Study on Effect of Soil Washing with Different Washing Cycles on Particle Size of Contaminated Soil

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Abstract— Soil contamination by heavy metals is a major problem at many contaminated sites now a day. According to EPA's list of priority pollutants cadmium, chromium, copper, lead, mercury, nickel, and zinc are the most hazardous heavy metals found at many soil contaminated sites. Many techniques are employed for the decontamination of soils. This consists of various physiochemical as well as biological methods. Among these process soil washing is a physiochemical method, which has a very high efficiency for heavy metal removal from contaminated soils. It is a simple, ex situ remediation technology. In this process by the addition of washing water, heavy metals can be transferred from the degraded sediment to wash solution. This process can be enhanced by addition of acid washing, chelating agents or surfactants. Particle size always plays an important role in the removal of heavy metals. In this research paper an attempt has made to soil washing technology for removal of Pb and Cr from contaminated soil with the help of different combination of EDTA and DI water cycle. Another attempt has also made to find out the effect of particle size i.e. soil, silt and clay on the soil washing.

Key words: Remediation, Heavy metals, Soil washing, EDTA, Particle size

I. INTRODUCTION

Soil, one of the important elements of the environment is at threat because of various pollutants. Soils are mostly contaminated by volatile organics, hydrophilic and hydrophobic organics, heavy metals, and radioactive materials [1]. Among all the pollutants heavy metals plays a significant role. The most common heavy metals found at contaminated sites are lead, chromium, arsenic, zinc, cadmium, copper and mercury. These heavy metals are non degradable therefore, persist for ever in the environment. These heavy metals are one of the major sources of environmental pollution. They affect the human health, animal's life by means of bioaccumulation. Heavy metal pollution can arise from many sources, but most commonly arise from the purification of metals, e.g. the smelting of copper and the preparation of nuclear fuels. Electroplating is the primary source of chromium and cadmium. Heavy metals also generated from industrial discharge energy production, chemical used in agricultural industry, construction activity, from vehicles exhaust, burning of fossil fuels etc. The E.P.A estimated over 20 million cubic yards of soil at current national priority list (NPL) sites are contaminated with metals. Metal is relatively immobile in sub surface system because of precipitation or adsorption reaction. The decontamination of soil includes the in- situ. The E.P.A estimated that over 20 million cubic yards of soil at current national priority list (NPL) sites are contaminated with metals. Metal s is relatively immobile in sub surface system because of precipitation or adsorption reaction. The decontamination of soil includes the in-situ as well as ex-situ remediation technique. The in-situ treatment mainly increases the stabilization of metals in sediment particles. The Ex-situ process achieved by extracting or separating metals from the contaminated sediment. Soil washing is a relatively simple and useful ex-situ remediation technology. In this technique washing water are added and heavy metal can be transferred from degraded sediment to wash solution. [2]

The performance of soil wash is increase by addition of various additives such as, acid (H_2SO_4, HNO_3), chelating agents (EDTA, EDDS, DTPA) or surfactants (eg. Rhamnolipid). Among all this additives chelating agents are most popular. Chelating agents such as Ethylenediamine Tetraacetic Acid (EDTA) can form stable and soluble complexes with heavy metal and increases metal removal from contaminated soil. Soil washing is useful for treatment of soil contaminated with heavy metals, hydrocarbons but it is less effective for VOC and pesticides [3]. Particle size also plays an important role in soil washing it is easy to remove heavy metal for larger size particle due to less molecular attraction between soil particles and heavy metals. But removal efficiency for very fine particles such as silt and clay is less compared to larger size particle due to strong molecular attraction.

II. MATERIALS AND METHODS

A. *Soil*

The soil sample was collected from VIT University campus. The samples were air dried at room temperature to remove excess moisture. Then the air dried samples were sieved by using 2.36mm sieve to remove stones, large particles and other unwanted things. Then the soil samples were completely mixed with hand. Thoroughly mixed samples were kept in airtight plastic bag at room temperature for further use in experiments.

B. *Soil Contamination Procedure*

From the stored soil about 5 Kg of sample was taken. That sample was mixed with a solution of deionized water (DI), dissolved salts of lead nitrate $Pb(NO_3)_2$, potassium dichromate $K_2Cr_2O_7$. The aim of mixing is to artificially contaminate the soil with Pb and Cr heavy metals. The conc. of heavy metals was kept around 5000ppm. For 10 days, the soil and heavy metals were properly mixed. Then particle size distribution of contaminated soil was performed with the help of 1700 microns – 53 microns sieve size. Concentration of heavy metals at each particle size was determined by soil digestion method. For soil digestion process was performed according to EPA 3050B method.

The physicochemical properties of soil are shown on Table 1. The pH of soil was determined by using 1:5 soils to water ratio by using pH meter. With the help of Walkley and Black rapid titration method total organic carbon was determined. Particle size distribution was performed by sieving method. Heavy metal concentration was determined by tri acid digestion method (Hcl+HNO3+H2O2). Heavy metal analysis performed by using Varian AA240 flame atomic absorption spectrometer.

Soil Components	Content
pH	8.48
Total Organic Carbon	1.5%
Medium Sand (< 2mm)	54.25%
Fine Sand (< 425µm)	41.1%
Slit and clay (<75µm)	4.3%
Heavy Metals (mgKg-1) (Background)	
Pb	26
Cr	61

Table 1: Physicochemical properties of soil sample

C. Soil Washing Procedure

Batch extraction process was performed by using 0.01M extracts concentration. In this procedure 2 gm of soil and 10 ml of EDTA agitated by using an orbital shaker at a speed of 150 RPM at room temperature for 6 hrs. Then suspension was centrifuged at 3000 RPM for 15-20 mins and supernants were filtered through filter paper. The concentration of heavy metal was measured by flame atomic absorption spectrometry (AAS). Analytical grade of washing reagents were prepared. All tests were performed at triplicates and results were presented as average of triplicate extracts. Different operating parameters were optimized. These parameters are EDTA concentration, pH concentration, liquid to solid ratio and RPM. Disodium salt of EDTA used for the whole experiments. In EDTA concentration, four different concentration were choose (0.005, 0.01, 0.05, 0.1) of Na2EDTA were used. For pH parameter 2-10 pH was adjusted with diluted HNO3 and NaOH. The liquid/solid ratio was optimized by 4, 5, 7, 10 and 15 ml of 0.01M Na2EDTA, giving liquid/solid ratio of 4, 5, 7, 10 and 15 respectively. In RPM test four different RPM (50, 100, 150, and 200) were chosen. The kinetic study of soil extraction was performed in the tubes containing 2 gm of soil and 10 ml of DI water and Na2EDTA for 0, 0.5, 1, 2, 4, 6, 8, 12, 18, 24, 30, 36, 48 hr. The soil washing with different washing cycles now performed with all the optimized parameters for Pb the optimized parameters were 0.1 M EDTA concentration, pH 4, 1:5 solid/liquid ratio, RPM 100, for Cr parameters were 0.1 M EDTA concentration, pH 8, 1:5 solid/liquid ratio, RPM 150 [4].

D. Soil Washing with Different DI and EDTA Cycles

Three different particle size of soil was been chosen i.e. 850, 300 and <53micron for soil washing with different combinations of DI water and EDTA cycles. These three particle size was selected based on the classification of the soil. According to the particle size distribution soil mainly divided into 3 types i.e. sand (<2mm to 0.2mm), silt (0.2mm to 0.02mm) and clay (0.02mm-0.002mm). Here an attempt has been made to find out the efficiency of soil washing for different particle size. Different particle size has different metal retaining capacity. Among these three particle size clay having the highest metal retaining capacity. The retained soil on particular sieve i.e. 850, 300 and <53 was taken removal percentage of Pb and Cr was determined. The optimized parameters for Lead and Chromium were employed for the washing cycles. For these experiments 0.1M of EDTA was used as the optimum doses. The mixed soil was also employed for soil washing with different DI and EDTA cycles. The effect of soil washing was also determined for the non-screened soil. The removal efficiency for non-screened soil was also determined. Table 2 gives the idea about different combinations of washing cycles:

Nomenclature	Washing cycle combinations
C1	DI+EDTA
C2	DI+EDTA+DI
C3	DI+DI+EDTA
C4	DI+EDTA+DI+EDTA
C5	DI+EDTA+EDTA
C6	EDTA+DI
C7	EDTA+EDTA+DI
C8	EDTA +DI+EDTA
C9	EDTA+DI+EDTA+DI
C10	EDTA+DI+DI

Table 2: Nomenclature of washing cycle combinations

III. RESULTS AND DISCUSSIONS

A. Particle Size vs. Contamination

As the particle size decreases the heavy metal concentration in the particle increases shown (in Fig. 1). The basic reason behind this, smaller particle size has larger surface area. Another reason behind this, soil contains mineral and humic constituents and in smaller fraction these are found in more concentration. These humic and mineral substances carry hydroxyl and carboxylic surface functional groups. These acid-base characteristics of these functional groups contribute to the formation of a surface charge that plays an important role in metal retention. Hence metal conc. increased in smaller fraction [5].

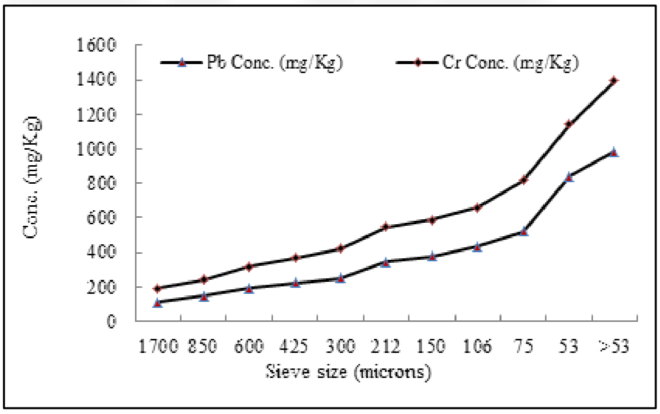

Fig. 1: Particle size and Heavy metal concentration

B. Removal of Pb with DI and EDTA Washing Cycles

Soil washing for soil contamination with Pb was carried out for different particle size *i.e.* 850, 300 and <53 micron using DI and EDTA washing cycles. For non-screened soil removal efficiency was also determined. For Pb, cycle 7 (*i.e.* EDTA+EDTA+DI) combination shows the highest removal efficiency. For 850 micron the highest removal efficiency was 78.53% (Fig. 2), for 300 micron it shows 77.89% (Fig. 3), for <53 micron the highest removal efficiency was 72.39% (Fig. 4). For non-screened soil 56.99% was the highest removal efficiency (Fig. 5). This combination shows the highest removal because EDTA complexion is dominant for cationic metal like Pb. The average removal of Pb for 850 micron was 66.16%, for 300 micron the average removal was 59.48%. For <53 microns the average removal was 61.15%. For non-screened soil the average percentage of removal was 44.13%. <53 microns shows the highest average removal because the concentration of heavy metal is higher compare to other particle size due to higher concentration the removal also higher.

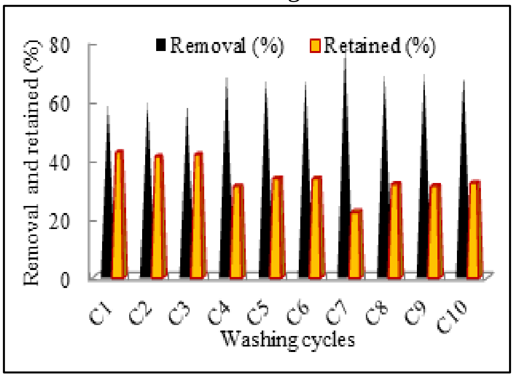

Fig. 2: Removal from 850 micron size soil

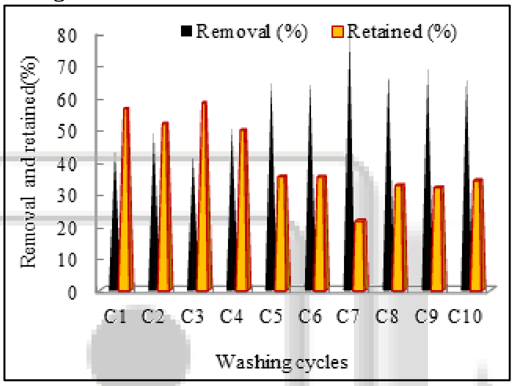

Fig. 3: Removal from 300 micron size soil

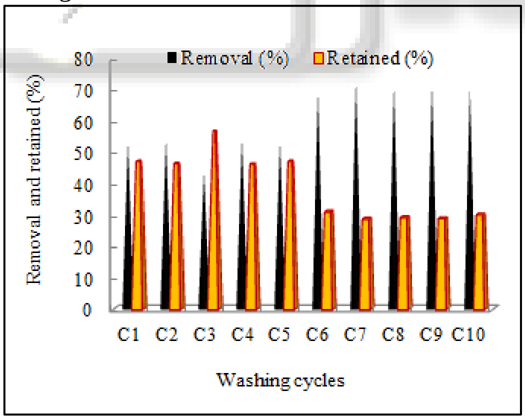

Fig. 4: Removal from <53 micron size soil

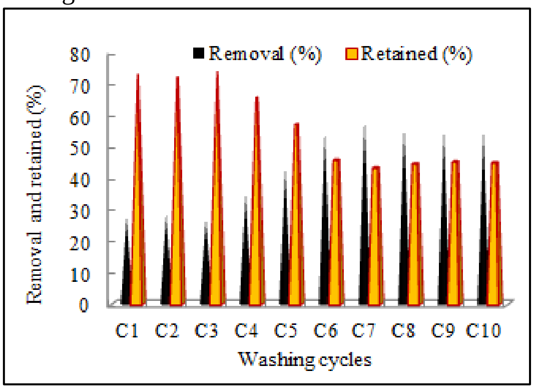

Fig. 5: Removal from non-screened soil

C. Removal of Cr with DI and EDTA Washing Cycles

Experiments were carried out to study Cr removal by soil washing from the 850, 300 and <53 micron particle size using different combinations DI and EDTA washing cycles. The removal efficiency was also determined for the non-screened soil. For Cr, cycle 4 (i.e. DI+EDTA+DI+EDTA) shows the highest removal efficiency. For 850 micron the highest removal efficiency was 76.5% (Fig. 6), the highest removal for 300 micron was 73.54% (Fig. 7), whereas for <53 micron the highest removal efficiency was 63.91% (Fig. 8). For non-screened soil 62.76% was the highest removal efficiency (Fig. 9). This combination shows the highest removal because the consecutive extractions using DI and EDTA were more effective than single extraction. The average removal of Pb for 850 micron was 68.09%, for 300 micron the average removal was 58.35%. For <53 microns the average removal was 56.50%. The average percentage of removal for non-screened soil was 57.45%.

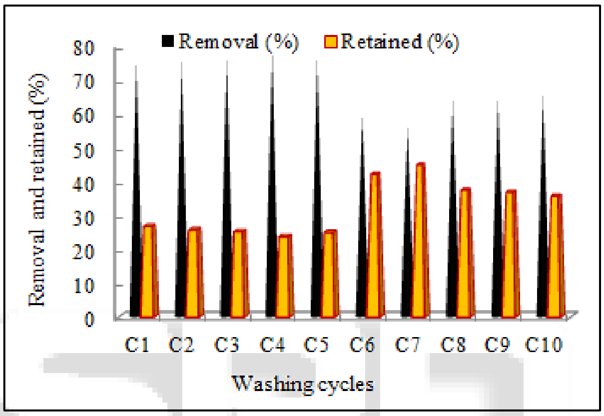

Fig. 6: Removal from 850 micron size soil

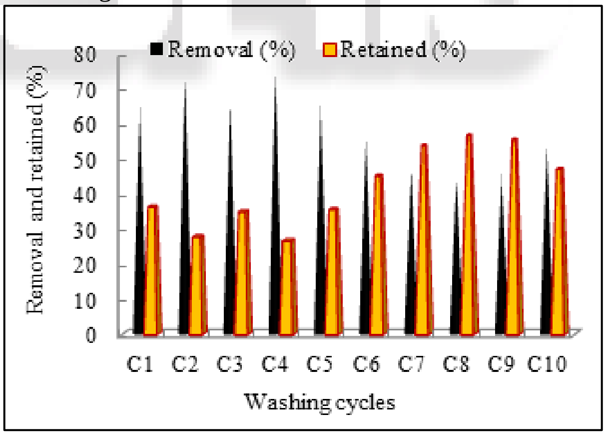

Fig. 7: Removal from 300 micron size soil

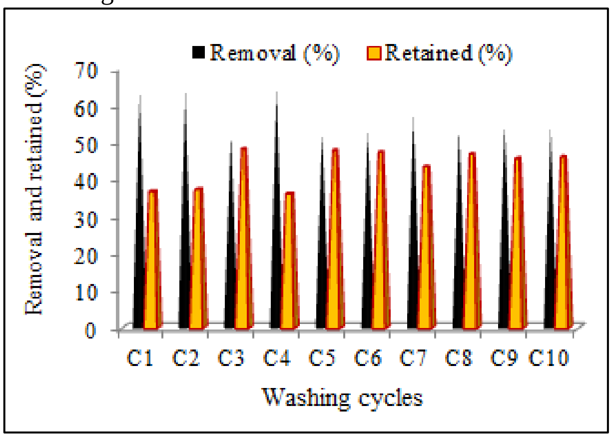

Fig. 8: Removal from <53 micron size soil

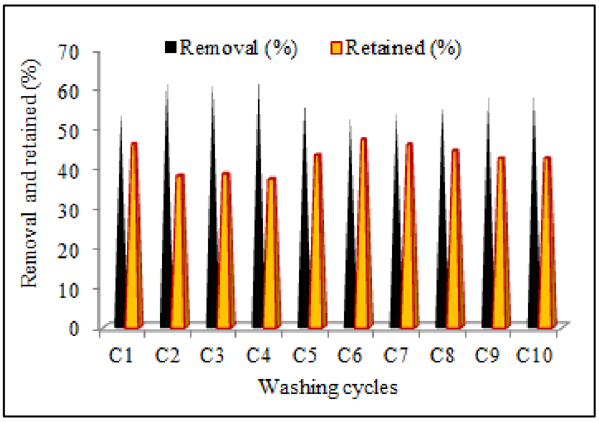

Fig. 9: Removal from non-screened soil

IV. CONCLUSION

This work shows that the combination of EDTA + EDTA + DI washing cycle gives highest Pb removal efficiency, i.e. around 72 %. Because the EDTA complexion is dominant for cationic metal removal. Whereas the DI+EDTA+DI+EDTA combination shows the highest removal efficiency for Cr. The consecutive extraction using DI and EDTA more effective than other combinations of washing cycle. The Cr removal efficiency is around 70 %.

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