

Remediation of the Contaminated Soils by Washing with an Aqueous Cysteamine Lixiviant

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Abstract

In order to decrease the content of heavy metals in the crops soils, a novel method based on using an aqueous solution bearing cysteamine as the key ingredient was studied to extract the polluted heavy metals including Cd, Cu, Zn, Ni and Pb. By using the single-factor method, remediation-related technical index were screened and they are, respectively, applied to the solid material whereby the heavy metals are released and extracted from the solid material. The biomass solution residues remaining in the solid material after the heavy metal extraction procedure is rapidly biodegradable, so that no objectionable traces remain in the solid materials or soils.

Keywords

Heavy Metal, Soil, Cysteamine, Extraction, Remediation

1. Introduction

Heavy metal-related contamination in the cultivated land-fields is a food-safety challenge in mainland, China [1] [2]. They may come from industrial or commercial sites where production residues were improperly stored or buried. In some cases, the contamination may have occurred by leaks or mishandling of the industrial waste-

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water and related hazardous waste sites [3] [4]. For the removal of metals from contaminated soils, usually soil washing procedures are utilized by means of acids and neutral chemicals (EDTA and related salts) [5] [6]. However, they show several disadvantages and lead to a substantial destruction of the soil material which is ecologically not desirable, because their working pH were limited in weak acidic media (for example, pH = 3 - 5). Another challenge comes from their slow kinetics and lower depth in the soil. In fact, decontamination can be an economically competitive alternative, particularly in instances where site re-utilization is deemed important. There are a variety of decontamination methodologies involving physical [7] [8], chemical [9] [10], thermal and (or) biological processes for soil treatment.

Soil decontamination is usually performed by excavating the contaminated zone, above ground treatment by isolation and removal or destruction of the pollutants, and redepositing the cleaned soil. Decontamination can also be accomplished through *in situ* soil washing [6] [11], in which a washing solution is applied to the contaminated zone by flooding or sprinkling in order to extract pollutants from the soil. In this paper, a novel lixiviant based on using cysteamine as the key ingredient was reported and its remediation-related processing parameters, including composition, pH, temperature and cysteamine dosage, were discussed.

2. Materials and Methods

2.1. Initial Soil Characterization

The test soil was obtained from a typical contaminated soil of Hunan Province mine area (Shuikoushan, Hengyang). The soil was passed through a No. 4 sieve 4.75 mm. Rocks and other large materials not passing through the sieve were removed. The soil was then thoroughly mixed to ensure uniformity and stored in a plastic barrel at room temperature for subsequent use in experiments. Its physical and chemical properties were shown in **Table 1**.

2.2. Experiments

Batch tests agitation studies were performed to get appropriate ranges of concentration and dosage of the washing solutions to extract the heavy metal pollutants from the contaminated soil. Cysteamine was selected as the main ingredient in the lixiviant composition to stabilize the heavy metal ions, and keep them in a stable state of aqueous “Mercapto-Heavy Metals” complex in the extracts. DI water washes were performed to provide a baseline for the removal obtained by chemical washing. The leaching tests were accomplished by placing certain amounts of soil in 150 ml plastic bottles followed by addition of varying volumes of the washing solution. The samples were then placed on a shaker table operated at 175 rpm at room temperature. A 4 h leaching time was deemed sufficient to extract the heavy metal ions from the contaminated soils. The leaching samples were allowed to settle for about 30 min and then filtered through a 0.45 mm membrane filter. Following S/L separation, the filtrate was acidified to a pH of 2.0 by use of 1:1 HNO₃ for heavy metal analysis. It was assumed that the metal concentration of the filtrate represents that released from the contaminated soil. Removal efficiency was determined by dividing the heavy metal release quantities by the initial data.

All heavy metal analyses were performed according to the standard GB/T17138-1997 and GB/T17140-1997, and they were detected by using a SHIMADZU AAS-6300 spectrometer. Standard concentrations including Pb, Cd, Ni and Cu were provided by Sigma-Aldrich Corp. Ltd., and ammonium hydroxide and hydrochloride acid were chosen as the pH adjustant. To get the optimum extracting condition, a set of batch experiments were conducted at room temperature (20°C ± 5°C) and fixed 1:10 soil-solution ratios. Effects of the lixiviant concentration (exactly cysteamine), leaching pH, agitation time and dosage of the sodium lignosulphonate (wetting agent) were discussed to understand the metal-extracting characteristics.

Table 1. Physical and chemical index of the tested soils before remediation (mg·kg⁻¹).

pH	Organic Matter	Total Metal Content					Exchangeable Metals				
		Pb	Cd	Cu	Zn	Ni	Pb	Cd	Cu	Zn	Ni
6.2	9570	3500	5.5	205	960	84	1650	1.5	16	150	57

3. Results and Discussion

3.1. Effect of the Concentration of Cysteamine on the Metal-Extraction at Natural pH

From **Figure 1**, it is easy to find that cysteamine is a very powerful extracting agent even at room temperature. Not only the exchangeable-state metals can be extracted fully but also the heavy metals in the form of carbonate, sulfate and oxide can be leached efficiently. Evidently the leaching efficiency of nickel is much higher than that of lead, because the ionic weight of lead is much heavier than that of nickel.

3.2. Effect of the Working pH on the Metal-Extraction

Obviously the extraction efficiency of the heavy metals is reliant on the pH closely, and heavy-metals can be transformed to aqueous complex at higher pH. It is optimize to get a clean soil on no risks of resulting in acidic lands. Another advantage of cysteamine comes from its organic-sulfur characteristic, because sulfur-bearing fertilizer is necessary and need supplemented periodically for crops harvest (**Figure 2**).

4. Summary

- 1) Transition-metals can be transformed to an aqueous stable complex even at higher pH by using cysteamine as the ligand.
- 2) Cysteamine can be used as a powerful lixiviant in remediation of soils to extract heavy metals from the contaminated land.

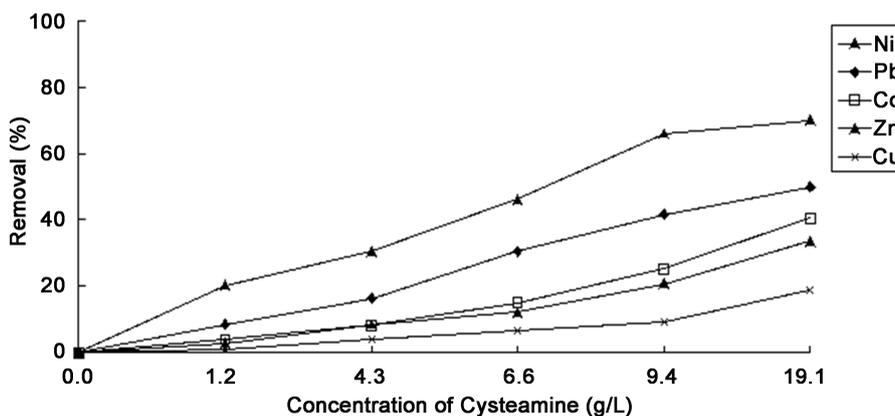


Figure 1. The relationship between the metal-extraction efficiency and the cysteamine concentration at room temperature and natural pH (6.4) in 48 hours.

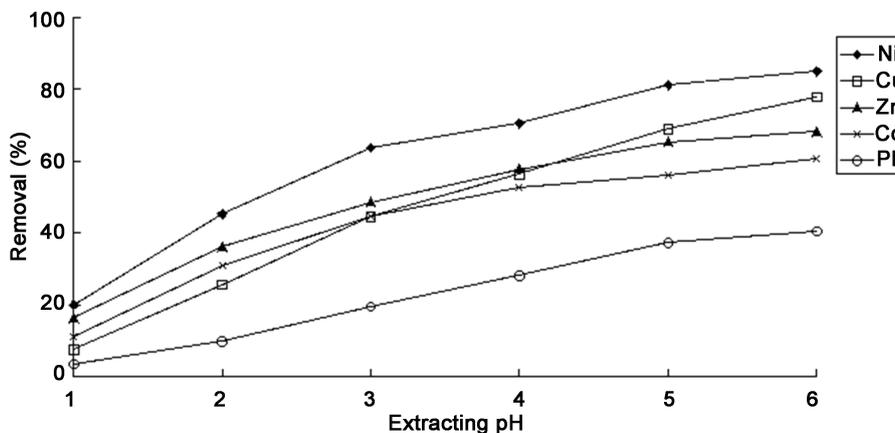


Figure 2. The relationship between the leaching pH and the metal-removal efficiency at room temperature and cysteamine concentration of 1.5 g/L in 48 hours.

- 3) Not only the exchangeable-state heavy metals can be extracted, but also those heavy metals in the form of carbonate, sulfate and oxide can be removed efficiently.
- 4) Extractive efficiency of the copper and nickel is obviously higher than that of lead.

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