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EMERGING TECHNOLOGIES IN HAZARDOUS WASTE MANAGEMENT VI

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REMEDIATION OF LEAD CONTAMINATED SOIL FROM ALBERTA USING AGGLOMERATION TECHNOLOGY

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INTRODUCTION

A variety of human activities have resulted in heavy metal contamination of soil and sediments[1]. In particular, lead has contributed substantially to pollution and represents a ubiquitous hazard in the biosphere. Because of its widespread existence in industrial and hazardous wastes and its presence on the US EPA Priority Pollutant list[2] lead was chosen as the study metal for the work described here.

For remediation of heavy metal contaminated soil the metals must be either physically removed or stabilized so that they are non-leachable[1]. Washing, to remove heavy metals as stable, soluble chelates, has only been successful with coarse soils[3]. Fixing metals prevents their migration into the groundwater through hydrolysis or desorption by exposure to varying conditions in the soil. The immobilized metals present no adverse environmental or health hazards in their treated state[4].

Existing technologies for the cleanup of contaminated soil or sediments are poorly suited for treating fine textured soils without adversely affecting the associated humic matter or soil mineralogy. At the National Research Council of Canada liquid phase agglomeration techniques have been successfully used for the remediation of organic contaminated soils. As an extension of this work strong metal binding materials have been incorporated into the soil agglomerates formed during solvent extraction of organic contaminants. The resulting combined process is expected to be advantageous in that it will allow concurrent removal of organics and fixation of heavy metals. The end result is a process more economical, in terms of material handling and equipment costs, than methods which require separate extraction and leaching steps for organic and heavy metals respectively.

EXPERIMENTAL METHODS

Materials. Soil - a sample of Eskrine soil from Alberta was used for this study. An artificially contaminated soil sample was prepared by spiking with a solution of lead nitrate.

Peat. A sample of agricultural peat moss was ground to about 150 μm particle size, using a Brinkman Centrifugal Grinding Mill ZM-1. The moisture and carbon contents were 25 ±5 w/w% and 49.7 ± 1.6 w/w% (dry basis) respectively. No detectable amounts of lead were found in the TCLP leachate of this sample.

Adsorption of Lead on Peat. For adsorption experiments, peat (1g) was added to each of a series of lead nitrate solutions (100 mL) with concentrations ranging from 100 to 20, 000μg/mL. The mixtures were sealed in polypropylene jars and agitated for 24 hours on a reciprocal shaker. The peat suspensions were filtered using a Whatman No. 41 filter paper. The solutions were analyzed for lead both before and after adsorption. All measurements were carried out in duplicate and only the means are reported.

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In other series of tests the effect of peat loading was determined. In this case concentration of lead in solution was kept constant and varying amounts of peat (1-10g) were added to a known amount of solution in separate jars.

Leaching Tests. The TCLP extractions were performed according to the methods described in the US Federal Register[5] and specified in SW-846[6].

Analysis of Lead. Lead was determined using quantitative Inductively Coupled Plasma Atomic Emission Spectroscopic analysis (ICP-AES)[7].

RESULTS AND DISCUSSION

Adsorption Isotherm for Lead on Peat

Figure 1, illustrates the experimental lead adsorption isotherm obtained for peat. Inspection of the adsorption isotherm, shows it to be an "H type", according to the Giles classification.[8] The amount of lead adsorbed reaches saturation when the equilibrium concentration exceeds 5000 mgs/L. At this concentration all possible available sites are filled with lead. H curves are indicative of the adsorption of ions on oppositely charged surfaces or exchange of high affinity ions with low affinity ions leading to chemisorption. These curves commence at a positive value on the "concentration in solid" axis. In this case, the solute has such a high affinity that in dilute solutions it is completely adsorbed and therefore, the initial part of the isotherm is vertical. H curves usually exhibit a long plateau, the length of which indicates the difficulty of formation of a second layer because of charge repulsion between the adsorbed material and that approaching from the solution.

The adsorption data can be fitted by a Langmuir isotherm model. This model was applied owing to its widespread use in describing the aqueous phase adsorptive behaviour of clay-carbon materials.[9-10] The model can be described by the equation:

$$q_e = Q^0 b C_e/(1 + bC_e) \quad \ldots\ldots (1)$$

where q_e is the amount of solute adsorbed per unit mass of adsorbent and C_e the equilibrium adsorbate concentration. The parameter Q^0 represents the solid-phase concentration corresponding to complete coverage of available adsorption sites and b can tentatively be related to the intensity of the adsorption reaction. The calculated Langmuir isotherm parameters for the lead-peat system are listed below:

Table 1. Adsorption isotherm parameters.

Q^0 (mg g^{-1})	105
b	0.05
r^2	0.998

The value of Q^0 represents the saturation value for the adsorption of lead on unit mass of peat. The value of b is much higher than results reported for the adsorption of various organic pollutants on clays and activated carbons.[9] This observation suggests a very strong interaction of lead with peat and, possibly, the formation of a peat-lead complex, by chelation with the ligands of humic matter.

Effect of Adsorbent Density

Figure 2 shows the effect of peat suspension density on the uptake of lead. The amount of lead adsorbed increased with increasing peat loading up to 750 mgs/L. At 700 mg/L of peat, nearly 50% of the lead in solution was removed. At peat loadings > 1000 mg peat/L, the lead uptake reached a plateau. This observation is consistent with the solution being in equilibrium with a sparingly soluble compound; this could be a surface-bound complex or a distinct physical phase such as $Pb(OH)_2$.

Sorption Mechanism

Humic substances are the major constituents of peat.[11] Numerous investigations of the complexation of heavy metals by humic substances have shown that they have a high affinity for metal ions.[12-14] The inorganic content of peat is relatively low (2.3%) and generally contributes little to the overall cation exchange capacity.[15] Therefore, it appears most likely that the polyacidic functional groups associated with the humic content of peat, are responsible for its cation exchange capacity.

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Figure 1. Lead Adsorption Isotherm for peat as a function of equilibrium concentration

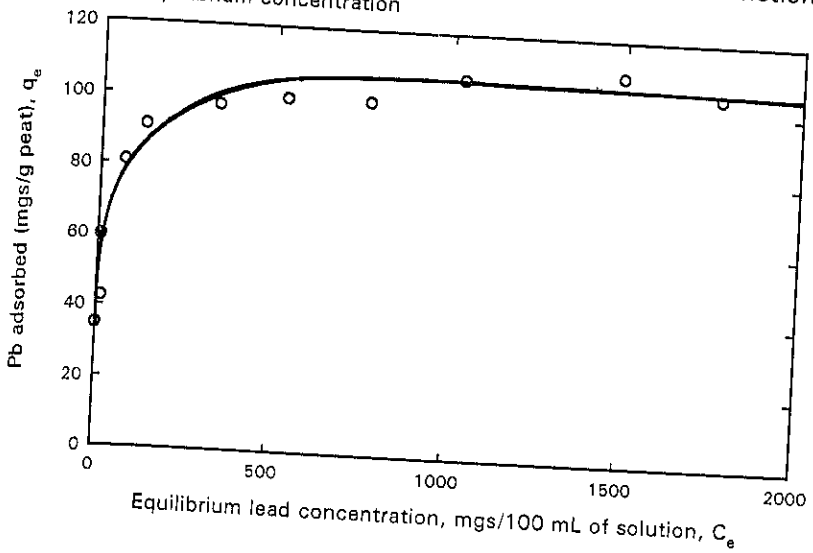

Figure 2. Effect of peat dosage on Pb(II) uptake: Initial Pb (II) concentration, 8900 mgs/L; agitation time, 24 hours