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Remediation of Used Motor Engine Oil Contaminated Soil: A Soil Washing Treatment Approach

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Abstract

The increasing contamination of soil by used motor oil is very common and of great concern to our society because of the possible harm that it can cause the environment. Remediation of contaminated soil is the application of suitable techniques in the removal of contaminants present in soil. Contaminants like heavy metals and aromatic hydrocarbons are found in used motor oil as a result of reactions in motor engines occurring during use of motor oil. The study determined the effect of soil washing using detergent as a remediation technique for soils contaminated with used motor oil. Detergent solution was added to soil contaminated by used motor oil. After twenty four (24) hours, the concentration of heavy metals (Cr, Zn, Cd, Pb, Ar, and Cu) and Polyaromatic Hydrocarbons (PAHs) in the soil residue were determined. A control experiment was carried out for a soil sample with no used motor oil added to it. The control experiment indicated that PAHs were not present in the soil before introduction of used motor oil. The removal rate of contaminants for this technique was 63.8% for Zn, 100% for Ar, 52.9% for Cd, 67.3% for Cr, 89.2% for Pb, 43.4% for Cu and 95.6% for PAHs. Soil washing was found to be effective in remediation of soils contaminated by low concentrations of used motor oil.

Keywords: Soil washing; Remediation; Contamination; Heavy metals; Aromatic hydrocarbons

Introduction

The contamination of soil is an important environmental problem throughout the world. The ability of contaminants to accumulate and become toxic to biological systems (plants and animals) has been reported [1-3]. In most industrialized countries, the treatment and disposal of hazardous wastes is carefully controlled through a variety of regulations, policies, incentive programs and voluntary efforts. Hydrocarbon contamination of land and water has been a problem since the discovery of oil as fuel service particularly in developing nations. The presence of various kinds of automobiles and machineries has caused an increase in the use of motor oil. Oil is widely used as a lubricant in motor vehicles and other machinery such as hydraulic pumps and motors, compressors and electrical transformers. Automotive and industrial oils compose of an organic base stock. For specific applications, additives are applied to the base stock to increase the performance and life of the oil. Due to physical and chemical reactions occurring during its use, used motor oil contains impurities such as heavy metals e.g. zinc, barium, chromium, copper, arsenic, calcium and aluminum. It also contains chlorinated and aromatic hydrocarbons e.g. benzene, toluene and xylene. Polychlorinated bi-phenyls have also been found in used oils. Remediation in relation to a contaminated site means the management of the site in order to prevent damage to human health or the environment and restoring all or part of the site to a useful purpose. Remediation techniques includes isolation and containment, mechanical separation, pyro-metallurgical separation, permeable treatment wall, soil flushing, molecular and phase separation, chemical destruction, soil washing, vapor extraction, electro kinetics and biodegradation. All these techniques can be successfully applied if the physicochemical properties of pollutants and soil particles are well understood before selecting any method [4-7]. The selection of the most appropriate soil and sediment remediation method depends on the site characteristics, concentration, types of pollutants to be removed and the end use of concentrated medium [8]. Contaminants can be removed from soils using various agents added to soil. These agents are inorganic acids such as sulfuric and hydrochloric acids with pH less than 2; organic acids including acetic and citric acids with pH less than 4; chelating agents such as Ethylene Diamante Triacetic Acid (EDTA) and Nitro Triacetate (NTA); and various combinations of the above. The cleared soil can then be returned to the original site. Soil with less than 10-20 % clay and organic content (sandy soils) are most effectively remediated with these extractants. Organics and metals are removed through soil washing [9,8]. Mobilization of the metals from contaminated soils by soil washing using suitable extractants has been found to be a potential method for soil remediation [10,9]. Remediation of contaminated soils has been investigated severally [11-14]. Many arable lands in Nigeria have been destroyed because of contamination from oil spills, used motor oil and heavy metals from mining oil exploration and other industrial activities. The objective of this study is determine the effect of soil washing using laundry detergent as a remediation technique for soils contaminated with used motor oil.

Materials and Methods

The used motor-oil contaminated soil samples were collected using a hand-operated auger from a depth of about 0.25m from ground surface at Umuchima, Owerri West L.G.A, Imo State, Nigeria. Soil classification test was carried out according to BS1377:1975 [15]. One hundred grams (100g) of soil sample obtained from the area was put into eight (8) containers labeled A to H, after which samples A, B, C, D, E, F, and G had 10ml, 20ml, 30ml, 40ml, and 50ml of used motor oil were added respectively to the samples. Sample H was the control with no used motor oil added. The samples were kept in the laboratory for two (2) weeks. Common household laundry detergent (whose composition include: surfactants, sodium carbonate, sodium silicate, sodium sulphate, sodium carboxymethyl, cellulose, enzymes and optical brightener) solution was prepared by dissolving 50g of detergent in 100ml of water. Then, 200ml of detergent solution was

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added to each of samples A to G. The content were stirred quickly for 4 minutes, followed by gentle stirring to bring about good contact between soil particles and detergent solution. The soil-detergent solution mixture was then allowed to stand for twenty four (24) hours for the surfactant to take effect and also allow fine particles to settle. The used motor engine oil laden with soil-detergent solution was carefully decanted so that the fine particles do not wash away. The soil was subsequently washed twice (by stirring) with water. The soil particles were filtered after washing. The soil residue was air-dried for two days. The heavy metals in the soil were extracted using double acid extraction method. The concentration of heavy metals in the soils was obtained using atomic absorption spectrophotometer while the concentration of the Polyaromatic Hydrocarbons (PAHs) was analyzed using gas chromatography. The process of testing each sample was repeated twice for a total period of six (6) weeks to establish consistency and accuracy of experimental findings.

Results

According to the unified soil classification system, if more than 50 % particles are smaller than 4.75mm and larger than 0.075 mm with Plasticity Index (P.I) greater than 7 then the soil is classified as Sandy Clay (SC). Table 1 shows some of the soil properties of soil sample including Liquid Limited (LL), Plastic Limit (PL) and Plasticity Index (PI). Thus, the soil used in this study is classified as SC [15]. Table 2 shows the concentration of heavy metals and PAHs in soil sample before contact with used motor oil. PAHs were not present in soil sample before the introduction of used motor oil to the soil. Lead (Pb) has the highest concentration in the soil with a value of 0.045ppm. The concentrations of heavy metals and PAHs in used motor oil are presented in Table 3. The high concentrations of cadmium and PAHs are explained by the fact that they are basic constituents of engine motor oil.

The percentage removal of PAHs and heavy metals were obtained using equation 1.

$$R\,(\%) = \frac{Ci - Cf}{Ci} \times 100 \qquad (1)$$

Where *Ci* is the contaminant concentration before (pre) remediation, *Cf* is contaminant concentration after (post) remediation and R (%) is the percentage removal of contaminant after remediation.

From Tables 4 to 10, the average removal rate of for the various contaminants were found to be 95.6% for PAHs, 63.8% for Zn, 100% for Ar, 43.4% for Cu, 52.9% for Cd, 89.2% for Pb and 67.3% for Cr. Generally, for most of the contaminants except Ar, as the volume of used motor oil that was used in soil contamination increased, the removal rate of contaminants using soil washing technique decreased (Figures 1 to 7). This implies that a remediation technique as simple as soil washing using household laundry detergent will be most effective in situations where small amount of oil contamination occurred i.e., oil spillage that has affected only a small area or expanse of land. Besides, the process requires common available material (detergent) for short term treatment of contaminated land area.

properties	Sand	clay	Silt	gravel	LL	PL	P.I
percentage	84	10	5	1	30.5	18.1	12.4

Table 1: Soil properties of soil sample.

Parameters	Pb	Cu	Cr	Cd	Zn	As	PAHs
Concentration (ppm)	0.045	0.014	0.0026	0.032	0.004	0.0002	0

Table 2: Concentration of heavy metals and PAHs in soil sample.

Parameters	Pb	Cu	Cr	Cd	Zn	As	PAHs
Concentration (ppm)	0.00285	0.00285	0.00285	0.00427	0.00285	0	66.85

Table 3: Concentration of heavy metals and PAHs in used motor oil.

Volume of used motor oil (ml)	Percentage removal (%)
10	94.11
20	95.49
30	95.73
40	96.16
50	96.19

Table 4: Percentage removal of PAHs after remediation.

Volume of used motor oil (ml)	Percentage removal (%)
10	93.8
20	80.3
30	75.6
40	36.74
50	32.4

Table 5: Percentage removal of Zinc after remediation.

Volume of used motor oil (ml)	Percentage removal (%)
10	100
20	100
30	100
40	100
50	100

Table 6: Percentage removal of Arsenic after remediation.

Volume of used motor oil (ml)	Percentage removal (%)
10	91.61
20	58.9
30	31.54
40	20.53
50	14.29

Table 7: Percentage removal of copper after remediation.

Volume of used motor oil (ml)	Percentage removal (%)
10	91.6
20	77.9
30	36.8
40	27.9
50	30.3

Table 8: Percentage removal of cadmium after remediation.

Volume of used motor oil (ml)	Percentage removal (%)
10	98.22
20	97.35
30	94.73
40	85.56
50	70

Table 9: Percentage removal of lead after remediation.

Volume of used motor oil (ml)	Percentage removal (%)
10	84.8
20	64.9
30	77.7
40	55.8
50	53.3

Table 10: Percentage removal of chromium after remediation.

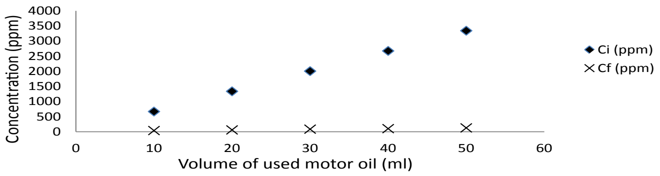

Figure 1: Concentration of PAHs pre and post remediation.

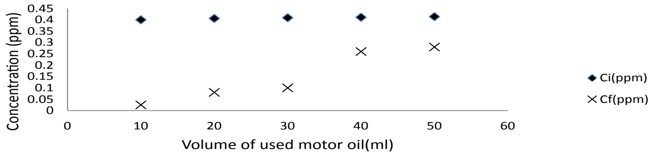

Figure 2: Concentration of Zinc pre and post remediation.

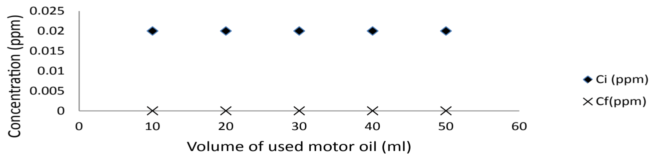

Figure 3: Concentration of Arsenic pre and post **remediation.**

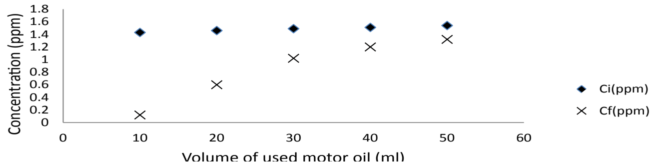

Figure 4: Concentration of copper pre and post remediation.

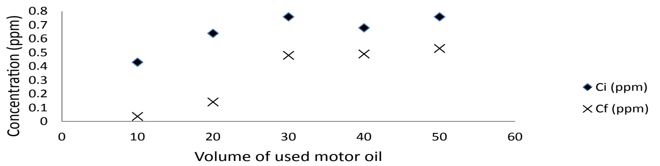

Figure 5: Concentration of Cadmium pre and post remediation.

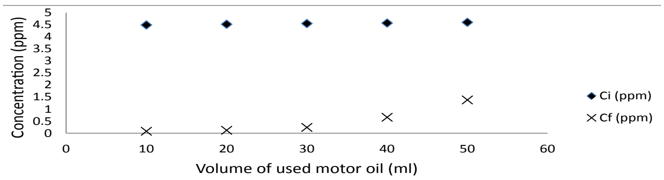

Figure 6: Concentration of lead pre and post remediation.

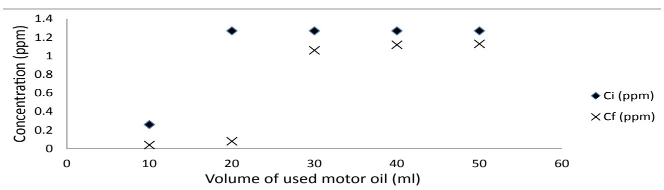

Figure 7: Concentration of Chromium pre and post remediation.

Conclusions and Recommendations

Lead had the highest concentration of 0.045 ppm in the soil compared to other heavy metals and PAHs. Cadmium was also found to have the highest concentration of heavy metals in the used motor oil. Soil washing technique was found to be effective in remediation of soils contaminated by used motor oil at low concentrations of used motor oil. The removal efficiency of heavy metals and PAHs were found to be low as the volume of used motor oil increased. Therefore, this remediation process is recommended for treatment of used engine oil contaminated soils and other small oil spills within small land areas.

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