Nigerian Journal of Technology (NIJOTECH)
Vol. 32. No. 3. November 2013, pp. **435 – 439**

ISSN: 1115-8443
www.nijotech.com

EFFECTS OF PARTICLE SIZE DISTRIBUTION ON BIOREMEDIATION OF CRUDE OIL POLLUTED SANDY SOILS

C. S. Adaba
DEPARTMENT OF CIVIL ENGINEERING, UNIVERSITY OF NIGERIA, NSUKKA, ENUGU STATE, NIGERIA
Email: realsandra@rocketmail.com

Abstract

Bioremediation has been proven to be the most effective method of cleaning up oil contaminated soils through the application of nutrients and microorganism. Hence, this research presents the effects of particle size distribution on bioremediation of crude oil polluted sandy soils. Six different soil samples were sieved using the B.S sieve sizes. The sieve sizes were classified into X and Y such that X is fine to coarse sand while Y is very fine to coarse sand according to U.S Bureau and Public Roads Administration (PRA) soil classification system. The soil samples were polluted with escravous sweet crude oil at a uniform rate concentration of 4% under aerobic condition. Treatment commenced after four days using nutrients (N.P.K 15:15:15 fertilizer and cow dung) and microorganism (Pseudomonas). Soil samples were examined for physiochemical and microbial characteristics for a period of 42days. The parameters examined were: moisture content, particle size distribution, total hydrocarbon content, soil pH, available nitrogen, available phosphorus, total heterotrophic bacteria and fungi count. The analysis of the soil characteristics throughout the remediation period showed that total heterotrophic bacteria and fungi counts increased in all the soil samples. THBC was highest in sample G for both fine to coarse sand(X) and very fine to coarse sand (Y) with values of 250cfu x10^5/g and 298cfu x10^5/g at least values of coefficient of uniformity(cu) respectively. There was a decrease in nitrogen, phosphorus, organic carbon content, moisture content, pH and total hydrocarbon content. The result of the study revealed that, the rate of hydrocarbon loss was higher in samples with less coefficient of uniformity values compared to samples of higher coefficient of uniformity (Cu) values, an indication that particle size distribution parameters could be one of the factors affecting bioremediation.The correlation coefficient(r) of Total hydrocarbon content versus Ccoefficient of uniformity for fine to coarse sand(X) is 0.867 while for very fine to coarse sand is 0.923.

Keywords: Oil pollution, bioremediation and soil characteristics

1. Introduction

In Nigeria, particularly in the Niger Delta regions; the soils found are mostly sandy soils in shades of different colour of white, brown, grey and red. Sandy soil has weight percentage of mineral particles less than 2mm and greater than or equal to 0.05mm in equivalent diameter. The sand separates recognized are: very coarse, coarse medium, fine and very fine determined from the particle size distribution curve. The property of a coarse grained material mass depends also on the uniformity of the sizes of the grain. William [1] defined coefficient of uniformity as an index value showing the average slope of grain size distribution in a soil. This depends on the gradation or distribution curve of the soil sample. The larger the numerical value of coefficient of uniformity, the more the range of particles [2]. Sand particles because of their size have a direct impact on the porosity of the soil.

The high incidence and frequency of crude oil spill have been of great concern to Environmental Engineers in Nigeria. This has given rise to intensive research to finding ways and means of generating information and data required to assist in bioremediation strategies of crude oil spills. It has been found that addition of certain nutrients and microorganisms to crude oil contaminated soils hastens the rate of hydrocarbon loss in a process called bioremediation. Analysis of biodegradation rate of crude oil contaminated soil using fertilizer or cow dung showed that fertilizer was a better nutrient source for biostimulation than cow dung [3]. Ayotamuno and Kogbara [4] in their various researches discovered that, crude oil contamination of agricultural soil limits the availability of oxygen in the soil layers and hence impedes the biodegradation process. Their findings did not investigate on the particle sizes of the soil layers to detect the porosity and voids. Other notable researchers have also carried out studies on physiochemical, microbial and geotechnical characteristics of the various soils polluted by crude oil, but not much has been done on the effects of particle size on bioremediation.

This study is aimed at, investigating the effects of particle size distribution parameter (coefficient of uniformity) on bioremediation and characterize the soil and crude oil samples used for the experiment. The realization of this objective will provide information and data about the soil particle size distribution on bioremediation which could be used for further bioremediation studies as well as adopt the most suitable method of remediation and cost estimate of remediation strategy.

2. Sample preparation and tests

The sandy soil samples used for this study were collected randomly from different locations in Nsukka which is situated 6^0 52′N and $7^0$24′E, 70km North of Enugu State. For the purpose of this research, the individual soil sample was air dried and passed through 212 micro B.S sieve. Classification was done based on the use of varying sieve sizes and numbers into X and Y. (X Sieve NO:8, 10,16,36,44,60,120 & 150 and Y Sieve NO: 8, 16, 30, 44, 60, 85, 120, 150, 170, 240 & 300) The soil particles retained on each sieve were poured into plastic containers (6 plastic container containing the sieved soil sample represents class X, while the other 6 plastic container containing the sieved soil sample represents class Y).

Escravous sweet crude oil was poured at a constant rate of 4% concentration on each plastic container containing the sieved soil sample, the crude oil was to serve as the pollutant. The moisture content of the polluted soil sample was determined immediately after adequate mixing. The soil samples were left for 4days before the commencement of treatment process. Prior to the treatment, the Physiochemical and Microbial analysis test on the soil samples were carried out.

The treatment process, commenced after 4days of pollution. This involved the application of about 100g of NPK 15:15:15 Fertilizer and about 250g of wet cow dung together with 2ml of pseudomonas, this was inoculated in a nutrient broth into the polluted soil samples. The soil samples were homogenously mixed by turning (aerobic condition) after the application. Samples were collected weekly for a period of 42 days to be tested for, chemical and microbial analysis under aerobic condition.

The parameters determined includes: moisture content, particle size distribution, soil pH, organic carbon content adapted from [5], available nitrogen, available phosphorus, total hydrocarbon content, total heterotrophic bacteria count (THBC) and total heterotrophic fungi count (THFC).

3. Results and discussion

The particle size distribution curve indicated that the soil type is sandy.Class X represents fine to coarse sand, while class Y represents very fine to coarse sand.The classification was done in accordance to U.S Bureau Soil Classification System.

Figure1A and B shows the classification of the soil samples. Due to the varied sieve sizes, there were variations in the Cu, D_{10} and D_{50} values, between the two classes (X and Y). The lower the Cu values, the faster the rate of hydrocarbon loss in the soil as shown in Figure2A and B.

During the periods of remediation, concentration of THC reduced; with sample G having the least concentration of THC of 2000 and 3000mg/kg for both Fine to Coarse Sand (X) and Very Fine to Coarse Sand (Y) respectively.From Figure2A and B below,it was observed that, the lower the coefficient of uniformity the faster the rate of hydrocarbon loss; this could be attributed to the larger voids being present in the soil sample; a favorable condition for microorganism to effectively utilize the nutrients contained in the sample, compared to the class with higher values of Cu. The correlation coefficient(r) of THC Vs Cu is 0.867 for Fine to Coarse Sand while the r value for Very Fine to Coarse Sand is higher with r value of 0.923. The percentage reduction in THC is shown in Figure3A and B below.

There was an increase in pH after 4 days of crude oil pollution. Braddy and Weil [6] had previously reported such variability in soil pH after pollution. The pH value slightly closer to the alkaline side was noticed in sample G with a value of 5.63 for fine to coarse sand and 5.58 for very fine to coarse sand at the end of remediation as shown in Figure4A and 4B respectively.

The moisture content reduced throughout the remediation period for all the soil samples, on the 8^{th} day of remediation, a moisture content of 24% was observed on sample H, which gradually reduced to 8% on day 42. Samples G,I,B and J had difference in percentage reduction of moisture content of 8%,10%,11% and 14% respectively between the 8^{th} day and last day of remediation as shown in Figure5A. This could be attributed to certain environmental condition like evaporation.High moisture content limits, the oxygen distribution thus; restricting diffusion of oxygen through the water phase [7].

Sample G of Figure6B showed a reduction in total organic carbon content from 3.0g/kg to 0.01g/kg at day 8 and day 42 periods of remediation respectively, while a reduction from 3.4g/kg to 0.9g/kg was noticed in sample G of Figure6A. A reduction difference in total organic carbon content between day 8 and day 42 periods of remediation for sample B .of Figure6A and 6B are 2.8g/kg and 2.4g/kg respectively. The reduction in total organic carbon could be attributed to the fact that, the microbes utilized these nutrients in order to increase in their population.

The available phosphorus content reduced to 0.7g/kg at the end of remediation for sample A of Figure8A, while a reduction of about 0.42g/kg was noticed in sample A of Figure8B. The reduction in phosphorus content for soil sample B of Figure8A and 8B between day 8 and day 15 periods of remediation are 0.09g/kg and 0.12g/kg respectively. Soil samples B,H,I and J of Figure7A showed a similar trend in reduction of available nitrogen throughout the periods of remediation. Sample G of Figure7A had a reduction of 0.07g/kg of available nitrogen between day 8 and day 42 remediation periods, while sample G of Figure7B had a reduction of 0.02g/kg of available nitrogen between day 8 and day 42 periods of remediation.

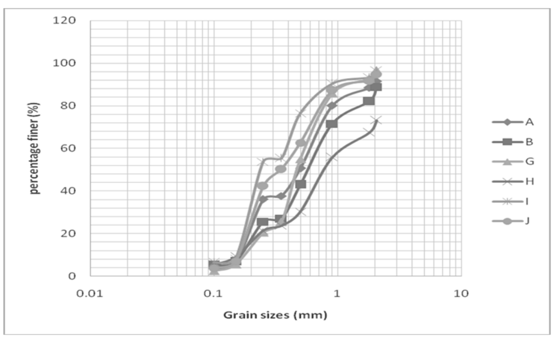

Figure1A: Particle size distribution curve for fine to coarse sand(X)

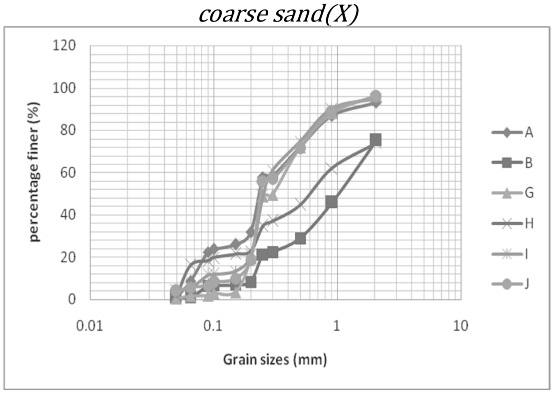

Figure1B: Particle size distribution curve for very fine to coarse sand (Y)

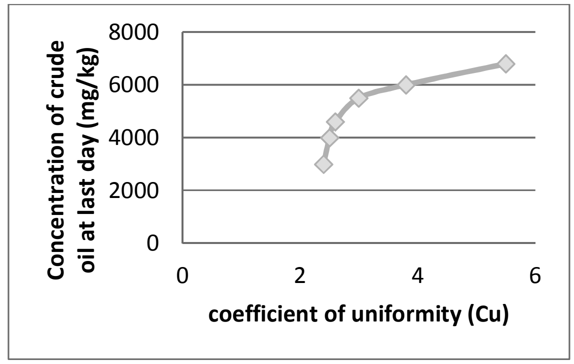

Figure2A: Concentration of Remaining Crude Oil (mg/kg) at last Day Vs Cu for fine to coarse sand(X)

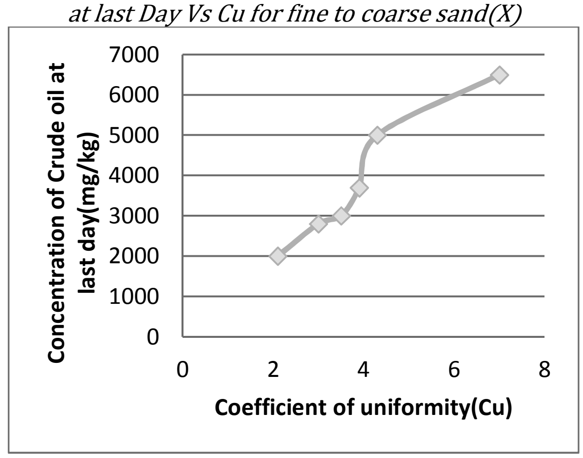

Figure2B: Concentration of Remaining Crude Oil (mg/kg) at last Day Vs Cu for very fine to coarse sand(Y)

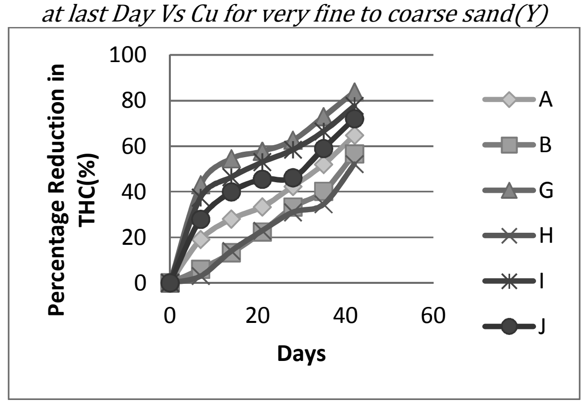

Figure3A: Rate of Hydrocarbon Loss (% Reduction Vs Days for fine to coarse sand(X)

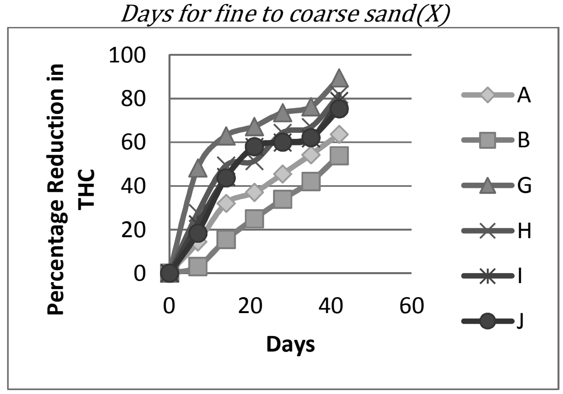

Figure3B: Rate of Hydrocarbon Loss (% Reduction) Vs Days for very fine to coarse sand (Y.)

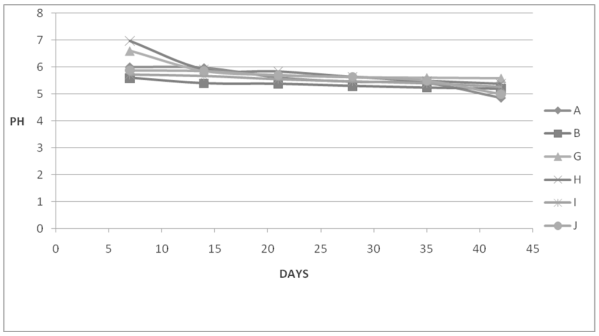

Figure4A: pH Vs Days for fine to coarse sand(X)

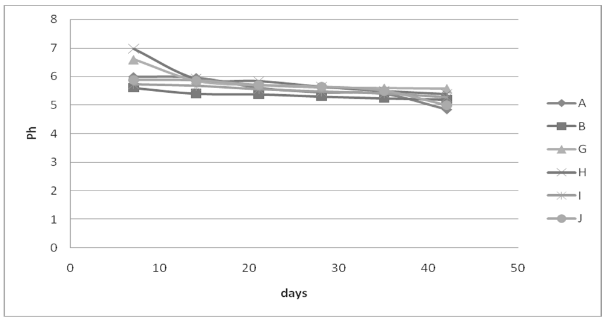

Figure4B: pH Vs Days for very fine to coarse sand(Y

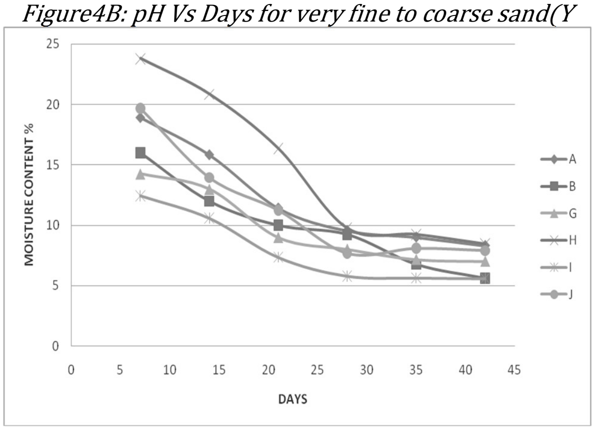

Figure5A: Moisture content Vs days for fine to coarse sand(X)

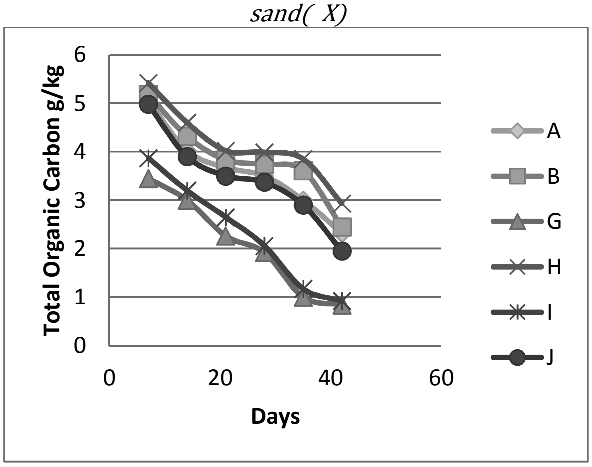

Fig.6A: Total organic carbon Vs days for fine to coarse sand(X)

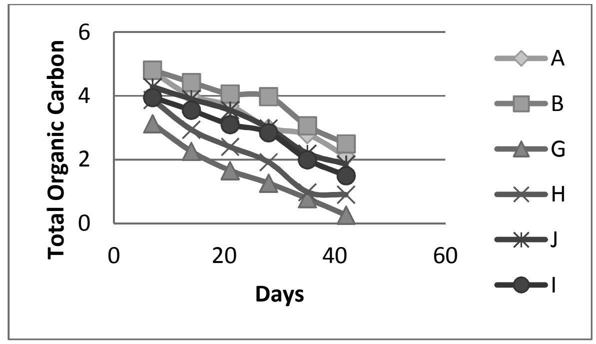

Figure6B: Total organic carbon vs days for very fine to coarse sand (Y)

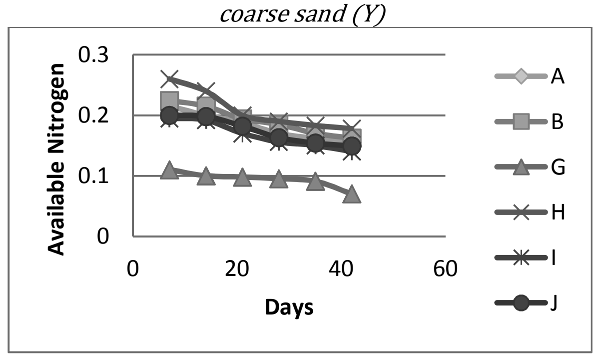

Figure7A: Available nitrogen Vs days for fine to coarse sand(X)

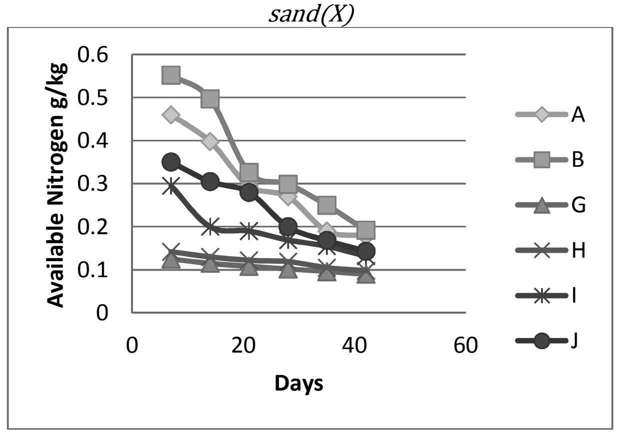

Figure7b: Available nitrogen Vs days for very fine to coarse sand(Y)

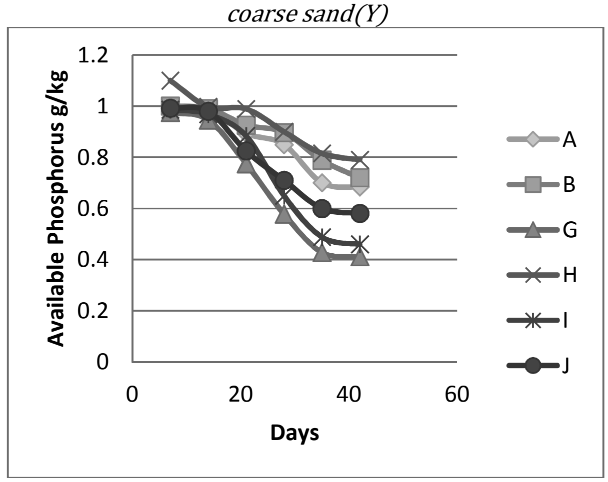

Figure8a: Available phosphorus Vs days for fine to coarse sand(X)

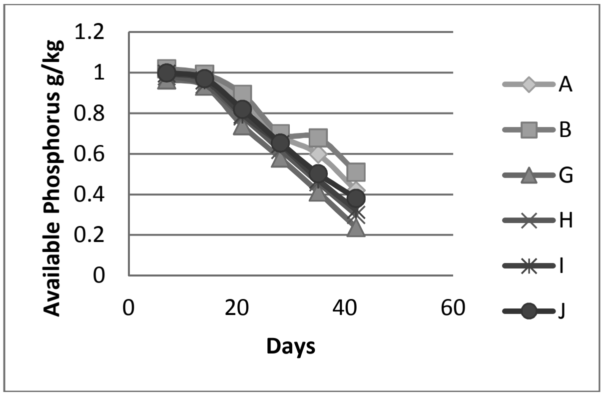

Figure8b: Available phosphorous Vs days for very fine to coarse sand(Y)

4. Conclusion

The use of nutrients and microorganism on crude oil polluted soils hastens the rate of hydrocarbon loss, a process called bioremediation. This research presents the effects of particle size distribution on bioremediation of crude oil polluted sandy soils.

The parameters determined includes: moisture content, particle size distribution, soil pH, organic carbon content, available nitrogen, available phosphorus, total hydrocarbon content, total heterotrophic bacteria count (THBC) and total heterotrophic fungi count (THFC).

From the result of this study, it was observed that, the lower the Cu values, the faster the rate of hydrocarbon loss. This showed that, particle size distribution parameter has influence on bioremediation. The correlation coefficient(r) of THC vs Cu for fine to coarse sand(X) is 0.867 while for very fine to coarse sand is 0.923.

Microbial biomass of both total heterotrophic bacteria and fungi counts increased on addition of nutrients of NPK 15:15:15 fertilizer, cow dung and microorganism (pseudomonas) on all the soil samples although, the nutrients were effectively utilized more by microorganisms present in soil samples with lower Cu values. However, data obtained from this research could be used for further bioremediation studies. This makes this research unique since, such data are yet to be available in literatures on Nigeria soils.

5. References

1. William,W.H.*Rail Road Engineering*, John Willey and Sons Inc, New York,1982.

2. Arora, K.K .*Soil Mechanics and Foundation Engineering*, Lomus Offset Press, Delhi, 2008.

3. Obahiagbon, K.O and Audu, T.O.K. "Analysis of Biodergradation Rate of Crude Oil Contaminated Soil using Fertilizer and Cow Dung," *NJERD*, Vol 1, 2002, Pp 42-45.

4. Ayotamuno, M. J and Kogbara, R. B. "Bioremediationof a Petroleum Hydrocarbon Polluted Agriculture Soil at Various Levels of Soil Tillage," *Nigerian Journal of Technology*, Vol.25, 2006, Pp 50.

5. Black,C.A., Evans,D.D., Whils, J. L. Ensmuger,L.E and Clerk, F.E.Methods of Chemical Analysis of Ecological Materials, *Am. Soc. of Agronomy Inc*, Madison Wiscosin USA,1965.

6. Braddy, N.C and Weil, R.R.*The Nature and Properties of Soils*, Prentice Hall, New Jessey, U.S.A, 1999.

7. Baker, K.H and Herson, D.S *Bioremediation*, McGrawHill, New York, 1994.

8. Draper, N.R., and Smith, H. *Applied Regression Analysis*, Second Edition, John Wiley and sons Inc, New York, 1981.