Advances in Science and Technology, Vol. 3, No. 2, September / October 2009, pp 125 - 129

Deep Tillage: A Physical Remediation Measure for Oil Polluted Agricultural Land

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(Submitted: January 27, 2009; Accepted: Sept 29, 2009)

Abstract

Chisel plowing and varied grades of harrowing were applied as remediation measures to oil spilled (polluted) agricultural soil. Some soil physiochemical properties namely moisture content, bulk density, penetration resistance, permeability and total hydrocarbon content were determined at (i) zero oil spillage, (ii) oil spill without treatments, (iii) oil spill with chiselling only, (iv) oil spill with chiselling and one harrow pass per week, (v) two harrow pass per week, (vi) three harrow pass per week, and (vii)four harrow pass per week respectively. Treatments i and ii showed significant differences in the mean values of the parameters measured. This indicated that oil spillage really affects the soil structure and content. Treatments iii to vii showed positive changes in the values of the parameters. From the figures, it could be deduced that 100% remediation is achievable with the treatments applied.

Keywords: remediation, chisel plowing, hydrocarbon, permeability, penetration resistance.

1.0 Introduction

Oil spillage on soil is now a common occurrence in the oil producing areas and their neighbouring communities due to obvious mechanical operations, natural occurrences, technical faults and human sabotage. Plant and animal growth inhibitors, soil structures modifier and other non carcinagenous substances in crude oil are introduced into the soil (agricultural land) as it spills over the ground thereby polluting the land (Okpokwasili and Odokuma, 1990). Hence, the ecosystem sustained by the natural ecology is fast depleting (Chindah and Braide, 2000; Rowell, 1977; Soane and Van Ouwerkerk, 1995). This thereby is contributing to the current global food crisis and gloth in agricultural based industrial raw materials.

The productive areas of the host communities are fast turning into wasteland with increasing soil infertility due to the destruction of soil micro-organism and dwindling agricultural productivity. Farmers have been forced to abandon farming and join the ever-increasing unemployment population which has resulted to urban drift, youth restiveness, frustration and hooliganism in the society. Apart from degradation and loss of farmlands, oil spill has led to extensive deforestation with inadequate re-planting practices which in effect has shortened fallow periods and compounded land use.

But, oil exploration cannot be abandoned because of the apparent buoyant economic landscape it is fashioning for the country. The solution to the problems posed by its drilling, processing, handling, and transportation is to find measures for remediating or reclaiming the polluted lands in order not to loose completely their benefits. This paper, therefore, estimates the effect of oil spillage on agricultural land and recommends appropriate measures to remediate and sufficiently recover the soil.

2.0 Effect of Crude Oil Pollution on Soil

Soil is made up of particles of broken rocks that have been altered by chemical and environmental processes including weathering, erosion and other human activities. In the process of soil alteration, physical, chemical and biological habitats that support growth of plants, animals and micro organisms are introduced into the soil. Soil has the ability to maintain its porous (void) structure to allow passage of air and water, withstand erosion forces and provide a medium for extension of plant roots. A dense structure will greatly reduce the amount of air and water that can move freely through. It will also affect the plant's ability to propagate roots.

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A contaminated soil is one that contains, above lethal level, substances that are potentially harmful to it. Harmfulness may be physical, chemical or biological changes in the soil that affect the ecosystem contrary to the intended use, performance or result.

At spill, the oil flows freely and spreads on the ground in multi directions, primarily propelled by the force of gravity and landscape. It then percolates into the soil through the pore spaces or soil capillaries either by van-der-waal forces or osmotic pressure differences or by the action of liquid finding its own level. In the process the:

- volatile (unsaturated) components of the oil will escape into the pore spaces of the soil.
- capillaries / pore spaces may be lined, blocked or filled with oil.
- cations in the hydrocarbons may be exchanged with those of the soil particles (Mitchell and Soga, 2005; Defra, 1990).

The escape of the volatile components will displace the natural air needed by the plant and micro organism in the soil for their survival and fertility of the soil. Aerobic activities in the soil will reduce hence, reducing the moisture content of the soil and thereby hardening the soil.

Capillaries lined by oil films reduce the internal diameter of the pores. As a result, volume of water and air in and out of the soil matrix will be reduced. Also due to the lining, water droplets adhere to the hydrophobic layer formed and prevents wetting of the inner part of the soil aggregate (Hyun *et al.*, 2008) resulting to hardening of the soil and infertility (Luthy *et al*, 1997).

Blocking of void either by trapping or total filling with oil, brings about total blockage of water transport and gaseous exchange routes within that zone resulting to reduced microbial activities, root penetration action, moisture content and air volume. The soil therefore becomes hardened and compacted. Soil compaction is a serious environmental problem. It affects crop productivity, soil workability and sustainability (Mc Gary, 2001). It affects the energy use in crop production which may be additional environmental problem (Soane and Van Ouwerkerk, 1995).

Cation exchange of the hydrocarbon and soil particle by absorption through van-der-waal forces and intercalation, form kaolinite, montimorilonite and others (Mitchell and Soga, 2005). On breaking down, they deplete both oxygen and nitrogen supplies in the soil.

Presence of crude oil in the soil increases the total hydrocarbon content in the soil. The aliphatic hydrocarbons introduced will remain persistently in the soil and cause significant deteroriation of the physical properties of the soil (Luthy *et al.*, 1997; Hyun *et al.*, 2008). It may also poison the human food produced and exhibit toxic actions towards different biological elements of the soil environment (Menzie *et al.*, 1992). Oil spill brings imbalance in Carbon – Nitrogen ratio that results to Nitrogen deficiency, bacteria growth retardation and utilisation of carbon sources, depletion of oxygen reserve and reduction in diffusion rate of oxygen to deeper layer (Molnaa and Grubbs, 1989).

3.0 Objectives

The objective of the work is to measure and evaluate some physiochemical properties of an oil spilled agricultural land, compare it with those from non-oil spilled land. Then treat the soil using various degrees of tillage and compare the values of the same physiochemical properties with those of non-oil spilled land. The physiochemical properties to be determined are moisture content, bulk density, penetration resistance, permeability and total hydrocarbon content. Also weed regrowth will be estimated on the plot after treatment.

4.0 Materials and Methods

4.1 Experimental plot

Experiments were conducted at Ohaji on a utilsol with a sandy loam structure. The mean annual rainfall of the environment is 2150mm and average daily temperature of 29°C Vegetation cover is derived tropical rainforest.

4.2 Soil Treatments

The oil spillage was stimulated by sprinkling the experimental site with oil from a perforated can. The oil was sprinkled to field capacity. A thin layer of oil of about 5mm deep was allowed on the soil after spillage. Seven days later, the plots were treated as stated:

Treatment

(i) Soil without oil spill and without any treatments (control)

(ii) Soil with oil spill but without any treatments

(iii) Soil with oil spill + chiselling only

(iv) Soil with oil spill + chisel + 1 harrow pass per week

(v) Soil with oil spill + chisel + 2 harrow passes per week

(vi) Soil with oil spill + chisel + 3 harrow passes per week

(vii) Soil with oil spill + chisel + 4 harrow passes per week

The chiselling is done with a chisel plow for the whole field to the depth of 35cm. The experimental plots were arranged in completely randomised block form. Each plot was replicated three times. The chiselling and harrowing were done using a tractor moving at a speed of 3.00km per hour through the assigned plots with differential lock on. The path traced by the tractor wheels were carefully marked and followed by subsequent passes. Each plot measured 1m x 10m with 5m headland between plots. All harrow passes for each plot were done in one day of the week. Fourteen days after the treatment, samples were taken and the plots treated again to wait for another two weeks for sample taking and treatment.

In determining the data, seven core samples of soil of 100cm^3 were taken randomly from each experimental plot at the uniform depth of 20cm for estimation of bulk density, soil moisture content and permeability using conventional laboratory methods. Also, seven penetration resistance measurements were taken per plot near the core sample plots sights using a cone penetrometer of base 0.10m with core angle of 30° operating at 1800mm/min.

The samples for total hydrocarbon content (THC) when collected were put into a litre glass bottle sealed with aluminium foil to guarantee the integrity of the result. The determination is made using the procedure reported by Concawe (1972).

Weed re-growth measurement was taken at 8th week after oil spillage and treatment on all the plots using a 25cm x 25cm quadrant dropped at random and all the weeds within counted. This measure is to quantify the degree of biological activities going on in the experimental plots.

5.0 Result and Discussion

Figures 1 to 6 are the mean values of moisture content, bulk density, penetration resistance, total hydrocarbon content, permeability and weed re-growth in the seven treatment plots.

Figure 1: Moisture content (%)

Figure 2: Bulk Density (mg/m^3)

Each of the Figures has seven bar clusters representing the seven treatments (i - vii) except Figure 6. Each cluster has four bars. The first bar is the mean value for measurements taken at 2 weeks after treatment, the next is the 4th week, the third is the 6th week then the last is the 8th week. The weed re-growth measurement was at 8th week only.

Coefficient of variability for values of treatment (i) (soil without oil spill and no treatment) and (ii) (soil

Figure 3: Penetration Resistance (Mpa)

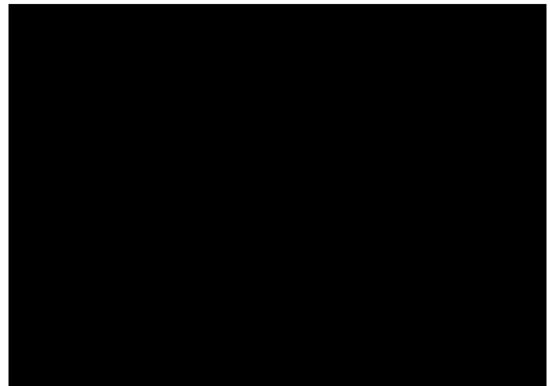

Figure 5: Permeability (mm/d)

Figure 4: Total Hydrocarbon Content (mgkg)

Figure 6: Weed Re-growth (No/m^2)

with oil spill and no treatment) were calculated and presented in Table 1.

The analysis is to estimate the relative deviation of the data within and between the plots and by extension, estimate the level of pollution and contamination introduced into the environment by oil spillage. From Table 1, the coefficient of variabilities in all the parameters measured in treatment 1, varies from 2.48% to 9.58% indicating that within the limits of experimental error, there is little or no variability within the measurement. While the values of treatment (ii), ranged from 16.08% to 69.38% implying significant differences within the measurements. As the measurements in treatments (i) and (ii) were carried out under the same conditions, by extension the values in the two treatments vary significantly indicating that the oil spillage had effect on the ecology of the environment and the effect is of high degree.

Treatments (iii) to (vii) were analysed using the analysis of variance (ANOVA). The calculated F-values of the treatments and spillage elapsed period were stated in Table 2.

From Table 2, it can be seen that the F-values of all the treatment for all the parameters and the elapsed period were all significant, showing that they played significant role in effecting the parameters. Also, by inspecting the trend of the values as the weeks from oil spillage elapses from figures 4 to 6, the parameter values in the oil contaminated plots approach those of the control values indicating that the treatments were helping to recover the soil. The F-values also showed that elapsed period alone can remediate the soil in some of the parameters except total hydrocarbon content that needs both for the soil to be recovered in a recorded time.

7.0 Conclusion

The result of the experimentation had revealed that oil flooding of the soil affect the natural ecology of

Table1: Coefficient of variabilities (%) of control plot (no oil no treatment) and oil spilled plot without treatment.

	Moisture Content	Bulk Density	Penetration Resistance	Total Hydrocarbon Content	Permeability
Treatment 1	9.58	2.48	6.47	5.45	5.34
Treatment 2	16.08	19.21	35.15	69.38	26.69

Table 2: ANOVA Values

	Moisture Content	Bulk Density	Penetration Resistance	Total Hydrocarbon Content	Permeability	Ftab/ (0.5)
Treatment	24.16	36.50	3.85	4.24	28.00	3.26
Elapse Period	5.29	107.67	11.91	4.94	82.45	3.49

the environment to a high degree. It can also be concluded that the compaction and hardness of the soil, blockage of pore spaces in the soil and increase in anaerobic activity of micro organism in the soil brought about by oil spillage can be reversed using systematic deep tillage and thereby recovering the soil in a record time.

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