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Remediation of Oil Polluted Well in Baruwa Area of Lagos State with Potassium Permanganate

Oluwalope MT*, Aramide OT and Ajayi OO

Department of Chemistry, Federal University of Technology Akure (FUTA), Akure, Nigeria

Abstract

Crude oil spills on soil, leakages from pipelines, underground and surface fuel storage tanks and careless disposal and mismanagement of waste and other petroleum by-products of the society, constitute the major sources of petroleum contamination in our environment. 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. Water samples were collected from seven hand dug wells (Jakande, Kamilla, Baale, Shodeinde, Oyewole, Lasunferanmi and Ajayi). Jakande was the control while the rest were the contaminated wells. All the wells contained TPH and Lasunferanmi had the highest TPH while Jakande had the lowest. It was observed that after the application of KMnO4 to the water samples from the oil polluted wells, the TPH concentration reduced significantly in the laboratory. Also, the kinetics of the remediation done for the reactions followed a second order reaction with a proof of linearity of the graphs and R2 value close to unity.

Keywords: Chemical remediation; Oil polluted wells; Potassium permanganate

Introduction

Water is a constant gift of nature that defines peace in life. It remains a veritable endowment of nature necessary for life sustenance of plants and animals [1]. Water support all forms of biological resources (plant and animal life) and are normally obtained from two major natural sources which are surface water (water bodies) such as rivers, streams, fresh water lakes and ground water (geological water) such as borehole and well water [2,3].

Oil is a general term used to denote liquid petroleum products which mainly consists of hydrocarbons. The release of oil into the natural environment is termed oil spill. The extraction, refining, transportation and storage of oil are accompanied by seepages and spills by operations or accidents. Deliberate act such as sabotage, oil bunkering, lack of maintenance of engineering equipment, tanker accidents causes oil spill. Oil spill can also occur through natural disasters like hurricane and earthquake, movement of tectonic plate and inadequate trap system [4].

There has been a significantly higher rate (spills per length of pipeline) of serious pipeline spills in the Niger Delta than in developed countries such as the USA, beyond that accounted for by sabotage. This, and other evidence, suggests that oil companies operating in the Niger Delta are not employing internationally recognized standards to prevent and control pipeline oil spills [5]. According to Opukri and Ibaba [6], environmental degradation issues are of tropical concern to communities in the Niger Delta as it is a major cause of productivity losses. The dominant view blames oil production and its attendant consequences for the declining productivity of local economies that are mainly based on fisheries and agriculture [7]. The literature on the Niger Delta highlights poverty, unemployment, underemployment, proletarianisation, and rural urban migration as the consequences [6]. The collapse of the local economies, induced by oil spillages, gas flaring and other activities of the oil industry had displaced many from their occupations, without providing viable alternatives.

Statement of the problem

Baruwa is a host community of NNPC pipeline which runs through the community from Mosinmi oil depot to Ejigbo oil facility.

The community had their wells and borehole contaminated with petroleum hydrocarbon due to oil leaks from the pipeline as a result of the aged and rusted pipeline. In the same vein, about 500,000 people have been deprived of drinkable water since 1996 because of the oil seepage from leaking underground NNPC (Nigerian National Petroleum Corporation) pipeline. According to Baale and the community residents, the residents have suffered persistent catarrh, irritation of the airways, wateriness, discoloration of the cornea of the eyes, skin rashes, and dermatitis [8].

Aims of the research

This research is concerned with the remediation of oil water samples from Baruwa Community in Lagos state by the application of potassium permanganate and the evaluation of the kinetics of remediation.

Materials and Methods

The study area

Baruwa community is located in the Alimosho Local Government of Lagos State. It lies between latitudes 6"36" 12"and longitude 3"16'. It is drained by Lagos lagoon, Badagry creek and Lekki lagoon which runs into the lagoon. Geographically, the community lies on a poorly sorted coastal sedimentary plain and recent alluvial deposit in Nigeria. The Local Council is richly blessed with arable landmass of about 57.621 km^2 and it is surrounded by rivers Owa and Oponu which are suitable for navigation, fishing and tourism purposes.

Groundwater in Baruwa is about 25 m below ground surface in wells. The wells are between 0.75 m and 2.00 m in diameter. The wells within the pilot scheme area are about 1.2 m in diameter. There are more than 200 hand dug domestic water supply wells contaminated with floating petroleum product of varying thickness (0.20 m to 0.65 m) at this site because of oil seepage from leaking underground NNPC (Nigerian

***Corresponding author:** Oluwalope MT, Department of Chemistry, Federal University of Technology Akure (FUTA), Akure, Nigeria, Tel: +2348038622658; E-mail: sirmantee@yahoo.com

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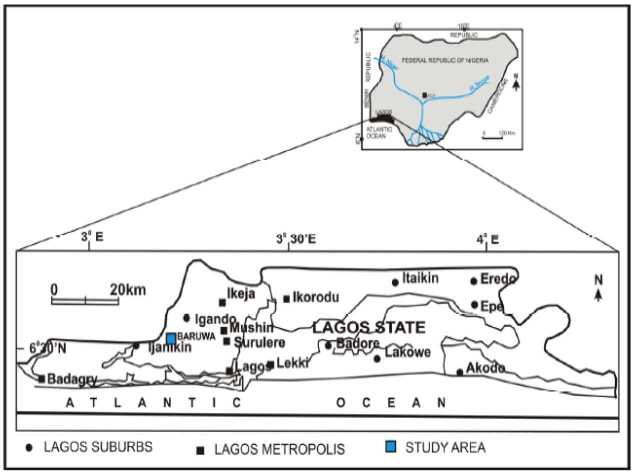
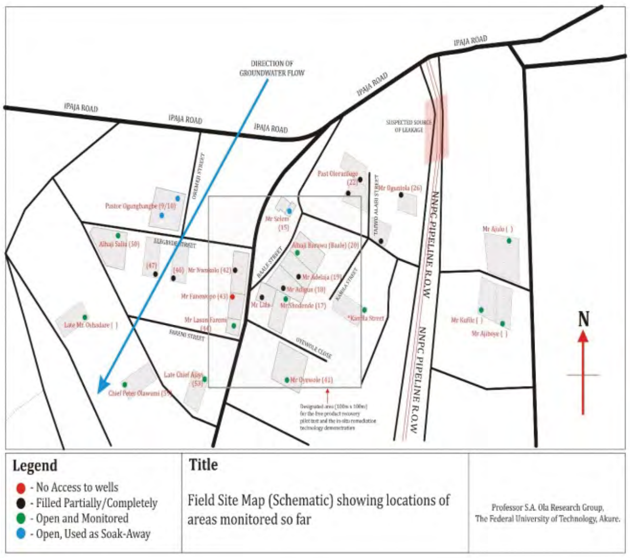
National Petroleum Corporation) pipeline. One well was selected for study, Ajayi's well and this represents one of the most polluted wells in Baruwa community.

Sample collection and preservation

The water samples for this study were collected from six wells within the pilot scheme and one well outside the pilot scheme as control in Baruwa area of Lagos State. Plastic bottles pretreated with dilute sulfuric acid and thoroughly rinsed with distilled water were used to collect samples for Total Petroleum Hydrocarbon (TPH) and 2 ml of concentrated sulphuric acid was added to each litre of the sample as preservative. The samples were stored in the refrigerator at 4°C prior to analysis [9].





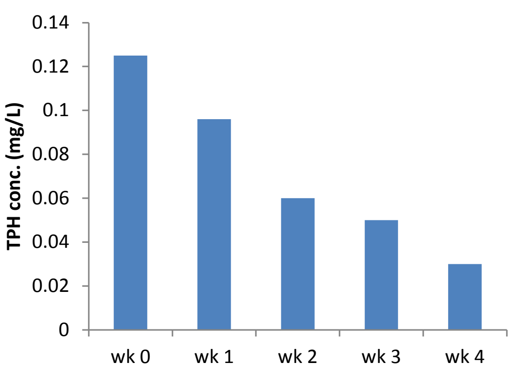


Figure 1.1: Bar chart of remediation of Oyewole with $KMnO_4$.

Methods

Determination of total petroleum hydrocarbon solvent extraction

50 ml of samples was collected into 250 ml separating flask. 30 ml of Dichloromethane (DCM) was added into the flask. The flask was shaken and pressure released at intervals. The sample was allowed to stand for few minutes and two layers were formed in the flask. The lower layer (extract) of the sample was collected into a beaker through a filter paper that was filled with anhydrous sodium sulphate (Na_2SO_4). The extraction was done in three batches.

Extracts clean-up and TPH analysis

Column preparation was carried out by inserting glass cotton into the column. Silica gel was dissolved with DCM to form slurry and the slurry was added into the column. Anhydrous Na_2SO_4 was also added and the extract was transferred into the column. The eluted sample was collected in a beaker below the column. This was then concentrated with a Rotary evaporator and then 5 ml of n-hexane was added and the solvent was left to evaporate to dryness. Thus, the TPH was calculated below:

Total Petroleum Hydrocarbon (TPH) mg/L=(A-B × 1000)/Sample Volume (ml)

where, A=Total gain in weight for experimental sample (mg); B=Gain in weight for blank (mg)

Procedure for remediation

The Total Petroleum Hydrocarbon (TPH) of each of the water samples were first determined to ascertain the initial concentration. Then 0.01 M of $KMnO_4$ solution was prepared and used for treatment. The molarities was applied to 250 ml of the the samples: Jakande (control), Kamilla, Baale, Shodeinde, Oyewole, Lasunferanmi, and Ajayi, first at 4 ml each for the first and second week, then 2 ml each in the third and fourth week and the TPH concentration was evaluated every week using gravimetric analysis. The volume of sample evaluated for TPH every week was 50 ml each.

Determination of TPH and kinetics of remediation

In Table 1, TPH ranged from 0.119 to 2.54 mg/L. Jakande (control) had the least concentration while Lasunferanmi had the highest concentration. Shodeinde and Oyewole had 0.544 and 0.466 mg/L respectively. In Figures 1.1 and 1.5, the remediation of Oyewole and Kamilla followed a trend that showed a slow and gradual decrease in TPH concentration at every week of the oxidation process. While in Figure 1.3, there was a very drastic decrease in the TPH value from 2.54 mg/L to 0.3 mg/L in the first week, while a slow and gradual decrease was observed in other weeks. Similarly, in Figure 1.7, there was also a sharp decrease in TPH value from 0-1 week while in week 2, the value increased but decreased again in week 3 and 4.

Kinetics of permanganate oxidative method was investigated for its order of reaction. The concentration of total petroleum hydrocarbon left was plotted against time as represented in Figures 1.2, 1.4, 1.6 and 1.8. It was observed that TPH decreased with time as reaction progressed. This was a strong indication that there was an interaction between

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total petroleum hydrocarbon molecules and the reacting species of the treatment solution in the permanganate-oxidative method employed in the study. The equation 1/(TPH left)=Kt+1/ (initial TPH) established the relationship between TPH concentration and time for a second-order reaction, where t=time and K=rate constant. Plot of 1/ (TPH left) against time gave a graph of good linearity confirming second order reaction kinetics for the permanganate–oxidation method. The graph of Bar Oyewole and Kamilla looked exactly the same, their R^2 values were close as well as their $t_{1/2}$: 0.912 and 0.937, and 1.33 and 1.15 week respectively. This was shown in Figures 1.2 and 1.5. However, in Figures 1.4 and 1.8, the $t_{1/2}$ of Lasunferanmi and Shodeinde were 0.41 and 0.96 week respectively. This implied that half of the TPH was already decomposed within few days- less than a week. This was a very good result because the half-life should be shorter in the early stage of the reaction when more of the reactant molecules were present to collide with each other.

R^2=0.912, K=6.025 week^{-1}

[A exp.]=0.125 mg/L, [A cal.]=0.178 mg/L

$T_{1/2}$=1.33 week

Site	TPH (mg/L)
Jakande	0.119
Kamilla	0.271
Baale	0.174
Shodeinde	0.544
Oyewole	0.125
Lasunferanmi	2.54
Ajayi	0.466

Table 1: Determination of TPH of the wells before remediation.

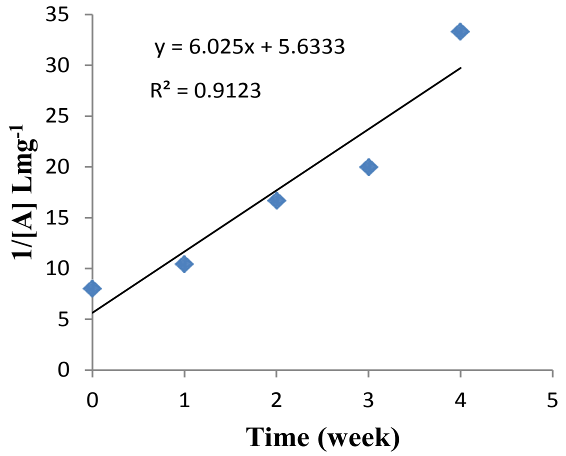

Figure 1.2: Graph of second order reaction of Oyewole.

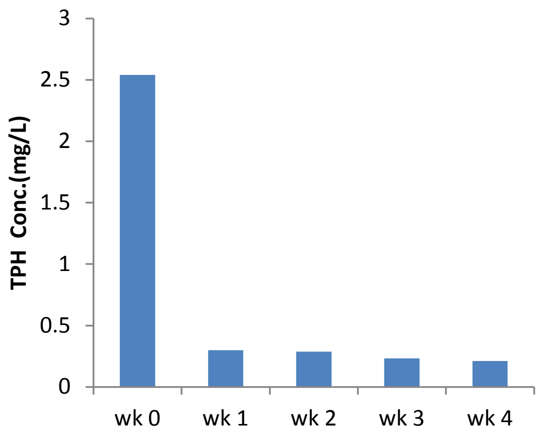

Figure 1.3: Bar chart of remediation of Lasunferanmi with $KMnO_4$.

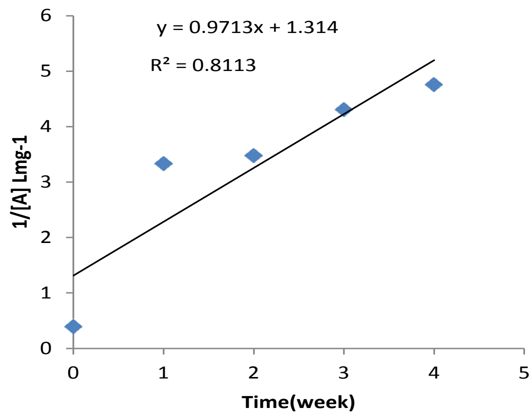

Figure 1.4: Graph of second order reaction of Lasunferanmi.

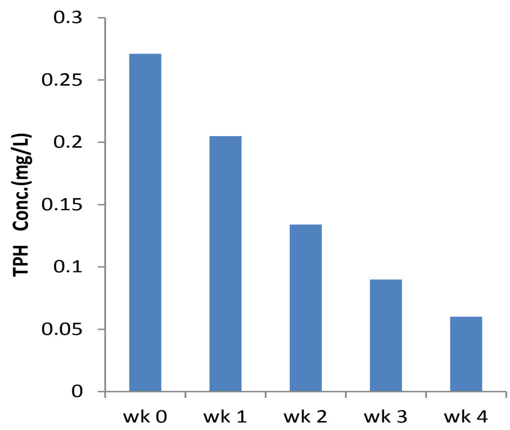

Figure 1.5: Bar chart of remediation of Kamilla with $KMnO_4$.

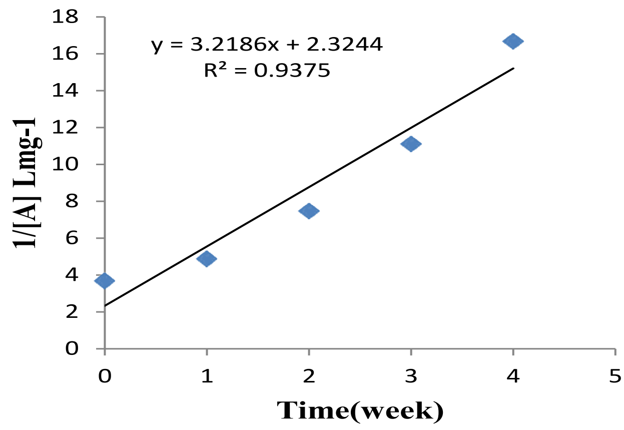

Figure 1.6: Graph of second order reaction of Kamilla.

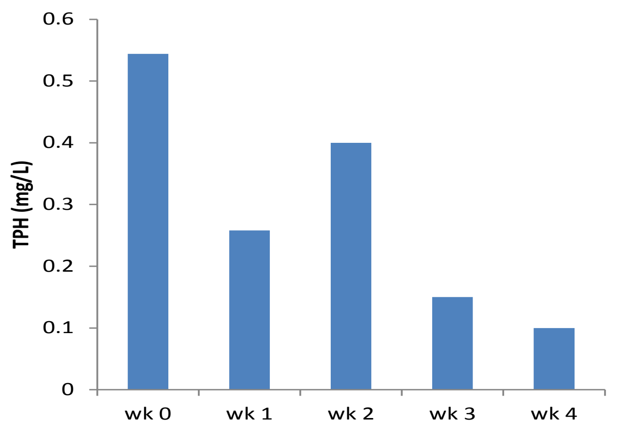

Figure 1.7: Bar chart of remediation progress of Shodeinde with $KMnO_4$.

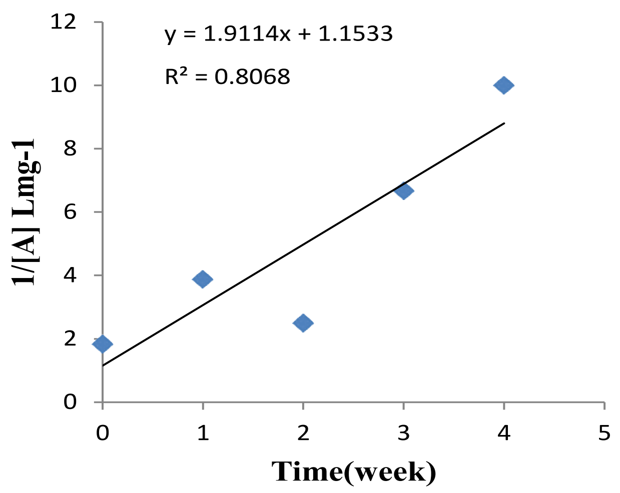

Figure 1.8: Graph of second order reaction of Shodeinde.

R^2=0.811, K=0.971 week^{-1}

[A exp.]=2.54 mg/L, [A cal.]=0.761 mg/L

$T_{1/2}$=0.41 week

R^2=0.937, K=3.218 week^{-1}

[A exp.]=0.271 mg/L, [A cal.]=0.430 mg/L

$T_{1/2}$=1.15 week

R^2=0.806, K=1.911 week^{-1}

[A exp.]=0.544 mg/L, [A cal.]=0.867 mg/L

$T_{1/2}$=0.96 week

Conclusion

The study revealed that all the wells contained TPH and are therefore polluted with petroleum hydrocarbon but at different concentrations. Even, the control (Jakande) also contained TPH. Geoenvironmental Engineering research group in Federal University of Technology Akure, Nigeria, had already pumped and skimmed off a large volume of petroleum hydrocarbon from the well before the samples were collected. The remediation of the wells with potassium permanganate followed a second order reaction. The graph of Oyewole and Kamilla followed the same pattern; their R^2 were closer to one than Shodeinde and lasunferanmi. Also, their half-life was greater than one week. While, the half-life of Lasunferanmi and Shodeinde was less than one week; with Lasunferanmi, being the least, 0.41 week and shodeinde, 0.96 week.

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