2015 2nd International Conference on Geological and Civil Engineering
IPCBEE vol. 80 (2015) © (2015) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2015. V80. 9

Effect of Diesel Oil Contamination on Soil Natural Recharge of Groundwater

Gbenga Matthew AYININUOLA[1 +] and Oluwatosin Feyisetan KWASHIMA[2]

[1, 2] Department of Civil Engineering, University of Ibadan, Ibadan, Nigeria

Abstract. The impact of diesel oil contamination on soil permeability was investigated and means of ameliorate its effect on aquifer natural recharge presented. Marine sandy soil samples were obtained from two streams in Ibadan. After preparation, each sample was contaminated with 0, 1, 3, 5 and 10% diesel oil by weight and altogether twenty contaminated samples were prepared. A set made of 10 contaminated samples covered in separate containers to disallow ingression of air and sunlight. Another ten samples were aerated and exposed to sunlight using flat containers. The soil samples coefficient of permeability was monitored for a period of 140 days. The results showed that after initial drop in soil permeability coefficient of exposed samples, their coefficient of permeability appreciated while those of covered samples continued to depreciate with time. Therefore, in order to increase natural recharge of groundwater potential of diesel oil contaminated soils such soil should be aerated and exposed to sunlight.

Keywords: Diesel Oil Contamination, Coefficient of Permeability, Natural Recharge, Sunlight, Groundwater.

1. Introduction

Soil contamination is caused by presence of man-made chemicals or other alteration in the natural soil environment. The contamination typically arises from the rupture of underground storage tanks, application of chemicals, and percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial waste to the soil. The most chemicals involved in soil contamination are petroleum hydrocarbons, solvents, pesticides, lead and other metal. The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage [1], [2]. The concern over soil contamination stems primarily from health risks. The USA has established guidelines for handling hazardous wastes and the cleanup of soil pollutions that are time consuming and expensive requiring extensive amounts of geology, hydrology, chemistry and computer modelling skills [3]. To understand the fundamental nature of soil contamination, it is necessary to envision the variety of mechanisms for pollutants to become entrained in soils. Most soils are contaminated as a result of pollutants adhering to the soil particle surfaces or lodging in interstices of soil matrices. Clearly, the equilibrium reached is a dynamic one where new pollutants may lodge on new soil particles and the action of groundwater over time transports some of the contaminants to other locations or depths [4].

Oil spill has occurred several times in Nigeria. Series of it occurred during transportation of refined petroleum products from depots to final consumers (filling stations) due to bad roads, reckless nature of driver and poor state of vehicles used. Oil spill has been described as release of a liquid petroleum hydrocarbon into the environment due to human activity [5]. The Niger Delta in Nigeria has been the attention of environmentalists with matter concern oil spill [6]. Oil spill scenario in Umusia, a rural community in Oyigbo local government area in River State, Nigeria that occurred as a result of a major blow-out at Shell railway manifold has been reported [7]. Oil spill due to rupture of pipelines belonging to

+ Corresponding author. Tel.: + +2348056131662
E-mail address: gm.ayininuola@mail.ui.edu.ng; ayigbenga@gmail.com.

Nigeria National Petroleum Corporation (NNPC) has been documented [8]. Oil spill at Ogoni land Nigeria was also reported by [6]. Soil sample is porous enough for oil to infiltrate especially within a time frame despite that it was well compacted [9]. Oil can seep within the voids of soil particles with time.

Permeability is a complex property that is controlled by physical properties of both the soil and the permeating fluid [10]. [11] studied the effect of crude oil on geotechnical properties of coastal soils and showed that the compatibility of soil samples increased with increasing oil content leading to reduction of maximum dry density and optimum water content. Oil contamination induced a reduction in permeability and strength in the soil samples. [12] concluded that oil-contaminated soils also indicated a lower maximum dry density (MDD) and optimum water content if compared with uncontaminated soils. A reduction in permeability was observed as a result of the oil contamination. The permeability of soil composite decreased upon increasing the fly ash content. The permeability of composite decreases further upon contamination with increasing percentages of diesel [13].

According to [14], groundwater refers to all subsurface water. The term more commonly refers to water beneath the surface of the earth. Some water underlies the earth's surface almost everywhere beneath hills, mountains, plains and deserts. Groundwater makes up about 20% of the World's fresh water [15]. Groundwater is naturally replenished by surface water from precipitation, streams, ices and rivers when this recharge reaches the water table. Groundwater can be referred to as long-term reservoir of the natural water cycle. Water cycle has been described as a conceptual model that further explains the storage and movement of water in the biosphere, atmosphere, lithosphere and hydrosphere [16]. Water moves from one reservoir to another by processes like evaporation, condensation, precipitation, deposition, runoff, infiltration, sublimation, transportation, and melting and groundwater flow [15]. Also, water is being more or less constantly moving or changing from one state to another. Groundwater is highly useful and often abundant resource. However overuse or overdraft can cause major problems to human users and to the environment [15]. The most evident problems are lowering of water table, subsidence and salt water intrusion. To avoid these problems there is need for groundwater to be naturally recharged. Oil in the voids will hinder normal infiltration of water to soil beneath. The study focused on the effect of oil spill such as diesel oil on soil permeability which will have direct impact on natural water recharge and how best the impact can be tackled.

2. Materials and Methodology

In order to mimic condition at riverine areas, soils for the study were taken at the beach or banks of large streams in Ibadan, Nigeria. The collection points were Eleyele and Ajibode streams. The soil samples were air dried and stock-piled. Soil taken at Eleyele stream bank was labelled A while that of Ajibode stream labelled B. The particle size distribution of each sample was determined in accordance with [17]. Each soil sample was divided into two parts. Each part was subdivided into five subsamples with each subsample receiving single dosage of 0, 1, 3, 5 and 10% by weight of diesel oil. Altogether, ten subsamples were produced from each soil sample and a pair of soil samples received single dosage of diesel oil. A set made of five subsamples from A and another set from B were stored in separate containers and sealed or covered to hindered interaction with air and sunlight from atmosphere. They were placed in shed. The remaining contaminated subsamples were exposed to air and sunlight. Each exposed subsample was placed on flat trail to receive air and sunlight. Sizeable quantity was taken from each subsample (covered or exposed), sieved with sieve 425 µm and its coefficient of permeability was tested in accordance with [17] for about 140 days. Determination of contaminated subsamples coefficients of permeability commenced on the 7^{th} day of contamination so that the effect of diesel could be fully observed or detected.

3. Results and Discussion

The particle size analysis confirmed that the two soil samples were predominantly sand with 81 and 76% of samples A and B respectively passing sieve with aperture 425 µm. Also, about 15% and 10 % of soil samples A and B respectively passed through sieve with aperture 75 µm. Therefore, the two samples were marine poorly graded sandy soils. The coefficients of permeability of covered and exposed contaminated soil samples A and B with time were shown in Fig. 1 to Fig. 4. The coefficients of permeability of the two soil samples without diesel remained constant throughout the test period. This shows clearly that variations observed in contaminated soils coefficients of permeability were as a result of diesel oil present. There was sharp reduction noticed in the values of coefficient of permeability of contaminated soil samples when compare with the value obtained for uncontaminated sample at 7th day of contamination. The reduction in permeability of the oil contaminated soil samples was similar to the findings of earlier works [11]-[13]. Also, the rate of permeability depends on soil surface texture [10]. Once the soil particles surfaces are coated with oil, they stick together to hinder passage of water. After day 7, exposed soil samples coefficient of permeability started to appreciate but never reached the uncontaminated one at day 140. The initial decrease in coefficient of permeability of uncovered contaminated soils and the rate of appreciation noticed depend on the level of dosage of diesel oil as shown in Fig. 1 and Fig. 2. In the case of covered contaminated soils, the values of coefficient of permeability decreased with time and never appreciated as observed for the exposed contaminated soils. The depreciation rate of coefficient of permeability noted was a function of level of diesel oil dosage received as shown in Fig. 3 and Fig. 4.

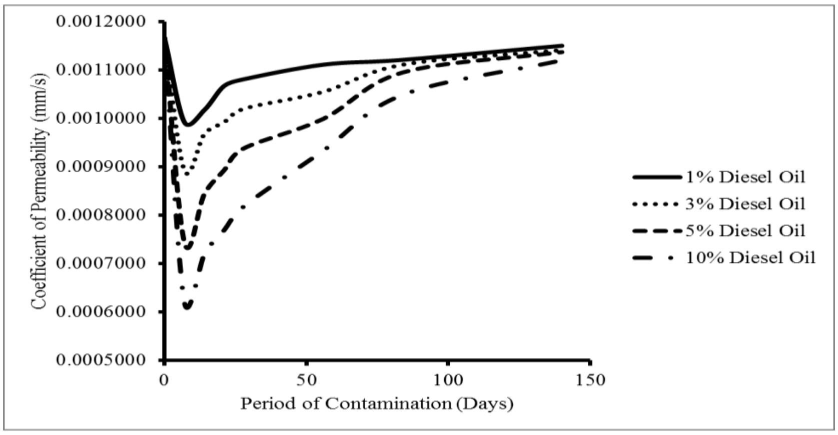

Fig. 1. Coefficient of permeability of exposed contaminated soil sample a with time

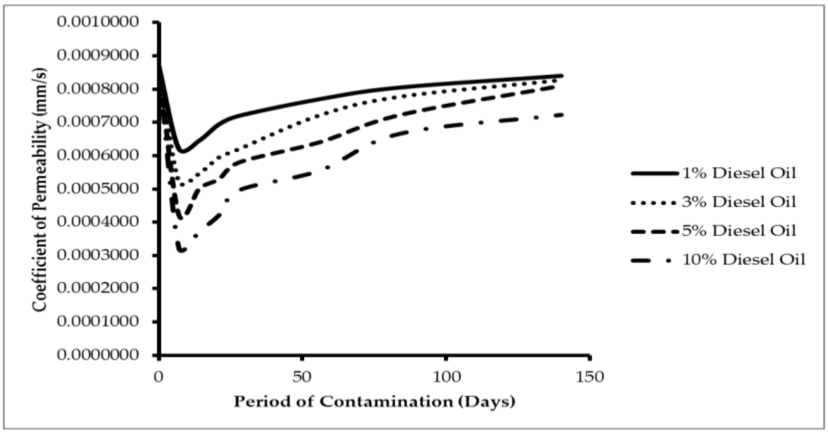

Fig. 2. Coefficient of permeability of exposed contaminated soil sample b with time

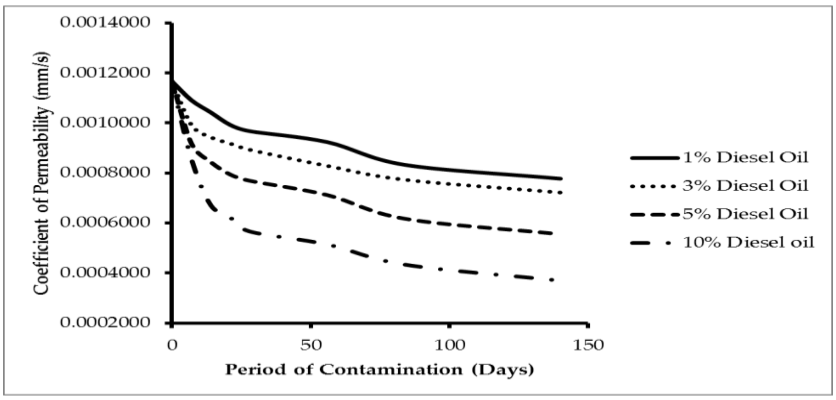

Fig. 3. Coefficient of permeability of unexposed contaminated soil sample a with time

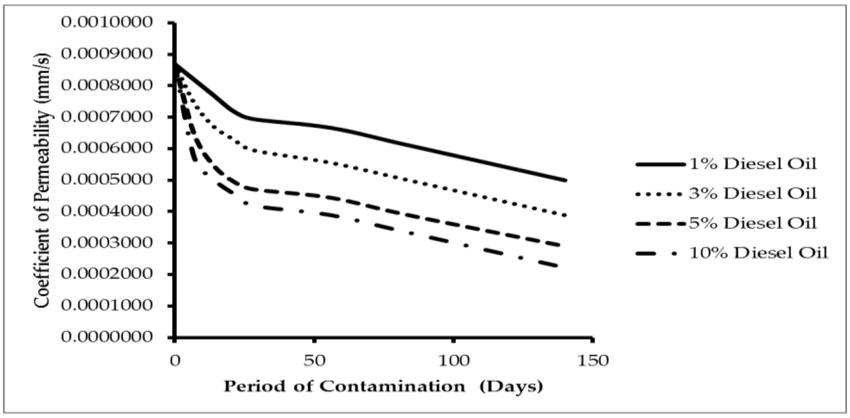

Fig. 4. Coefficient of permeability of unexposed contaminated soil sample b with time

The appreciation rate recorded in the coefficient of permeability of contaminated soils when exposed to atmosphere was due to the following. Firstly, the air assisted micro-organisms present to act on the oil thereby producing less complex substances. This process is referred to as bioremediation. The microbes, surfactants micronutrient decomposed the contaminants present to harmless by-products such as water and carbon-dioxide. The longer the soil was exposed the better its coefficient of permeability. Secondly, the sun energy aided evaporation of oil that has direct impact on soil coefficient of permeability. The covered contaminated soils received no air and sunlight to aid bioremediation. In addition, the longer the presence of oil in the soil, the more voids occupied by oil and as such, the soil permeability will continue to reduce.

Based on the findings in the study, coefficient of permeability of soil contaminated with diesel oil spill will be less than its uncontaminated one and the aquifer under such contaminated soil will receive less water from precipitation. The natural recharge rate will reduce and if water from aquifer in the affected area is drawn at high rate from boreholes located in the vicinity, there will be depletion in groundwater level. In order to enhance water infiltration rate which will invariably increase the aquifer recharge, the contaminated soil should be exposed to atmosphere. The soil surface area should be enlarged by spreading it over large area with the aid of machines such as bulldozer, spreader, etc.

4. Conclusion

An in-depth study of the effect of diesel oil contamination on soil permeability was carried out. The findings showed that depending on the level or degree of contamination, soil permeability decreased with time for soil not exposed to the atmosphere. Also, for soil exposed to the atmosphere and sunlight, its permeability increased with time after initial drop experienced due to contamination. Therefore in the area contaminated with diesel oil, its natural recharge of groundwater potential can be enhanced by aerating the soil and allow it to receive direct sunlight to improve its permeability coefficient. The oxygen and sunlight aid bioremediation of contaminated soil to improve its infiltration capacity.

5. References

[1] Wikipedia, Free Encyclopedia. Soil Contamination. 2008. Accessed March 21 2009. http://en.wikipedia.org/wiki/soilcontamination.

[2] R. Stegmann. Treatment of contaminated soil, analysis, application. Journal of Environmental Geology, 2001, 45(2): 252 – 288.

[3] U.S. Environmental Protection Agency. *Soil Contamination.* 2009. Accessed May 16 2009. http://epa.gov/superfund/students/wastesite/index.htm.

[4] H. Jung. Earthworm toxicity during chemical oxidation of diesel contaminated land. Journal of Environmental Technology, 2005, 2: 233 – 267.

[5] L. E. Anderson, E. Howlett, K. Jayko, V. Kolluru, M. Reed, M. L. Spaulding. The worldwide Oil Spill Model (WOSM): An Overview. *Proceedings of th 16th Arctic and Marine oil Spill Program, Technical Seminar*, Ottawa, Ontario: Environment Canada ,1993, pp 627 – 646.

[6] S. Olukoya. Sound of shell's fire in Ogoni, Baraale, Tai LGA, River State, Nigeria, Environmental Right Action Report, 2002: 1 – 5.

[7] P. Naagbanton. Shell fails to clean spill, refuses to pay compensation Amuse, Oyigbe Local Government Area, River State. *Environmental Right Action Report* , 1999: 10 – 16.

[8] V. Raphael. Spewing premium motor spirit from NNPC pipelines around Adeje town, Warri South Local Government Area, Delta State. Environmental Right Action Report, 2000: 7 – 12.

[9] J. M. Keller, C. S. Simmons. The Influence of selected Liquid and Soil Properties on the Propagation of Spills over flat Permeable Surface. Pacific Northwest National Laboratory, Richland, Washington, 2005.

[10] D. J. DeGroot, D. W. Ostendorf, A. I. Judge. In situ measurement of hydraulic conductivity of saturated soils. *Geotechnical Engineering Journal of the SEAGS and AGSSEA*, 2012, 43(4): 63 – 72.

[11] M. Khamehchiyan, A. H. Charkhabi, M. Tajik. Effect of crude oil contamination on geotechnical properties of clayey and sandy soil. Engineering Geology, 2007: 220 - 229.

[12] Z. A. Rahman, H. Umar, N. Ahmad. Geotechnical characteristics of oil contaminated granitic and meta sedimentary soils. Asian Journal of Applied Science, 2010, 3: 237 – 249.

[13] R. K. Sharma. Effect of Diesel Pollution on Sub-Grade and Permeability Characteristics of Fly Ash-Sand Composite. Proceedings of the Clute Institute International Academic Conference, Munich Germany, 2014, pp 451 – 461.

[14] G. Hussein. Groundwater. 2007. Accessed July 21 2009. http://www.eoearth.org/article/Groundwater.

[15] D. Ludwig, R. Hilborn, and C. Walters. Uncertainty, resource exploitation and conservation: lessons from history. *Science*, 1993, 260: 17.

[16] J. Hubbart. *The Hydrologic Cycle*. 2007. Accessed June 9 2009. http://www.eoearth.org/article/Hydrologiccycle.

[17] BS 1377. *Methods of test for Soils for Civil Engineering Purposes*, England: British Standards Institution, 1998.