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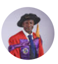
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SITE REMEDIATION IN NIGERIA: PROVEN AND INNOVATIVE TECHNOLOGIES (RECOVERY OF FREE HYDROCARBON FROM SOIL/GROUNDWATER)

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ABSTRACT

This research is concerned with geo-environmental impact assessment and remediation of contaminated soil/groundwater. The specific study site is Baruwa community (Latitude 06˚ 35' 12" N, Longitude 03˚ 16' 21" E), in Alimosho Local government area of Lagos state, Nigeria. The estimated 65,000 people of Baruwa own about 350 hand dug wells for domestic water supply; more than 200 of these wells are at present, under lock and key because of the oil seepage from leaking underground NNPC (Nigerian National Petroleum Corporation) pipeline. The Geoenvironmental Engineering research group in F.U.T.Akure, started Geoenvironmental site assessment, geotechnical, background and natural attenuation studies for the site in 2006. This has enabled delineation of the contaminated zone. Eight (8) hydrocarbon recovery/monitoring wells (W16, W17, W18, W19, W20, W42, W43, and W44) and two bore holes (W401 and W402) were used for the pilot recovery test. Existing contaminated water supply wells were used as hydrocarbon recovery/monitoring wells to minimize cost. Two boreholes were installed for soil vapour extracting and gas surveys in addition to the eight existing wells within the 100m x 100m designated pilot test area. We have already established that water supply wells are covered by pure phase leaking hydrocarbon products from the underground pipes. Tested well waters had been found to be as much as 95 percent petrol and up to 600 mm thickness of free hydrocarbon product on top of the ground water. Volumetric characterization of the pure phase hydrocarbon using Oil/Water Interface meter/ areal measurements and monitoring together with assessment of various technologies (Natural Attenuation, In Situ Chemical Oxidation and Bioremediation) for remediation was implemented for this site.

Keywords: Petroleum hydrocarbon, Volumetric characterization, Remediation, Pilot test, Innovative Technologies

INTRODUCTION

The Geoenvironmental Engineering research group in Federal University of Technology, Akure (FUTA), started Geoenvironmental site assessment, geotechnical, background and natural attenuation studies for the site in 2006. The site is now basically characterized with water table contour maps/direction of groundwater flow, liquid hydrocarbon thickness contour map, periodic hydrocarbon isoconcentration maps, periodic geochemical parameter test data and geotechnical/stratigraphic profiles from geophysical and geotechnical data [1]. This has enabled delineation of the contaminated zone and identification of the likely source of hydrocarbon contamination. Numerical modeling has also been used to predict a period of about 48 years for the natural attenuation of hydrocarbon contaminants at this site [2][3]. The prevalence of the casual handling of petroleum hydrocarbon storage, distribution and dispensing facilities (underground tanks, pipelines and gasoline stations) in developing countries like Nigeria necessitates focus of this study. This is highly relevant in the light of the increasing awareness of the precarious trend of lack of monitoring and remedial feasibility data for the subsoil environment in the thousands of gasoline fuel stations, and petroleum storage/distribution underground infrastructure in Nigeria. In Nigeria, 335,200 deaths occur annually from sanitation, water and hygiene related infections, signifying a 16.7% of total deaths from all sources. This is indicated in the World Health Organization, country-by-country data on the burden of water, sanitation and hygiene related deaths globally [4]. There is now an urgent need to scientifically harness both human and material resources especially in the emerging field of geoenvironmental engineering in order to meet the target 10 (Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation) of the pertinent Millennium Development Goal (Goal 7 – Ensure Environmental Sustainability).

FUTA has a mandate to appropriate technology for environmental sustainability through effective management of environmental (air, water and land) resources in order to have a direct impact on the immediate community and the country at large. Effective management of our environmental resources would certainly contribute to the eradication of extreme poverty and hunger, and ultimately ensure environmental sustainability, thereby addressing goals number one (1) and number seven (7) of the United Nations' Millennium Development Goals (MDG) [5].

METHODOLOGY

Description of the Study Area

The case study site is Baruwa community in Alimosho Local government area of Lagos state (Latitude 6[degrees] 35' N, Longitude 3[degrees] 16' E). The height above the sea level is about 42meters (141 feet). The neighboring towns near the community to the East are Kadara and Akinogun while Fatode and Oduwale are to the south. It has an abundant rainfall of over 2,000 millimeter per year. "BARUWA" is a Lagos suburb Community in Alimosho Local Government Area of Lagos State; South Western Nigeria (Figure 1a). The community is located between the famous Iyana Ipaja and Ikotun. The petroleum hydrocarbon contaminated site is approximately 940m x 740m in size, within which a pilot scheme area of 100m x 100m is earmarked(Figure1b).

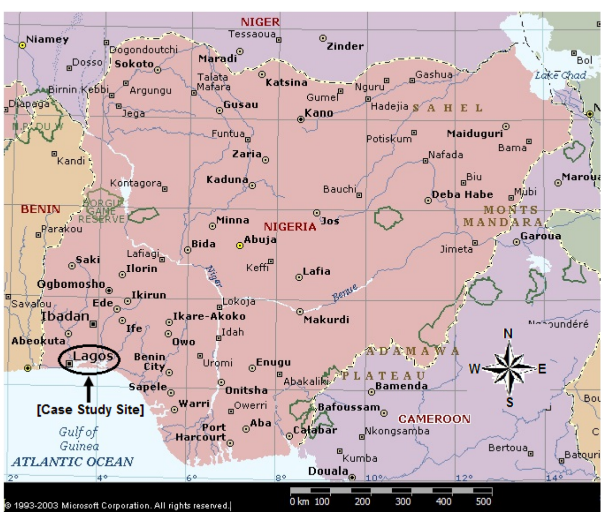

Fig.1a. Map of Nigeria showing Lagos the case study site.

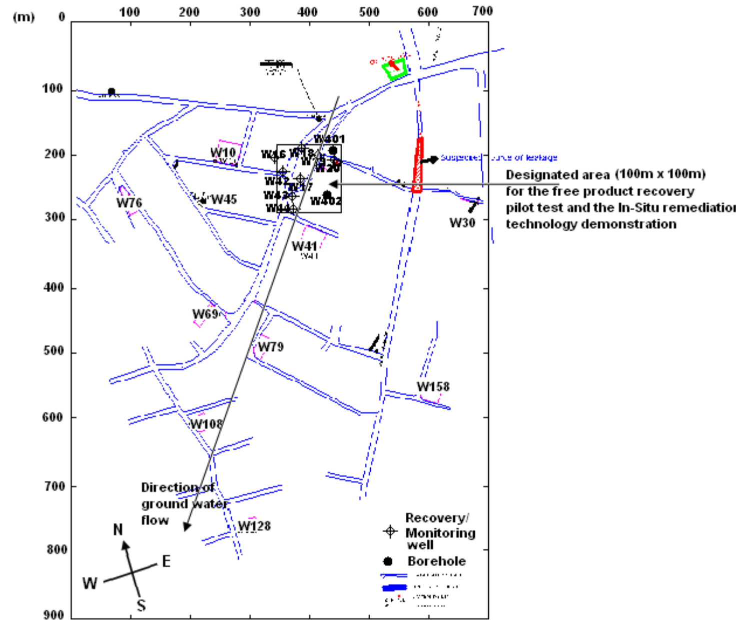

Fig. 1b: Field site (Baruwa, Nigeria) diagram showing location of free product recovery pilot test/In-situ remediation demonstration area.

The estimated 65,000 people of Baruwa own about 350 hand dug wells for domestic water supply and more than 200 of these wells are at present, under lock and key because of the oil seepage from leaking underground NNPC (Nigerian National Petroleum Corporation) pipeline.The Baruwa community is a predominantly residential setting. Majority of the people within this area depend on the groundwater for their survival. Farming was their main occupation until civilization and development brought in diverse infrastructure to the community. This community suffered from the ruptured pipelines of NNPC/PPMC between 1994 and 1996. The leakage went unchecked for several weeks and contaminated the underground water bodies of these areas, polluting wells and boreholes, thus rendering the waters unhealthy for consumption. Nigerian National Petroleum Corporation (NNPC's) Pipeline Product Marketing Company (PPMC's) leaking pipes, running through the community from the Mosimi depot in Shagamu, Ogun State, to the Ejigbo depot in Lagos, had polluted the entire place, destroying farms and making cultivation impossible anymore. The Community's wells had been polluted with no good water available anywhere in the area for the people. Wells and boreholes were covered by leaking products from the pipes. Tested well waters had been found to be as much as 95 percent petrol. Baruwa village is just a few kilometres away from the state capital, Ikeja, but the authorities have failed to stop the pipeline leakage in the community. Because of the oil leaks village wells have to be kept under lock and key to prevent a potential fire disaster.

Field Exerimental Programme

Design and Implementation of pilot Test:

There are more than 200 hand dug domestic water supply wells contaminated with floating petroleum product of varying thickness (0.20m to 0.65m) at this site. Groundwater is about 25m below ground surface in the wells. The wells are between 0.75m and 2.00m in diameter. The geotechnical/Geoenvironmental research group in F.U.T.Akure has an inventory of one hundred and sixty seven (167) existing contaminated wells in Baruwa, Nigeria with well identification numbers and exact location description. Remediation started with a pilot scheme area (100m x 100m), with existing 10 wells within the pilot scheme area. Baruwa site is lithologically underlain with inter bedded sands, gravelly sands, silts and clays and reddish lateritic sandy clays. The lithology is essentially an alternating sequence of sands and clay layers from the ground surface to a depth of about 102m (Table 1).

Table 1:- Typical Borehole Log for Study Area

Case> size 0.15-0.200m **G.W.L = 26.55m**

Layers	Depths (m)	Thickness (m)	Description of the strata
i.	0.00	3.00	Surface Red Sand
ii.	3.00	7.45	Red and Yellow Clay
iii.	10.45	4.05	Red Clay with Sand
iv.	15.00	1.45	Yellow Coarse Sand
v.	16.45	1.55	Hard with Clay
vi.	18.00	16.45	White Sand with Clay
vii.	34.45	1.55	Black Sand
viii.	36.00	1.20	White Hard Clay
ix.	37.20	2.20	Red Sand
x.	39.00	1.20	Red Sand and Clay
xi.	40.20	1.80	Fine Sand and Yellow Clay
xii.	42.00	3.00	White Sand and Red Clay
xiii.	45.00	3.00	Fine Sand and Yellow Clay
xiv.	48.00	3.00	Casey Clay
xv.	51.00	1.45	Soft Black Clay
xvi.	52.45	4.55	Hard Ash Clay
xvii.	57.00	3.00	Sandy Clay
xviii.	60.00	1.80	White Clay
xix.	61.80	4.20	White Fine Sand
xx.	66.00	2.10	Hard White Clay
xxi.	68.10	2.70	Sandy Clay
xxii.	70.80	0.60	Hard White Clay
xxiii.	71.40	0.60	Soft Black Clay
xxiv.	72.00	3.00	Hard White Clay
xxv.	75.00	1.90	White Coarse Sand
xxvi.	76.90	1.10	Medium Sand
xxvii.	78.00	3.00	Soft Black Clay
xxviii.	81.00	3.18	Medium Sand
xxix.	84.18	2.82	White Coarse Sand
xxx.	87.00	13.90	White Coarse Sand
xxxi.	100.90	1.10	Gravel mixed with Clay
xxxii.	102.00	3.15	White Sand mixed with Clay

GWL: Groundwater Level
Total depth drilled = 102.00m
Casing size = 0.150 – 0.200m (6" – 8")
Source: Lagos State Water Corporation (2006)

The method adopted is as follows; use of the PETROXTRACTOR (Model 8) BELT OIL SKIMMER (Figure 2a) to remove most of the free petroleum hydrocarbon product from the wells; Use of potassium permanganate ($KMnO_4$) for in-situ chemical oxidation for the well water together with in-situ bioremediation. The above two methods could be adequate, making it simple and cheap so that it can be replicated in hundreds of such sites in Nigeria. As a contingency, the equipment for air sparge and soil vapour extraction system and dual phase extraction system would be acquired.

There was meeting with the local people to intimate them of the site remediation programme, followed by demarcation of Pilot Test location and site reconnaissance/ identification of monitoring wells and sampling locations for the free product recovery pilot test. Ten (10) hydrocarbon recovery/monitoring wells were earmarked for use in the pilot recovery test (Figure 3). Existing contaminated water supply wells are being used as hydrocarbon recovery/monitoring wells to minimize cost. We have already established that water supply wells are covered by pure phase leaking hydrocarbon products from the underground pipes.

Oil/Water Interface meter (Figure 2) was used to measure the depth to ground water for earmarked wells and to measure thickness of free hydrocarbon on groundwater in water supply wells.

Belt-type oil skimmers use an endless belt of corrosion resistant steel or synthetic medium, were lowered into the well to be skimmed. The belt passes through resilient wiper blades where the oil was removed from both sides of the medium. The Model 8 Oil Skimmer purchased from Abanaki Corporation had a belt 200mm wide and 26 m long.

Fig. 2 Model 122 (CSA) Interface Meter, P8/LM3/60m (Solinst)

RESULTS/DISCUSSION

Monitoring

After meeting with the local people and establishing contact with necessary Agencies, Monitoring and Oil skimming started from Mr. Shodende's compound which had a total free hydrocarbon product thickness of 0.52m totaling about 1.33m^3 of Liquid Hydrocarbon. Other wells monitored within and outside the pilot test area had between 0.22 to 0.001m of liquid hydrocarbon

The present status of the examined wells within the pilot scheme area is indicated in Figure 3 and the monitoring test results presented in Table 2 and Figure 4.

It was realized that most compounds had carried out the filling and sealing up of their respective wells. Only three out of the ten wells within the earmarked pilot test scheme were still opened, others wells had been sealed while some others visited had been utilized for effluent discharge and refuse.

It was quite disappointing to realize that many of them cited losing hope in our coming, previous "promise and fail" experiences they had had and the no longer tolerable fume emission from the wells as reasons for embarking on filling and sealing up the wells. Many of them had carried out deep depth borehole drilling in their compounds as substitutes for the filled wells, although they also found the water to be non-drinkable.

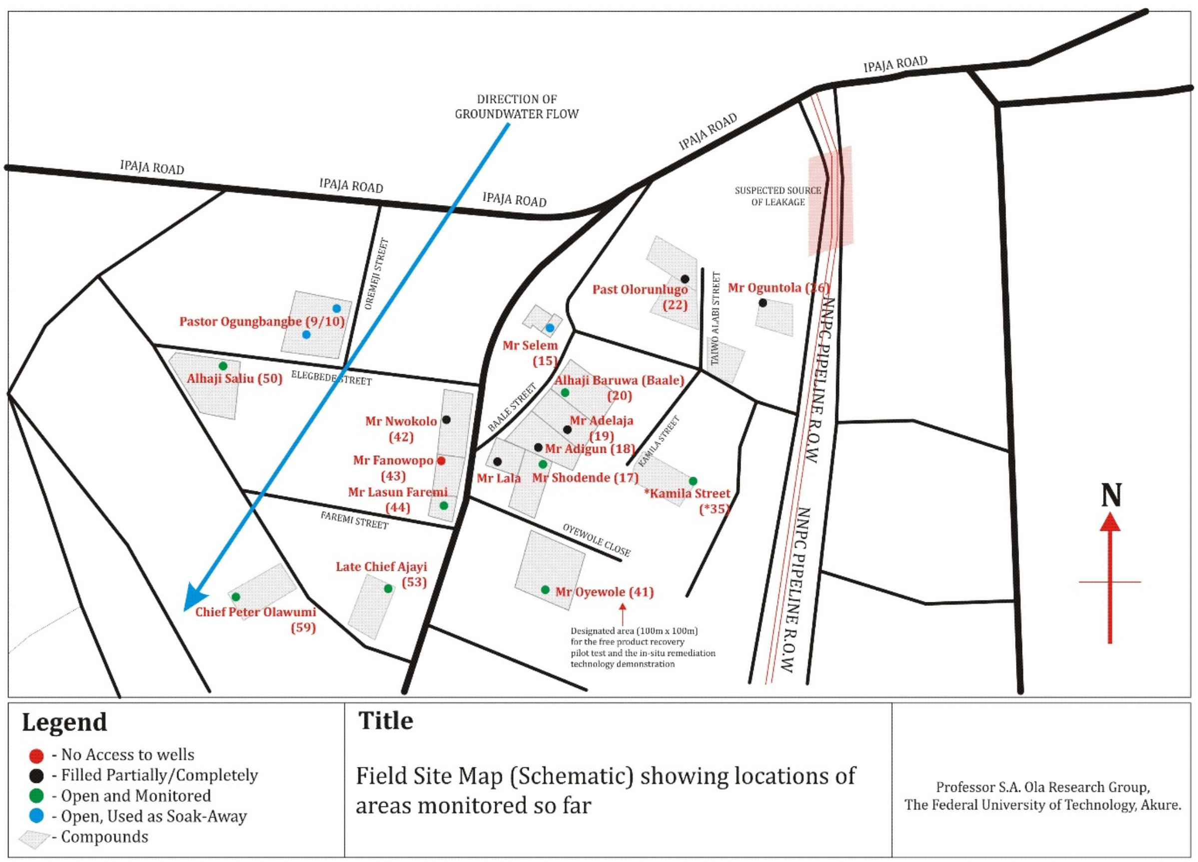

Fig 3 Demarcation of Pilot Test location showing state of the earmarked wells for the pilot recovery test

Table 2: Information from Monitored Wells.

S/N	ID No.	Owners Name	Depth to Liquid Surface from Ground Level (m)	Depth to Water in the Well (m)	Depth to Bottom of Well from Ground Level (m)	Thickness of Liquid Hydrocarbon above water surface in the wells (m)	Thickness of water in the wells (m)	Elevation of Ground level (m)
	20	Alhaji Baruwa	23.721	23.725	24.506	0.004	0.781	49
2	15	Pa Selem	Sealed with Concrete Slab Covering, but on accessing has been converted to soak-away.					50
3	19	Mr. Adelaja	Filled with Sand and Sealed with Concrete.					
4	18	Mr Adigun	Filled with Sand and Sealed with Concrete.					
5	16	Mr Lala	Filled with Earth and other Materials Partially.					
6	42	Mr Nwokolo	Filled with Earth and other Materials Partially.					
7	43	Mr Fanawopo	Building Construction Demolished, No Access to Wells.					
8	44	Mr Lasun Faremi						
9	17	Mr Shodende	23.542	24.033	24.651	**0.491**	0.618	44
10	41	Pa Oyewole	23.459	23.46	24.179	0.001	0.718	48
11	10	Pastor Ogungbangbe	Converted to soak-away					
12	26	Mr Oguntola	Filled with Earth Partially and currently being used for Refuse Collection					
13	35*	Kamila Street*	24.216	24.437	25.25	0.221	0.813	58
14	22	Pastor Olorunlugo	Filled with Sand and Sealed with Concrete.					
15	50	Alhaji Saliu	24.492	24.493	25.487	0.001	0.993	54
16	59	Chief Peter Olawunmi	23.519	23.52	24.47	0.001	0.95	53
17	53	Late Chief Ajayi	24.022	24.055	25.842	0.033	1.787	57

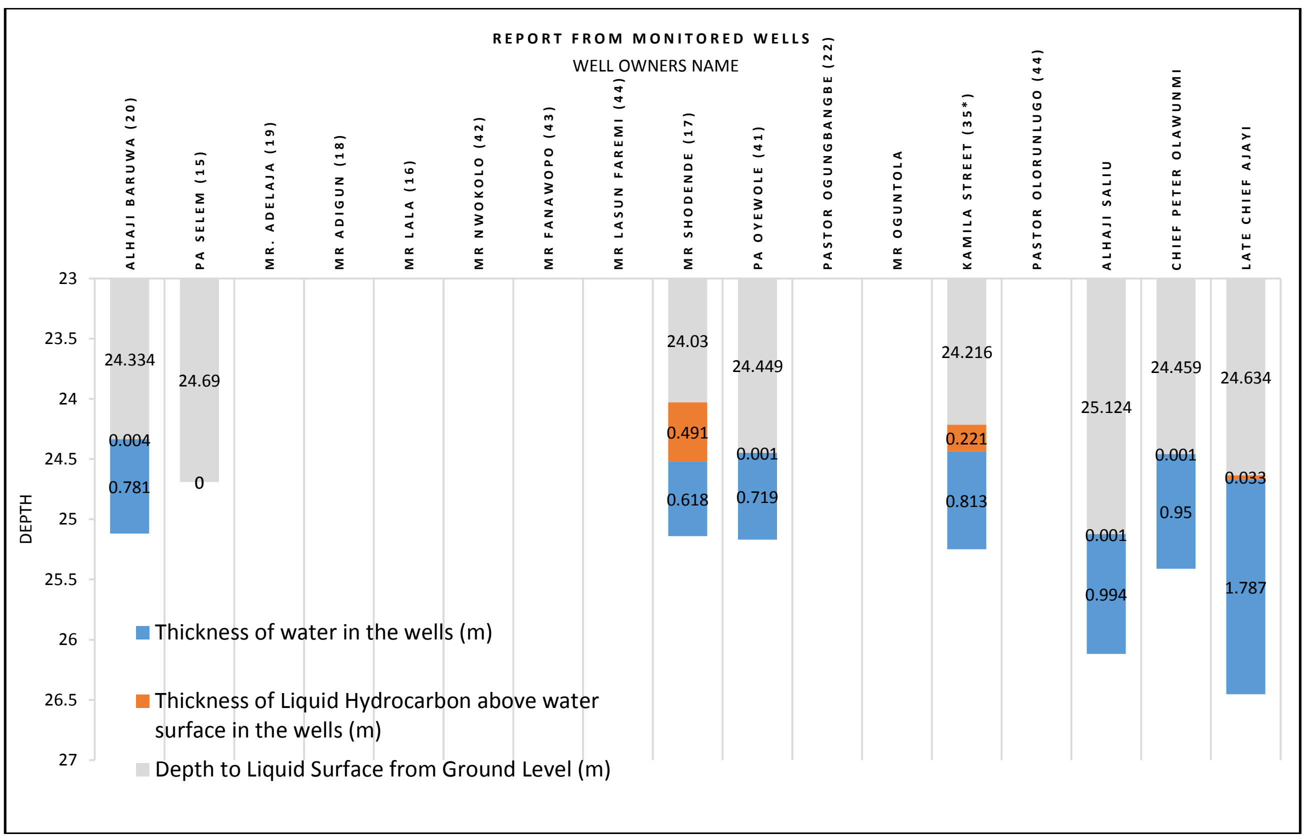

Fig 4 Reports of all wells monitored showing the various thicknesses of free hydrocarbon product and water

Oil Skimming

The oil skimmer was employed in recovery the free product form the wells were it had been discovered. Skimming essentially started from the well with the highest amount of free product discovered (Well 17) and progressed to others which had just a sheen on the surface of the water within the wells. The placement of the belt/yoke assembly was adjusted to ensure that it was within the hydrocarbon product. Samples were collected at one-hour intervals and analyzed. An improvised bailer was combined with the oil skimmer to increase the rate of recovery of free product. At Well 17, about over 84 Litres of free product hydrocarbon was recovered.

CONCLUSION

With the use of an improvised bailer and measuring buckets, the bailer was carefully adjusted to fall only within the free product zone so that minimal amount of water/sludge was obtained in the final collection.
It was realized that within a little above an hour, a total of 104.5 litres (Free product – 84 Litres, Sludge – 3.1 Litres, Water – 17.4 Litres) of liquid mixture was bailed out. Bailing was found to be very effective in collection of free product, with very stringent safety measures put in place. Oil Skimming was adopted alongside bailing to bring the free product to almost sheen level. Bailing was found to have recovered more sludge-water mix than the oil skimmer, recovering about 10% more than the use of the oil skimmer. This is still found satisfactory owing to the speed of recovery. Recovered Free Product was still within the 80% range.
Methods employed in recovering free hydrocarbon product on the pilot test scheme site were found to be effective in removing free product from the contaminated wells. Currently, the wells are being pumped and samples collected before and after each pumping to determine the extent of contamination in the water. Other wells would be dug within the area to be able to access the actual amount of contamination within the various strata in the formation of the area.

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