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PREPRINT EXTENDED ABSTRACT
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APPLICATION OF THE SESR PROCESS FOR REMEDIATION OF A HIGHLY SALINE INDUSTRIAL SOIL CONTAMINATED WITH HEAVY OIL AND METALS

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INTRODUCTION

Contamination of soil by hazardous organic pollutants and/or heavy metals is a serious environmental problem facing the global community. Over time, these pollutants, trapped in the soil matrix, leach through inadequate holding facilities and migrate deep into the earth, finally making their way to groundwater aquifers. Once contaminated, these aquifers carry the toxins through the ecological system, bringing them into the food chain.

Typically, both heavy metals and hydrocarbon contaminants are associated with the finer particle fractions of soils and sediments. Most techniques for the removal of metals involve contacting the soil with an aqueous solution. Similarly, some processes remove hydrocarbon contaminants by aqueous washing methods. For fine textured, high clay soils these techniques tend to produce intractable sludges having poor solid-liquid separation characteristics. Other soil cleaning technologies, such as thermal desorption, are also poorly suited for treating fine textured top soils because of adverse effects on the associated humic matter or soil mineralogy. In such cases the treated soil may have to be landfilled or used as subsoil because of impaired soil fertility.

At the National Research Council of Canada liquid phase agglomeration techniques, in combination with solvent extraction have been successfully used for the remediation of fine textured, organic contaminated soils. Agglomeration of fine and coarse particles greatly improves the efficiency of solids-liquid separation, required to achieve effective treatment. Typically, only a few extraction steps are required. As an extension of this work, metal binding materials have been incorporated into the soil agglomerates formed during the solvent extraction of organic contaminants. The combined process allows concurrent removal of organics and fixation of heavy metals. As a result, soil treatment should be more economical, in terms of material handling and equipment costs, than methods which require separate extraction and leaching steps for organic contaminants and heavy metals.

Another advantage of the solvent extraction soil agglomeration process is the ease of salt leaching from the dried extracted soil agglomerates. Soil agglomerates produced using liquid phase agglomeration techniques are more stable than similar sized natural soil aggregates of the same soil. The drying of these agglomerates results in efflorescence of water-soluble salts. Availability of salts at agglomerate surfaces facilitates their subsequent leaching by water[1].

In this work we present the results for tests in which the SESR process was used to treat a highly saline, industrial soil sample, contaminated with organics and heavy metals. Concurrent removal of the hydrocarbon and fixation of heavy metals by incorporation of metal binding agents into the agglomerates was investigated. The effectiveness of heavy metal fixation was followed using the US EPA's Toxicity Characteristics Leaching Procedure (TLCP) on the dried agglomerates. The leaching of soluble salts by percolation through a packed bed of agglomerated soil was also carried out.

EXPERIMENTAL METHODS

Materials: the soil sample was a mixture of tank bottoms, frac sand and spill material containing a range of organic and inorganic contaminants; it was provided courtesy of Newalta Corporation, Calgary, Alberta. Peat used in this study was a sample of agricultural peat moss, ground to about 150 μm particle size, using a Brinkman Centrifugal Grinding Mill model ZM-1. Coal combustion by-products were obtained courtesy of Western Ash Company, Arizona.

Estimation of Oil Content of Contaminated Solids: the amount of oil in the contaminated solids was estimated by extraction with toluene, using the Dean and Stark Soxhlet method[2]; quantitation was carried out using spectrophotometric method[3]. Oil for calibration purpose was obtained from methylene chloride extracts of the soil sample.

Agglomeration Procedure: the agglomeration procedure used in this study has been reported previously[4].

Multi-stage Extraction: a multi-stage extraction procedure was used to test the contaminant removal efficiency. The agglomerates obtained from each stage were redispersed in fresh solvent. High shear agitation was applied for one minute in order to break the agglomerates. This was followed by a low shear agitation for five minutes. The process was repeated four more times with fresh solvent. Five separate tests were carried out in order to obtain samples of agglomerates after each extraction stage. These agglomerates were surface washed three times with fresh solvent before transferring into the extraction thimble for the determination of residual contaminant.

Electrical Conductivity of the Extracted Solids: electrical conductivity of extracted solids was measured using the Ontario Ministry of Environment and Energy (OMEE) revised procedure[5]. This method requires a fixed 2:1 water:soil ratio; guidelines recommend conductivities of 0.7 mS/cm for agricultural, residential and parkland sites and 1.4 mS/cm for commercial and industrial sites.

Leaching of Soluble Salts: leaching of brine contaminated agglomerates was carried out by percolation through a packed bed of agglomerated soil.

Heavy Metal Leaching Tests: heavy metal leaching potential of the treated solids was measured using US-EPA toxicity test method 1310A and Toxicity Characteristics Leaching Procedure method 1311 as described in the US Federal Register[6] and specified in SW-846[7]. Long term stability of the treated solids in terms of metal leaching was tested using US-EPA's multiple extraction procedure method 1320.

Analysis of Metals: heavy metals were analyzed by Inductively Coupled Plasma Spectroscopic Analysis (ICP).

FINDINGS

A highly saline industrial soil sample contaminated with a heavy oil and several heavy metals was successfully remediated using the modified SESR process. Concurrent removal of the hydrocarbon contaminant and the fixation of heavy metals were achieved by incorporation of metal binding agents into the agglomerates. Over 90% of the contaminant was removed using a single stage process. The amount of residual contaminant in the treated soil was within OMEE guidelines of <5000 ppm for subsurface soil category. Additives used for the fixation of heavy metals did not affect the basic extraction efficiency of the process. However, in one case the additive had a beneficial effect on the extraction efficiency of the process and the amount of contaminant removed exceeded the amount recovered by Soxhlet extraction. This result was confirmed by data from XPS analysis of the extracted solids.

A five stage SESR extraction process reduced the residual contaminant levels to meet OMEE guidelines for residential and parkland use.

The additives tested for the fixation of heavy metals were effective in rendering these metals non-leachable under the conditions of acid rain. However, when a more rigorous leaching procedure such as EPA's TCLP was used, three of the six additives used were found to be completely effective. The remaining three additives fixed mercury entirely but lead only partially.

Dried agglomerates were leached in a fixed bed, water-leaching system to remove soluble salts. Leaching from dried agglomerates was faster and required less water than was the case for dry solids from Soxhlet extraction of the original soil.

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ABBREVIATIONS:

SESR	Solvent Extraction Soil Remediation
OMEE	Ontario Ministry of the Environment and Energy
EPA	Environmental Protection Agency
TCLP	Toxicity Characteristics Leaching Procedure
ICP	Inductively Coupled Plasma
ND	Not Detected

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