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Soil faunal activity of an oil-polluted tropical alfisol amended with organic wastes as determined by micromorphological observations

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ABSTRACT

This study evaluates the effect of used-lubricating oil (spent oil) and organic nutrient supplements as derived from animal droppings on faunal activity as expressed in the incidence of faunal excrement and related micromorphological features. This approach allows the effects of the treatments to be evaluated even if the organisms are no longer present. The main-plot treatments included control (C), cow dung (CD), poultry droppings or manure (PM) and pig droppings or waste (PW) each at 10 Mg ha^{-1} each. The sub-plot treatments were control (no applied contaminant), 0.5%, 2.5% and 5% spent oil (SP) applied at 10, 50 and 100 Mg ha^{-1} (w/w), respectively. Residual oil blobs were clear in soil thin sections and the results from point counting demonstrated a significant reduction in oil content following the addition of organic wastes to the polluted soils. Spheroids of organic material interpreted as excrement from enchytraeids dominated thin sections from the control and treated plots. Other observed excrement types were undifferentiated (fused) excrements formed from coalesced or "aged" excrements. The occurrence of the total excrements showed no faunal activity in plots polluted with 0.5%, 2.5% and 5% SP, indicating elimination of soil fauna by oil pollution. Results from point counting of excremental features indicated significant faunal activity with CD, PM and PW treatments, and in oil-polluted plots supplemented with organic wastes. The treatments with PM and PW were better than CD in stimulating oil degradation. Treatments also showed a reduction in total porosity with an increase in oil concentrations whereas no significant improvement was observed in oil-polluted soils amended with organic wastes. However, addition of the organic wastes to oil-polluted soils showed evidence of increased decomposition in the order PM > PW > CD. In conclusion, the substantial reduction in soil faunal activity as a result of oil treatment confirmed the deleterious effect of petroleum products on living organisms, but the addition of PM and PW were effective in ameliorating this negative impact.

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1. Introduction

Contamination of soil and groundwater with petroleum oil and mineral oil-based products is a major pollution issue in Nigeria. Waste lubricating oil, obtained after servicing and subsequent draining from automobile, generators and industrial machines is disposed off indiscriminately in Nigeria and adequate attention has not been given to this (Anoliefo and Vwioko, 1995). This waste-oil usually contains appreciable amounts of toxic hydrocarbons and heavy metals such as Va, Pb, Al, Ni and Fe (Whisman et al., 1974) and Cr and Zn. Since Nigeria produces annually $>87 \times 10^6$ l of waste lubricating oil (Anon., 1985), the need to evaluate the long-term effects of this waste-oil on soil biology is important. There are particular advantages in evaluating low-cost approaches such as the application of animal manures. The goal of bioremediation is not only to enhance the degradation, transformation, remediation, or detoxification of these pollutants by biological means, but also to protect soil quality (Andriano et al., 1999). Soil quality has emerged as an issue of vital importance to the use and management of land, water and air (Sims et al., 1997). A significant decline in soil quality has occurred in many areas of the world through adverse changes in physical, chemical and biological properties from contamination by inorganic and organic chemicals (Arshad and Martin, 2002).

Oil has adverse effects on soils (Rowell, 1977), microorganisms and plants (Baker, 1970). Sensitivity of soil organisms to petroleum hydrocarbons depends on the quantity and quality of oil spilled and as well as previous applications (Bossert and Bertha, 1984). Petroleum hydrocarbon utilizers can tolerate oil-contaminated environments because they can utilize oil as an energy source (Song et al., 1990). Other species which may include N-fixing and heterotrophic microbes relevant to maintaining soil fertility may not and are gradually eliminated (Amadi et al., 1996). Although most microbes can metabolize a wide range of C-compounds (La-Rue, 1977), only certain N-fixers can grow on media entirely free or very low in N-sources (Macura and Kune, 1976). However, certain changes may induce negative changes in microbes involved in mineralization and oil degradation (Amadi et al., 1996). For example, Amadi et al. (1996) reported that N is limiting to degradation of oil by microbes because N and P availability are sometimes impeded by the presence of petroleum hydrocarbons. Odu (1981) reported that contamination of soil with 1–5% oil normally acts as a boost to soil organic matter while Schwindinger (1968) observed that at >3% concentration, oil becomes increasingly deleterious to soil biota and crop growth.

Only a few beneficial effects of well-degraded oil on soil biota have been reported (McGill, 1980). However, a few investigators have examined the effect of post-oil spill rehabilitation measures on soil recovery and crop improvement (Amadi et al., 1993; Toogood et al., 1977). In all cases of oil pollution, N and P were observed to be limiting to both biodegradation of oil and crop development (Amadi et al., 1993; Bossert and Bertha, 1984). Petroleum products are generally spoken of as single entities, but each is a complex mixture of many organic chemicals with their own properties and behaviour when in contact with soils and water (Nyer and Skladany, 1993). Therefore, remediation efforts must address the treatment of specific hydrocarbons.

Dijkstra (1998) studied the development of humus profiles in heavy metal-polluted and non-polluted forest soils under Scots pine by micromorphological observations and by field observations; the conclusion was that micromorphology in combination with field observation and chemical analysis was a good way to study the relationships between vegetation types, soil biological processes and the long-term effects of heavy metal pollution on the decomposition of SOM in humus profiles. As a result this study in evaluating the effect of waste lubricating oil and organic waste treatments on soil faunal activity adopted a micromorphological approach. The nature and distribution of excrement (faecal pellets) and other pedofeatures as observed in thin sections from the surface layer were investigated for treated and control plots.

2. Materials and methods

2.1. Site description and sampling

The experiment was sited at the University of Agriculture, Teaching and Research Farm, Abeokuta, southwestern Nigeria (Lat. 7.12° N and Long. 3.23° E) located within the transition zone of the sub-humid forest to the south and the derived savannah to the northwest (Keay, 1959). The soil at this research site is a well-drained sandy loam on the surface with gravelly sandy clay loam on the sub-surface derived from basement complex; the soil is an Oxic Paleustalf (FDALR, 1990). Selected physical and chemical properties of this site are given in Table 1. The area has a bimodal rainfall pattern with rainfall usually commencing in late March or early April and ending in late October or early November with a short dry spell in August. The mean annual rainfall is about 1470 mm with the maximum in July and September; the mean monthly temperature range varies between 28 and 32 °C.

A land area of 0.0289 ha was used for this study. The experiment was a split plot in randomized complete block design (RCBD). The field layout consisted of four blocks with four treatments in each main and sub-plots. The main treatment plots measured $12.25\ m^2$ ($3.5\ m \times 3.5\ m$), while the sub-plots were $2.25\ m^2$ ($1.5\ m \times 1.5\ m$). Each treatment was replicated four times, i.e. each of the 16 treatment combinations were randomly allocated to one subplot of each block, making a total of 64 plots. The plots were raised beds with guiding borders to prevent flow between the plots, and they were separated by 50 cm border rows. Organic waste treatments included cow dung (CD), poultry manure (PM), and pig waste (PW) at 10 Mg ha^{-1} each; for the waste lubricating oil (Rubia S SAE 40), also called spent oil, treatments were 0.5% (5000 mg kg^{-1}), 2.5% (25,000 mg kg^{-1}) and 5% (50,000 mg kg^{-1}) spent oil (SP) applied at 0, 10, 50 and 100 Mg ha^{-1}, respectively. Control plots were integral to both the organic waste treatments and the spent oil treatments. This spent oil was sourced from heavy machines, and each concentration was uniformly applied on the surface of each plot and mixed with the soil.