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Decontamination of Lead Contaminated Soil Using EDTA as a Chelating Agent

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Abstract

Soil is an important natural resource. Pollution and contamination of soil is very common in the present-day scenario. Lead contamination in soil is a serious hazard posing a great thread to environmental sustainability. Lead contaminations in the soil can adversely impact the health of animals and human when they eat plants or animals that have themselves been affected by soil contamination. Remediation of lead contaminated soil is therefore essential. Contaminated soil samples were collected from Perungudi Dumping Ground, a municipal solid waste dumpsite. Heavy metal quantification technique was done using ICP-AEP (Inductively coupled plasma–Atomic emission spectrometer) in the laboratory. Concentration of different metals in the soil samples was found. For the present study, the concentration of lead alone was compared with Indian Compost Standards. The results showed the concentration to be above he regulatory limits. Therefore, the samples were subjected to decontamination technique. Decontamination technique was done using ethylenediaminetetraacetic acid EDTA. After applying decontamination technique, the lead concentration of the decontaminated samples was analyzed again using ICP-AES. Results showed the lead concentration to be below the Indian Compost Standards. The average efficiency of the EDTA technique was found to be 77%. This showed that the EDTA technique applied to be an effective.

***Keywords:** Atomic emission spectrometer; Inductively coupled plasma; Ethylenediaminetetraacetic acid; Decontamination*

Introduction

Everywhere in the world where people change a natural ecosystem, the land degrades. Soil contamination typically arises from rupture of underground storage tanks, application of pesticides and herbicides, percolation of contaminated surface water to subsurface strata, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbon, solvents, pesticides, herbicides, lead and other heavy metals.

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Lead is one of the most common heavy metal contaminates found in soil. Lead occurs most commonly with an oxidation state of 0 or +II. Pb (II) is the more common and reactive from of lead and forms mononuclear and polynuclear oxides and hydroxides. Under most conditions Pb^{2+} and lead-hydroxy complexes are the most stable form of lead by Pietrzak and Uren [1]. Bodek et al. [2] stated that low solubility compounds are formed by complexation with inorganic and organic ligands (humic and fulvic acids, EDTA, amino acids). Lead carbonate solids form above pH 6 and Pb is the most stable solid when high sulfide concentrations are present under reducing conditions. Lead gets accumulated in soil as a result of a number of activities, including the application of industrial waste, fertilizers, pesticides or detergents. Mining, smelting and metal plating/metal finishing operations, or automobile battery production are also responsible of this contamination. But, the major source of lead pollution is the burning of gasoline and thus the vehicle emissions by Chulsung et al. [3]. Evans [4] found that most lead that is released to the environment is retained in the soil. The primary process influencing the fate of lead in solid includes adsorption, ion exchange, precipitation and complexation with sorbed organic matter. These processes limit the amount of lead that can be transported in to the surface water or groundwater. The relative volatile organolead compound tetramethyl lead may from in anaerobic sediments as a result of alkylation by microorganisms by Raymond et al. [5], Esakku et al. [6] has conducted an assessment of heavy metals in a municipal solid waste dumpsite. The current solid waste generated from the Chennai city is disposed by open dumping at the Kodungaiyur and Perungudi. A comparison of the quality in the two sites showed that the pollution potential of Perungudi leachates was slightly higher than that of Kodungaiyur. Ming and Lena [7] has described three commonly used digestion procedures, hot plate aqua regia, microwave aqua regia and microwave aqua regia +HF. The conventional aqua regia digestion procedure consists of digestion soil samples on a hotplate with a 3:1 mixture of HCl and HNO_3. Residual elements that are not released by aqua regia digestion are mostly bound to silicate minerals and are considered unimportant for estimating the mobility and behavior of the elements by Niskavaara et al. [8], Tessiar et al. [9] has developed an analytical procedure involving sequential chemical extractions for the partitioning of particulate trace metals and which is widely used for metal speciation. Lasat [10] indicated that hyper accumulators were used for the extraction of metals from soil or water.

In order to find out a suitable decontamination technique, the present study aimed to assess the heavy metal concentration at dumping ground with the following steps like to evaluate lead concentration in the soil at different locations of the dumping ground, apply a suitable decontamination technique suited for the site, monitor and asses the concentration of the lead content after the decontamination and finally to evaluate the efficiency of the applied decontamination technique.

Methodology

The soil samples collected from Perungudi dumping ground for experimental investigation. The methods adopted regarding soil collection, heavy metal quantification and decontamination technique is discussed. The Perungudi area is located in the Chennai Metropolitan in Saidapet Taluk. The Perungudi dumping ground (PDG) lies at 12°57’13.5” north and 80°14’5.8” east. The Perungudi dumping ground (PDG) is located approximately 15 km south of the centre of city. The PDG is low lying and poorly drained being occupied by extensive areas of marshy land permanently wet. Total area of this site is about 250 ha in which about 22 ha is used for dumping.

Contaminated soil samples were collected using auger by test pit method. An adequate number of sampling locations were established in order to determine the extent of soil contaminations. Samples were collected at every 1 m interval (0 m to 1 m, 1 m to 2 m, 2 m to 3 m). Samples were collected using a hand auger at depths of 1 m and 2 m and using split spoon sampler

at depth of 3 m. Samples were preserved in polyethylene bags and properly labeled according to the location and depth. A total of 4 samples were collected from 3 locations and brought to the laboratory for analysis shown in TABLE 1.

TABLE 1. **Sample collection from different locations at different depth at PDG.**

Sample no	Location	Depth (m)
1	A	1-2
2	B	0-1
3	B	2-3
4	C	0-1

The collected samples were oven-dried in the laboratory. Then the samples were screened to remove stones, vegetable matter and other particles larger than 2 mm in size using fine meh sieves. The samples were sieved using 1.18 mm size sieve. The particles passing through the sieve were collected. Thus, the dried fine samples (of size less than 2 mm) were separated and labeled properly and used for further analysis.

Heavy metal extractions

Heavy metal extractions were done using digestion procedure using hot plate aqua-regia.

- 3 gm of the dried fine samples were taken in a conical flask.
- About 21 ml aqua regia ($HCL+HNO_3$ in the ratio 3:1) were added into the conical flask and then heated in a hot plate at a temperature of about 120 degrees Celsius for about 2 h or until the soil sample becomes colourless.
- Then the soil sample was allowed to cool.
- The samples were filtered using Whatman 42 filter paper and the solution was made unto 100 ml using distilled water.
- The filtrate was preserved in plastic bottles for heavy metal analysis.

Heavy metal (lead) analysis

Heavy metal analysis was done using ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometer).

Light source: Plasma torch

Detector: Charge inspection device camera

Gas: Argon gas high purity

Principle: Beer-Lambert Law

Procedural Setup

The instrumental parameters of the ICP-AES system are adjusted in accordance with the manufacture's manual. About 30 min prior to measurement, the instrument is adjusted to working condition. The sensitivity and the stability of the system are checked. The wavelength calibration is checked as often as required by the manufacturer. Suitable wavelength for measurement and background subtraction are selected or alternatively multivariate calibration procedures are applied. The rinsing times are defined depending on the length of the flow. Linear calibration function was used. From the calibration curve, the concentration of the heavy metal in the unknown sample is found out.

Decontamination using EDTA

- Fine grains of the <2 mm size soil was taken.
- 150 ml of EDTA solution was added to 10 gm of the soil in 250 ml centrifugal bottles.
- The normality of EDTA solution ranged from 0.1 N to 0.2 N in order to find out the lead removal efficiency on varying concentrations of EDTA.
- After 72 h of shaking, the sample was allowed to settle for some time.
- The extract solution was filtered through whatman'42 filter paper.
- 100 ml of the extract solution was taken to determine lead concentration by ICP-AES.
- The residual lead concentration was found by subtracting the pb concentration in the extract from the initial lead concentration.

Results and Discussion

Soil samples were collected from Perungudi Dumping Ground was analyzed. Digestion procedure was done using hot plate aqua regia. The results thus obtained using Inductively Coupled Plasma-Atomic Emission Spectroscopy are presented below. The concentration of various metals at various locations of Perungudi Dumping Ground obtained before applying decontamination technique are tabulated as below in TABLE 2.

TABLE 2. **Table showing various metal concentrations at various locations of PDG before decontamination.**

Sample	Ni (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Cu (mg/kg)
Location A at 1 m	24.64	0.3	17.02	130.56	372.6
Location B at 1 m	26.64	0.37	16.65	66.6	229.1
Location B at 3 m	17.98	0.17	15.65	374.63	217.3
Location C at 1 m	25.97	0.23	13.32	90	264.4

From the quantification of various metals, we found the metal concentrations to vary as below. Nickel concentration was found to vary from 17.98 mg/kg to 26.64 mg/kg, cadmium concentration was found to vary from 0.17 mg/kg to 0.37 mg/kg, chromium concentration was found to vary from 13.32 mg/kg to 17.02 mg/kg, copper concentration was found to vary from 217.3 mg/kg to 372.6 mg/kg, lead concentration was found to vary 66.6 mg/kg to 374.63 mg/kg. TABLE 3 shows the regulatory limits of various heavy metals as per Indian Compost Standards.

TABLE 3. **Indian Compost Standards for various metals.**

Metals	Indian Compost Standards (mg/kg)
Hg	0.15
As	10.0
Cd	5.0
Ni	50
Pb	100
Cu	300
Cr	50
Zn	1000

As per the Indian Compost Standards, the regulatory limit for lead is 100 mg/kg. From the results obtained, two of those samples which showed lead concentration above the regulatory limits were taken for the further work on decontamination.

Lead decontamination

Two samples taken from Location A at 0m to 1 m, Location C at 2 m to 3 m which showed lead concentrations above the regulatory limits were taken for decontamination. Decontamination was done using EDTA. The results of the samples after applying decontamination technique are as follows in TABLE 4.

TABLE 4. **Table showing various metal concentrations at various location of PDG after decontamination.**

Sample	Lead content after decontamination (mg/kg)
Location A at 1 m (0.1 N)	36.58
Location A at 1 m (0.2 N)	31.36
Location B at 3 m (0.1 N)	82.43
Location B at 3 m (0.2 N)	71.19

Results showed the lead concentration to be below the Indian Compost Standards. The efficiency of the decontaminated samples using EDTA was evaluated and tabulated in TABLE 5.

TABLE 5. **Table showing efficiency of the decontaminated samples using EDTA.**

Sample	Pb concentration before decontamination (mg/kg)	Pb concentration after decontamination (mg/kg)	Efficiency (%)
Location A at 1 m (0.1 N)	130.65	36.58	72
Location A at 1 m (0.2 N)	130.65	31.36	76
Location B at 3 m (0.1 N)	374.63	82.43	78
Location B at 3 m (0.2 N)	374.63	71.19	81

The average efficiency of the decontamination procedure using EDTA was found to be 77%. This showed the EDTA technique to be effective.

Conclusion

The decontamination technique used in our study can be applied for remediation of lead contaminated sites. This will result in reduced polluted levels of contamination in soil and thereby reduce its harmful effects. Soil can thus for beneficial uses and thereby maintain sustainable development.

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