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Distribution of heavy metals and hydrocarbon contents in an alfisol contaminated with waste-lubricating oil amended with organic wastes

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Abstract

Contamination of soil and groundwater with mineral oil-based products is among the most common sources of pollution in Nigeria. This study evaluated the distribution of some heavy metals and hydrocarbon content in soil contaminated with waste-lubricating oil (spent oil), and the effectiveness of some abundantly available organic wastes from animal source as remediation alternative to the expensive chemical and physical methods. The main-plot treatments include control (C), cow dung (CD), poultry manure (PM) and pig waste (PW) applied at 10 Mg/ha each; while the sub-plot treatments were control (0%), 0.5%, 2.5% and 5% spent oil (SP) applied at 10, 50 and 100 Mg/ha, respectively arranged in a split-plot in Randomized Complete Block Design (RCBD) with four replications. These treatments were applied once each year for two consecutive years. Soil samples (0–20 cm) were collected at 3, 6 and 12 months each year and analyzed for Cr, Ni, Pb and Zn, while the residual total hydrocarbon content (THC) was determined at the end of the 2 years study. Results show significant ($p < 0.05$) accumulation of these metals with spent oil pollution following the sequence 5%SP > 2.5%SP > 0.5%SP, indicating higher metal pollution with increase in oil pollution. General distribution of Cr, Ni, Pb and Zn, relative to sampling periods, followed 3 months > 6 months > 12 months in the 1st year indicating reduction in metal levels with time. The trend for 2nd year indicated higher accumulation of Cr and Ni in 12 months, while Pb and Zn decreased with time of sampling. The results further showed higher accumulation of Cr followed by Zn, relative to other metals, with oil pollution. However, addition of organic wastes to the oil polluted soils significantly ($p < 0.05$) led to reduction in the levels of the metals and THC following the order PM > PW > CD.

Keywords: Waste-lubricating oil; Heavy metals; Hydrocarbon content; Organic wastes; Soil contamination

1. Introduction

The soil is the primary recipient by design or accident of a myriad of waste products and chemicals used in modern industrial society (Brady and Weil, 2002). Contamination of soil and groundwater with petroleum mineral oil and mineral oil-based products is among the most common sources of pollution in Nigeria. The spent oil, otherwise called 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 its disposal (Anoliefo and Vwioko, 1995).

Analytical procedures commonly used to assess contamination by petroleum products are determination of hydrocarbon fractions, total hydrocarbon and heavy metal contents. The heavy metals and hydrocarbon belong to types of toxic substances that have adverse effects on health. Environment Canada (1996) reported that heavy metals might adversely affect specific tissues, reproduction

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and development. This may also cause anemia, nervous system disorders and depressed immune systems, resulting in mortality and effects on population levels (Environment Canada, 1996). Whereas, hydrocarbon contamination exerts adverse effect on soil condition such as higher acidity, reduced C, N, P and exchangeable cations availability, and depressed microbial activity. Industrial wastes containing heavy metals are one of major sources of water pollution (Al-Ashen et al., 1999). The type of metals present in certain waste depends on processes which generated this waste. While Edebiri and Nwanokwale (1981) reported that metals present in spent oil are not necessarily the same as those present in the unused lubricants, Whisman et al. (1974) observed that most heavy metals like Va, Pb, Al, Ni and Fe that are below detection in unused lubricants oil gave high concentration values in used oil. Since Nigeria was reported to account for more than 87 million litres of spent oil waste annually (Anon, 1985), the need to evaluate the risk posed by this pollutant becomes imperative.

Remediation approaches are generally classified as physical, chemical and biological. The conventional methods include soil extraction and landfill of the top contaminated soils ex situ is highly effective and clear-cutting (Zhu et al., 2004). This method is often too expensive due to high cost involved in the disposal of the contaminated soil, transportation and backfill of the original site with clean soil (Zhu et al., 2004; Ryan et al., 2001). Hence, in situ bioremediation has been one of the preferred methods for the remediation of petroleum-contaminated site because it is cost-effective and naturally converts the hydrocarbons to harmless by-products such as carbon dioxide and water. The soil is not transported elsewhere as with landfilling, and easier to scale up to treat large volume of wastes. However, design of in situ bioremediation under specific on-site conditions may remain a challenging issue (Huang et al., 2006). Also, Mohan and Singh (2002) noted that techniques utilizing biological materials, mineral oxides and activated carbon or polymer resins have evolved as options for adsorption of metals which cannot be removed by other techniques.

Therefore, this study focused on (i) distribution of some metals (Cr, Ni, Pb and Zn) and total hydrocarbon content (THC) in soil contaminated with varying levels of spent oil and spent oil contaminated soil amended with organic wastes from animal source and (ii) evaluation of differential effectiveness of cow dung (CD), poultry manure (PM) and pig waste (PW) as remediation option. Addition of the organic wastes to some contaminated plots was to serve as nutrients supplement aimed at stimulating biodegradation of this spent oil and to ameliorate the risk of metals from the oil on the environment. The choice of CD, PM and PW was because these wastes are abundantly available in Nigeria, and are cheaper as remediation alternative to the chemical and physical methods that are expensive.

2. Methods

2.1. Site description

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 derived savannah to the northwest (Keay, 1959). The soil of this research site is well-drained sandy

Table 1
Selected properties of the experimental site, and organic wastes and spent oil applied

Parameter	Units	Soil	CD	PM	PW	SP[a]
Sand (2000–50 μm)	g/kg	836	–	–	–	–
Silt (50–2 μm)	g/kg	48	–	–	–	–
Clay (<2 μm)	g/kg	116	–	–	–	–
Texture		Sandy loam	–	–	–	–
pH (H_2O)	5.8	6.4	6.7	7.5	–	
OC	g/kg	8.3	2.4	39.5	13.2	30.7
Total N	g/kg	0.71	0.97	4.0	1.30	2.66
C:N	–	11.7	12	9.9	10.2	11.5
Average P	mg/kg	7.4	126.5	143.6	74.8	0.1
Ca	cmol/kg	6.09	103.4	116.8	75.0	
Mg	cmol/kg	2.21	105.8	129.4	75.8	
K	cmol/kg	1.24	0.9	1.1	0.9	
Na	cmol/kg	1.13	10.5	3.6	3.0	
Exch. Acidity	cmol/kg	0.6	0.2	0.1	1.2	
ECEC	cmol/kg	11.27	–	–	–	
Cr[b]	mg/kg	39.5	342	114.8	269.7	6.5
Ni[b]	mg/kg	0.33	8.9	28.9	33.6	3.07
Pb[b]	mg/kg	6.25	BD	BD	BD	240
Zn[b]	mg/kg	7.11	31.1	38.6	121.8	486

BD = Below determined.
[a] mg/l.
[b] Metal concentrations in soil were determined by Aqua Regia-soluble extraction method, while metals in CD, PM, PW and SP was by extraction with $HClO_4$, HNO_3 and H_2SO_4 method.