners Name	Depth to Liquid Surface from Ground Level (m)	Depth to Water in the Well (m)	Thickness of Liquid Hydrocarbon above Water Surface in the Wells (m)
1	W_{17}	Mr Shodende	23.542	24.033	0.491
2	W_{20}	Alhaji Baruwa	23.565	23.575	0.010
3	W_{35}	Kamila Street	23.851	24.101	0.250
4	W_{41}	Pa Oyewole	23.459	23.460	0.001(sheen)
5	W_{44}	Lasun Faremi	23.720	23.721	0.001(sheen)
6	W_{53}	Late Chief Ajayi	24.022	24.055	0.033

The oil/water interface meter indicated sheen on wells W_{41} and W_{44}. Consequently, oil skimming was carried out in the other four wells (W_{17}, W_{20}, W_{35} and W_{53}) as they contained appreciable thickness of hydrocarbon on groundwater surface.

Table 5: Comparison of Percentage Constituents of Skimmed Samples at W17 (16th June, 2014)

Time of Skimming (1 hour each)	CONSTITUENTS (ml)				% CONSTITUENTS		
	LNAPL	Sludge	Contaminated Water	Total	LNAPL	Sludge	Contaminated Water
9am – 10am	1020	40	90	1150	88.70	3.5	7.80
10am – 11am	1040	30	80	1150	90.40	2.6	7.00
11am – 12pm	1130	30	70	1230	91.90	2.4	5.70
12pm – 1pm	1060	20	50	1130	93.80	1.77	4.42
1pm – 2pm	1120	30	80	1230	91.10	2.44	6.50
AVERAGE				**1176.7**	**90.30**	**2.54**	**6.28**

For the fuzzy belt, the rate of skimming as determined in the field was about 12 litres of fuel per hour compared to about 2 litres per hour recovered when poly belt was used. It was therefore decided to use the fuzzy belt for the whole of the field remediation programme. Analysis of the recovered product in Table 5 shows that about 90.3% of the recovered product was petrol while 2.54% was sludge and 6.28% was contaminated water.

4.0 CONCLUSIONS

The conclusions obtained from this study are as itemised below;

1. Oil skimming technique is more effective in recovering petrol from contaminated groundwater surface of Baruwa Community because of the ease with which the belt assembly of the equipment is lowered down into the well to recover free product.

2. Light fuel oil fuzzy belt has the highest sorption capacity of 0.65 among other synthetic belt materials and it removes petrol fuel at the rate of about 12litres per hour. Consequently, its suitability in recovering light non-aqueous-phase liquids (LNAPLs) was confirmed as it removed more than 90% of pure petrol while less than 10% is water and sludge.

3. Cotton fibre has the highest sorption capacity of 1.70 of all the twelve tested samples and it is about 63% efficient in petrol fuel. This shows that that there is a great potential for absorbents made from natural fibres to replace synthetic oil absorbents.

5.0 ACKNOWLEDGEMENT

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