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Characterization and Remediation of Waste Motor Oil-Contaminated Soil

Boniface Chinedu Ngolube[1], A. E. Ahizi[2], C. Nzeoma[3], M. C. Udoye[4]
[1,2,3,4]Department of Chemical Engineering, Federal University of Technology, Owerri, Imo State, Nigeria
([1]ngolubechinedu@gmail.com)

Abstract-Soil is a very vital component of agriculture. The reckless spilling or disposing of spent motor oil to the environment especially around an auto-mechanic village has become a matter of urgent concern in most part of the world. The contamination of soil by waste motor oil results in change in soil properties and renders farmlands unsuitable for agricultural and other purposes. The study is aimed to characterize and remediate waste motor oil contaminated soil for heavy metals. Samples of waste motor oil-contaminated soil were obtained from Avu mechanic village in Owerri West Imo state and analyzed for five heavy metals (Zn, Pb, Cd, Cr and Cu). Before remediation, the initial concentration of the heavy metals in the soil samples were found to be 0.179mg/l for copper, 0.428mg/l for lead, 0.578mg/l for zinc, 0.622mg/l for cadmium and 0.475mg/l for chromium. The contaminated soil sample was remediated using mycoremediation, phytoremediation, bio-stimulation, soil washing and adsorption methods at an interval of 2 weeks to ascertain the final concentration of these heavy metals after treatment. It was found that there was a steady decrease in the concentration of the heavy metals in the soil after each remediation method. Copper was least removed in the soil for all remediation method used. Copper remediates better using adoption method with percentage removal of 60.89%. Lead and chromium remediate better in soil washing and adsorption method with percentage removal of 97.20% and 97.18% respectively while zinc remediates well in all remediation method used. Adsorption method proves to be better remediation method.

Keywords- *Motor Oil, Soil, Remediation, Heavy Metals, Mycoremediation, Phytoremediation, Bio-stimulation, Adsorption, Soil Washing*

I. INTRODUCTION

A. *Background of the Study*

Soil is the most vital non-renewable natural resource, an actively living system which performs major environmental functions that consist of diversity of micro and macro fauna and flora, that play major role in maintaining the soil quality. It is a complex mixture of mineral nutrients, organic matter, water, air, and living organisms determined by various environmental factors such as climate, parent material, relief, organisms, and time factors. The disposal of used motor oil on land can lead to loss in soil quality by minimizing the abundance and variety of microorganisms in soil. These changes affect the soil quality on a global scale and the degradation hampers economic growth and healthy environment. Soil quality includes physical, chemical, and biological properties of soil that depend on the soil nutrient pools and reserves, which are modulated by land use and a number of other management factors.

As motor oil is used in automobile, it picks up a number of additional compounds from motor wear. These include iron, steel, copper, zinc, lead, barium, cadmium, sulfur, dirt and ash. Because of the additives and contaminants, used motor oil disposal can be more environmentally damaging than crude oil pollution (Abioye, et al., (2012). These additives and contaminants may cause both short and long term effect if they are allowed to enter the environment through water ways or soil. Once motor oil is drained off an motor, it is no longer clean because it has picked up materials, dirt particles, and other chemicals during motor operation, thus such lubricating oil is now classified as Spent Motor Oil.

In automobile workshops, there are accidental or deliberate discharges of lubricants on soil surface. Many of these petroleum products are organic and synthetic chemicals that can be highly toxic and hazardous to soil fauna and man. Used oil is less viscous than unused oil; when disposed of into the soil, it adsorbs to the soil particles, reduces porosity and therefore reduces aeration of soil. These have a way of affecting the soil quality: the physical, chemical and biological constituents/ parameters including heavy metal contamination (Uchendu, and Ogwo, 2014).

Avu Mechanic Village in Owerri west, Imo state was selected as the study area. The quantity of Spent motor Oil generated in this area is very enormous. The mechanic village covers an area of about 3000m2 with a population of about 1500 artisans. These artisans are mainly vehicle mechanics, panel beaters, welders, automobile electricians, painters, automobile upholstery workers, automobile spare part dealers, vulcanizers and blacksmiths. Most of these artisans and vendors belong to the informal sector of the economy. The increasing number of vehicles being serviced or repaired at these mechanic workshops is at increase as more artisans round the state relocate to this automobile mechanic village steadily. It can therefore be established that the amount of used motor oil from vehicles is in steady increase, and therefore calls for an urgent attention to address the situation.

Pollution arising from the disposal of used motor oil is one of the environmental problems in Africa, and is more widespread than crude oil pollution which calls for urgent attention. Constant degradation of soil by spent motor oil is a serious environmental problem that needs to be addressed because of the possible harm it can cause to our environment. Contaminated soil by spent motor oil can be seen mostly in an automobile workshop and are so harmful to human, plants and animal. Therefore, this work is aimed to characterize and remediate waste motor oil-contaminated soil for heavy metals using bio-stimulation, soil washing, adsorption, mycoremediation and phytoremediation.

II. MATERIALS AND METHOD

A. Materials/Equipment

1) Materials

Soil sample contaminated with spent motor oil, Corn cob, Concentrated H_2SO_4, Concentrated HCL, Distilled water, NPK fertilizer, Detergent solution, Corn seeds, Aspergillius niger culture

2) Equipment

Equipment used are: Grinder, moisture bottle, Measuring Cylinder, Beakers, pipette, magnetic stirrer, electronic scale, Sieve, Flask (Flat bottom), Atomic Absorption Spectrophotometer (model 210VGP Buck Scientific), PH meter and plastic Funnels.

B. Method

1) Collection of Soil Samples:

Samples of motor oil contaminated soil were collected from Avu Mechanic Village in Owerri West Imo state. The contaminated soil was dried at room temperature. After drying, the soil samples were weighed and separated into five different bowls with one serving as control for proximate analyses to be carried out on them.

2) Characterization of the contaminated soil sample

- PH

10g of the air dried sample of the contaminated soil was weighed using the electronic scale and put in moisture bottle. 25ml of deionized water was measured using the measuring cylinder and poured into the moisture bottle containing the contaminated soil. The mixture was put on a magnetic stirrer and allowed to swirl for 15 minutes. The resulting mixture was allowed to sit for 30 minutes. The PH of the soil was determined using the PH meter by placing the electrode of the meter into the mixture.

- Organic Carbon Content

0.5g of the sir dried contaminated soil was weighed using the electronic scale and put in a moisture bottle. 5ml 00f 1N potassium heptaoxodichromate (V) was measured using the pipette and poured into the moisture bottle containing the contaminated soil. The mixture was put on a magnetic stirrer and allowed to swirl for thirty 30 minutes to disperse the soil. After swirling, 10ml of concentrated hydrochloric acid was added to the mixture and allowed to swirl for 5 minutes to ensure adequate mixing. 50ml of deionized water was measured using the measuring cylinder and added to the mixture. The resulting mixture was titrated with 0.5N iron (II) sulphate solution using three drops of methyl orange as indicator. The end point of the solution was reached when the colour the mixture changed from orange to dark green. Ten drops of 0.5N iron (II) sulphate was added and the colour changed from dark green to red (maroon). The dichromate was standardized by repeating these procedures without the soil. The organic carbon content was calculated using the formula below:

$$\% \text{ organic carbon} = \frac{(MeK_2CrO_7 - MeFeSO_4)x\ 0.003\ x\ 100\ x\ f}{mass\ of\ dry\ soil} \quad (1)$$

where:

Me=Normality of solution x volume of solution used

F=correction factor, 1.33

- Heavy Metal Analysis (Test for Copper, Zinc, Cadmium, Lead and Chromium)

3g of soil was weighed and mixed with 50ml of distilled water in a beaker. Concentrated H_2SO_4 and HCl were mixed in the ratio 3:2, 50ml of the weighed sample were added to each of the remediated soil, the samples were heated for 40minutes. After heating, the samples were filtered and the heavy metals were analyzed using an Atomic Absorption Spectrophotometer (AAS) model 210VGP Buck Scientific. The formula for percentage heavy metal removal is given as:

$$\frac{H_R}{H_I} x \frac{100}{1} \quad (2)$$

H_R = Total amount of heavy metal removed

H_I = Initial concentration of heavy metal

3) Remediation of the contaminated soil sample

a) Mycoremediation

400g of dried contaminated soil samples was weighed using a weighing balance and put in a bowl, 300ml of Aspergillius niger was measured using a measuring cylinder and mixed it properly with the soil. The mixture was kept for a period of 8 weeks and at an interval of 2 weeks, heavy metal analysis was carried out on the remediated soil.

b) Phytoremediation

Maize seed was checked for viability i.e. planting for 2 days to see if it would germinate. After which 400g of contaminated soil was measured in a bowl using a weighing balance. The seeds were planted in the soil and were watered for 4 days in a week to ensure youthful germination. (A total of 10 seeds were planted). After an interval of 2 weeks, there was a sprout. The soil samples were collected from roots of the germinating plants and heavy metal analysis was checked for a period of 8 weeks.

c) Bio-stimulation

NPK with the ratio of 15:15:15 was mixed thoroughly in a weighed contaminated soil sample of 400g.The NPK was weighed in a weighing balance as 800g and also a small range of bacteria (streptococcus) was added to the soil to enhance the growth of the bacteria in the remediation process. For a total period of 8 weeks, soil samples were collected and analyzed for heavy metals in the soil.

d) Soil washing

400g of contaminated soil samples was measured with a weighing balance. Common household laundry detergent solution (whose composition includes surfactants, sodium carbonate, sodium silicate) was prepared by dissolving 100g of detergent in 200ml of water. 250ml of the detergent solution was then added to the 400g of soil sample. The contents were stirred quickly for 4 minutes followed by a gentle stirring to improve the contact between soil particles and detergent solution. The soil-detergent mixture was then allowed to stand for 24 hours for the surfactant to penetrate the soil and allow the particles to settle. The used motor 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, so that the soil particles were filtered after washing and air dried for 4 days. In an interval of 2 weeks and a total period of 8 weeks, the concentration of heavy metals was analyzed.

e) Adsorption

Corn cobs were obtained and dried for 2 days. The cobs were then ground into fine particles and sieved with a 15mm mesh into the contaminate soil sample. The ground cob were carbonized and activated at a temperature 200 degree Celsius for four hours each and rinsed thoroughly with distilled water. The activated corn cobs was mixed thoroughly with the contaminated soil and allowed to absorb the metals. The heavy metal content of the soil was checked in an interval of 2 weeks for a total period of 8 weeks.

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Results

TABLE I. CHARACTERIZATION OF THE SOIL SAMPLE

PH	7.10				
Organic carbon (%)	5.29				
Heavy metals	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Cadmium	Cromium
Concentration (mg/l)	0.179	9.428	0.578	0.622	0.567

TABLE II. HEAVY METAL CONCENTRATIONS (MG/L) FROM ZERO TO EIGHT WEEKS AND ITS PERCENTAGE REMOVAL (%RE) FOR MYCOREMEDIATION

Days	Cu	Pb	Zn	Cd	Cr
0	0.179	0.428	0.578	0.622	0.567
14	0.157	0.384	0.474	0.511	0.475
28	0.130	0.273	0.359	0.400	0.369
42	0.121	0.165	0.295	0.254	0.235
56	0.106	0.040	0.025	0.090	0.038
%RE	40.78	90.65	95.67	85.53	93.30

TABLE III. HEAVY METAL CONCENTRATIONS (MG/L) FROM ZERO TO EIGHT WEEKS AND ITS PERCENTAGE REMOVAL FOR ADSORPTION METHOD

Days	Cu	Pb	Zn	Cd	Cr
0	0.179	0.428	0.578	0.622	0.567
14	0.132	0.345	0.451	0.436	0.453
28	0.091	0.281	0.314	0.357	0.335
42	0.121	0.165	0.295	0.254	0.235
56	0.070	0.018	0.039	0.036	0.017
%RE	60.89	95.79	93.25	94.21	97.00

TABLE IV. HEAVY METAL CONCENTRATIONS (MG/L) FROM ZERO TO EIGHT WEEKS AND ITS PERCENTAGE REMOVAL FOR PHYTOREMEDIATION METHOD

Days	Cu	Pb	Zn	Cd	Cr
0	0.179	0.428	0.578	0.622	0.567
14	0.146	0.372	0.447	0.498	0.444
28	0.118	0.267	0.335	0.392	0.321
42	0.107	0.158	0.257	0.235	0.147
56	0.097	0.048	0.024	0.087	0.027
%RE	45.81	88.79	95.85	86.01	95.23

TABLE V. HEAVY METAL CONCENTRATIONS (MG/L) FROM ZERO TO EIGHT WEEKS AND ITS PERCENTAGE REMOVAL FOR SOIL WASHING METHOD

Days	Cu	Pb	Zn	Cd	Cr
0	0.179	0.428	0.578	0.622	0.567
14	0.119	0.367	0.462	0.451	0.416
28	0.107	0.215	0.345	0.363	0.362
42	0.095	0.193	0.284	0.261	0.289
56	0.076	0.012	0.023	0.075	0.016
%RE	57.54	97.20	96.02	87.94	97.18

TABLE VI. HEAVY METAL CONCENTRATIONS (MG/L) FROM ZERO TO EIGHT WEEKS AND ITS PERCENTAGE REMOVAL FOR BIO-STIMULATION METHOD

Days	Cu	Pb	Zn	Cd	Cr
0	0.179	0.428	0.578	0.622	0.567
14	0.151	0.363	0.459	0.473	0.428
28	0.125	0.2	0.322	0.379	0.352
42	0.104	0.119	0.247	0.253	0.280
56	0.083	0.037	0.026	0.086	0.045
% RE	53.63	91.36	95.50	86.17	92.06

TABLE VII. PERCENTAGE REMOVAL EFFICIENCY FOR ALL REMEDIATION METHODS

Methods	Percentage of Heavy metals removed (%)				
	Cu	Pb	Zn	Cd	Cr
Bio-stimulation	53.63	91.36	95.50	86.17	92.06
Mycoremediation	40.78	90.65	95.67	85.53	93.30
Phytoremediation	45.81	88.79	95.85	86.01	95.23
Adsorption	60.89	95.79	93.25	94.21	97.00
Soil washing	57.54	97.20	96.02	87.94	97.18

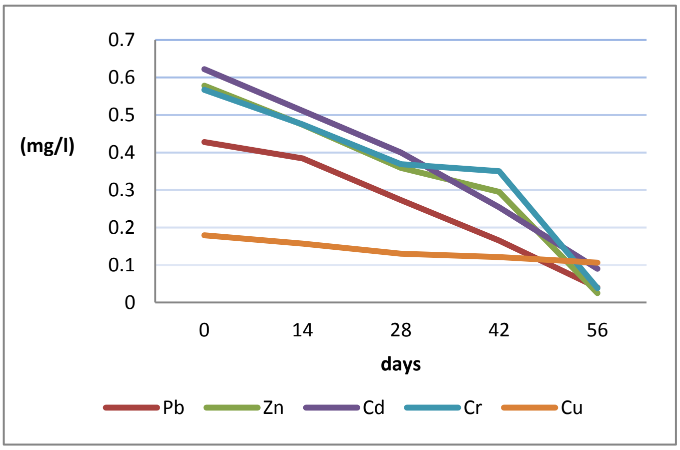

Figure 1. Heavy metal Concentration against days for mycoremediation

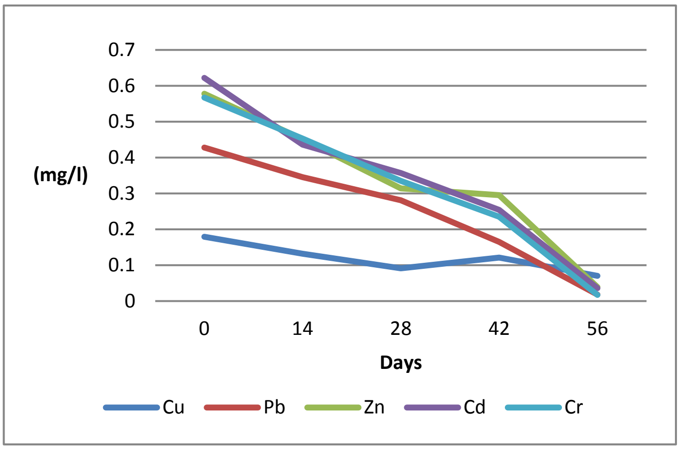

Figure 2. Heavy metal Concentration against days for Adsorption

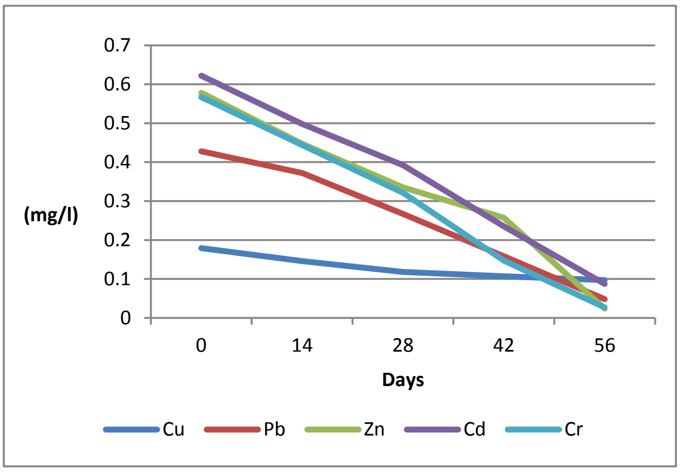

Figure 3. Heavy metal Concentration against days for Phytoremediation

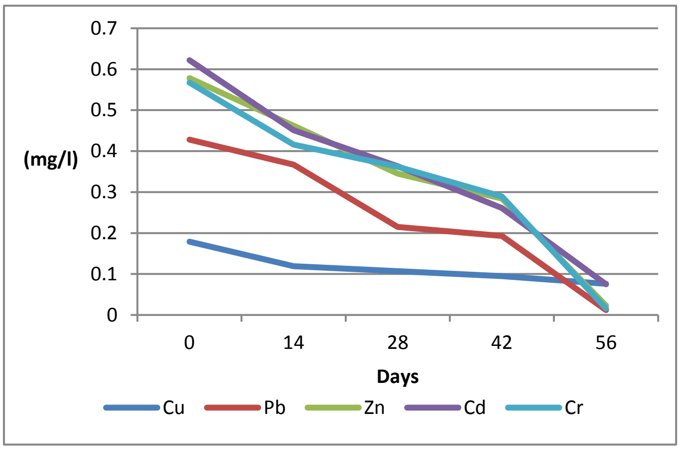

Figure 4. Heavy metal Concentration against days for Soil washing

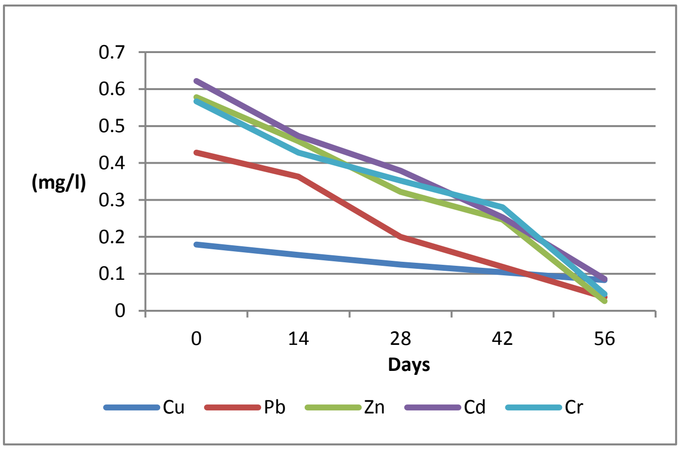

Figure 5. Heavy metal Concentration against days for Biostimulation

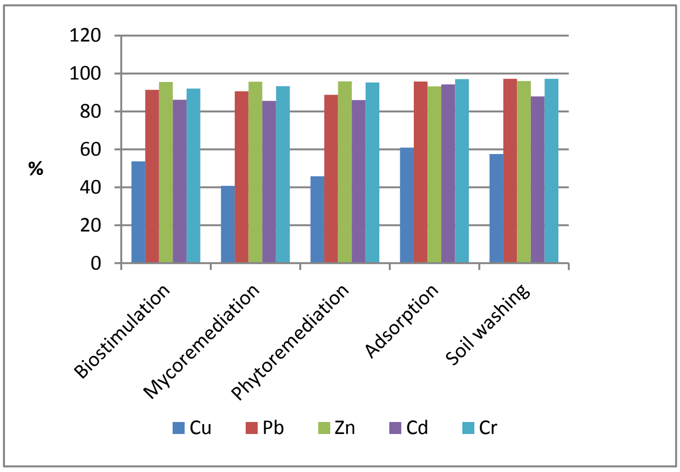

Figure 6. Percentage of heavy metals removed for all remediation methods

B. *Discussion of Results*

Table 1 shows that the contaminated soil sample has a PH of 7.20 and total organic carbon of 5.29%. The heavy metal analysis showed that the contaminated soil contains high concentration of cadmium (0.622mg/l) and copper has the least concentration (0.179mg/l).

1) *Effect of Mycoremediation on Heavy Metal Removal*

The result of mycoremediation (figure 1) shows that the concentration of heavy metals in the soil decreases with time. After 56 days, the concentration of copper decreases from (0179 to 0.106) mg/l; lead decreases from (0.428 to 0.040) mg/l; zinc decreases from (0.578 to 0.025) mg/l; cadmium decreases from (0.622 to 0.09) mg/l; and chromium decreases from (0.567 to 0.038) mg/l. Zn was highly remediated in the soil by mycoremediation with percentage removal of 95.67%, while copper is least remediated with percentage removal of 40.78%.

2) *Effect of Adsorption method on heavy metal removal*

Figure 2 shows that adoption method reduces copper concentration in soil from (0.179 to 0.070) mg/l. Lead was reduced from (0.428 to 0.018) mg/l. Zn concentration decreases from (0.578 to 0.039) mg/l. Cadmium concentration was reduced from (0.622 to 0.036) mg/l and Chromium concentration decreases from (0.567 to 0.017) mg/l. Adsorption has proven to be a better remediation method for copper metal having 60.89% removal as compared to other remediation method. This method still serve as the preferred method for lead, zinc, cadmium, iron and chromium ions clean up with percentage removal of 95.75%, 93.25%, 94.21%, 85.09% and 97.0% respectively.

3) *Effect of phytoremediation on heavy metal removal*

In figure 3, the phytoremediation of the soil using maize plant shows that the heavy metals concentration in the soil decreases to a certain extent after 56 days. Copper concentration decreases from (0.179 to 0.097) mg/l; lead concentration reduces from (0.428 to 0.048) mg/l; Zn concentration decreases from (0.578 to 0.025) mg/l; cadmium decreases from (0.622 to 0.09) mg/l; while chromium reduces from (0.578 to 0.038) mg/l. The result of phytoremediation shows that Zinc was highly remediated in the soil with percentage removal of 95.85% while copper is least remediated in the soil with percentage removal of 46%.

4) *Effect of soil washing on heavy metal removal*

The surfactant present in detergents can be used to clean up heavy metals in a waste motor oil-contaminated soil. Figure 4 shows that soil washing method decreases the concentration of copper from (0.179 to 0.076) mg/l with percentage removal of 57.54%. Lead was reduced from (0.428 to 0.012) mg/l with percentage removal of 97.20%. The concentration of Zn reduces from (0.578 to 0.023) mg/l with percentage removal of 96.02%. cadmium concentration decreases from (0.622 to 0.075) mg/l with percentage removal of 87.94%. Chromium concentration decreases from 0.578 to 0.289) mg/l with percentage removal of 97.18%. Lead, chromium and Zinc remediate better than other method in soil washing. Soil washing has proven to be a better remediation method but equally not environmental friendly.

5) *Effect of soil Biostimulation on Heavy Metal Removal*

The stimulation of soil bacterial with nitrogen phosphorous potassium (NPK) fertilizer is in line with the investigation of Abid, et al., (204). Figure 5 shows that the use of biostimulant (NPK fertilizer) reduces the concentration of copper metal from (0.179 to 0.083) mg/l. lead concentration decreases from (0.428 to 0.037) mg/l. Zinc concentration decreases from (0.057 to 0.026) mg/l. cadmium concentration reduces from (0.622 to 0.086) mg/l and Chromium concentration decreases from (0.567 to 0.045) mg/l. this result shows that zinc remediate higher in biostimulation compare to other metals with percentage removal of 95.5%, while copper remediate very low with percentage removal of 53.63%.

In figure 6, copper was least remediated in the soil for all remediation method used. Copper remediate better using adoption method with percentage removal of 60.89%. Lead and chromium remediate better in soil washing and adsorption method with percentage removal of 97.20% and 97.18% respectively. Zinc remediates well in all remediation method used.

IV. CONCLUSION AND RECOMMENDATIONS

A. *Conclusion*

The characterization and remediation of motor-oil contaminated soil for heavy metals has been studied. All remediation method used have proved to be effective in remediating the contaminated soil for the heavy metals tested as the concentration of the heavy metals decreases with time. Zinc was highly remediated in the soil for all remediation method while copper show the least percentage removal.

B. *Recommendations*

It was recommended that:

i. The combination of multiple bioremediation techniques in remediating waste motor oil contaminated soil as bioremediation method proved to be efficient, environmental friendly and cheap

ii. The use of all remediation method in remediating Zinc from the contaminated soil since they have proved to be efficient in remediating zinc from the contaminated soil.

iii. Further research should be carried out to investigate why copper remediated less in all remediation method used.

Government on their part should check and regulate the disposal of these spent motor-oils by these mechanics or rather provide a disposal-bin so that the spent motor-oil will not be littered round the workshop. This will help safeguard the environment.

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