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CLEANING UP METAL AND HYDROCARBON CONTAMINATED SOILS USING THE CHEMTECH SOIL TREATMENT PROCESS

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ABSTRACT

The ChemTech soil treatment system differs substantially from the present commercial approaches to soil remediation. Rather than the "no-tech" approach of land filling or the apparent "bio-tech" route of bioremediation, the ChemTech process configures chemical engineering and mineral processing unit operations to deliver a comprehensive, rapid, flexible and economic treatment to a range of contaminated soils.

The soil treatment process is a portable treatment system which effectively removes both metals and petroleum hydrocarbons from soils or sediments. Its chemical and power cost is in the order of $20 to 25 per tonne, pricing remediation below the cost of landfilling in many jurisdictions. The treatment does not generate important quantities of solid wastes, contaminated liquid effluent, or air emissions. A mobile pilot plant is trailer mounted for on-site demonstration, requiring only a supply of fresh water, compressed air, and electrical power.

The patent pending process uses the turbulent mixing of a continuously fed three phase fluidized bed with soil contaminant chemistry to separate the feed soil into coarse (clean) and fine (contaminated) fractions. Extremely high air flow velocities in the turbulent zone of the continuously fed fluidized bed provides for slurrying, wetting, and scouring of the soil particle surface to result in removal of the adhered contaminants. The continuously fed fluidized bed effectively encapsulates a number of the concepts of tar sands extraction in a single unit and does so in an physically intense but mechanically simple manner. The result is a flexible, high capacity system with attractive operating and capital costs, well suited to environmental cleanup of a range of soil and sediment types.

The process has been verified at bench and pilot scales using a number of industrially contaminated soils to segregate metal and petroleum hydrocarbon contaminants from soil or sediments. The results obtained indicate that decontamination of soils can be achieved in a rapid (nominally 5 minute residence time) and effective manner with a minimum of inputs. Identifying the operating conditions would be performed at a bench scale for each soil prior to on-site demonstration and commercial scale remediation.

INTRODUCTION

Soil contaminants from industrial spills are not homogeneously distributed through the soil matrix but are rather associated with the organic and fine soil fractions. Petroleum hydrocarbon spills result in their coating and adherence to otherwise uncontaminated sand and grit. Removing these fractions from the bulk of the soil matrix decreases the volume of contaminants which must be subsequently treated or disposed. Any ex-situ process can benefit from segregating soil into clean and contaminated portions: the lower the volume of soils that requires treatment or disposal, the lower the cost.

Properties of soil and soil contaminants such as particle size, settling velocity, and surface chemistry can be exploited for their remediation. Commercially available soil segregation systems consist of a number of more or less standard mineral processing unit operations configured in a number of ways. Designing a process to exploit a number of soil properties is necessary to be most successful in effecting contaminant segregation.

The ideal system would be effective to segregate both metal as well as hydrocarbon contaminants into a very small mass fraction. It would be adaptable to a variety of soils and contaminants, and have a high specific capacity. Rapid treatment would enable the apparatus to be small and mobile so that it rather than the contaminated soil, could be easily transported to site. The setup would be mechanically simple, leading to a requirement for few operators and minimal maintenance. The process would involve neither incineration nor the use of hazardous chemicals, for ease of permitting and occupational health and safety reasons respectively. This describes the ChemTech approach.

PROCESS DESCRIPTION

The soil segregation process involves the excavation of contaminated soil, mechanical segregation of large rocks and debris, and delivery of the smaller particle fraction into a soil hopper. The hopper conducts soil to the fluidized bed where soil is slurried in a hot, pH adjusted, aqueous media with surfactant. The fluidized bed provides for high air flow rates result in turbulent mixing and interparticle scouring of the soil particle surfaces to assist in the abrasion and removal of adsorbed contaminants. The overflow is then pumped through a classifier with the adjustable pumping rate set to retain only the large, uncontaminated soil particles. The small, contaminated soil particles are ellutriated out of the classifier and are pumped either back to the fluidized bed or to the pressure filter. Filtrate from the pressure filter is returned back to the fluidized bed or sent to water treatment. In order to not accumulate excessive contaminant loads in the water circuit, water treatment removes petroleum hydrocarbons and/or metals by means of coagulation and/or high density sludge respectively. Figure 1 illustrates the process.

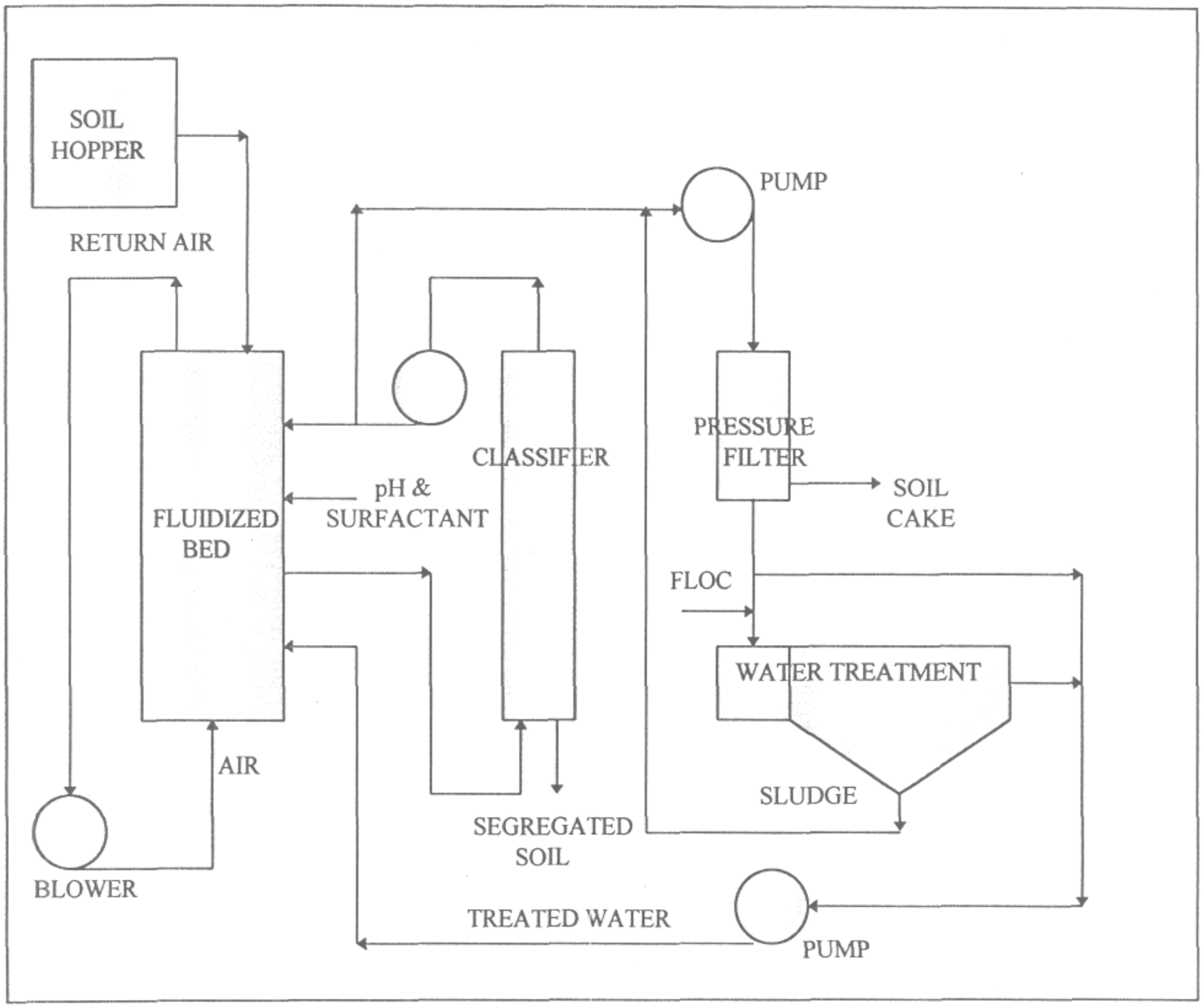

Figure 1 - ChemTech Process to Segregate Metals and Hydrocarbons from Soil

This approach integrates fluidization, chemistry, and elutriation to select the advantages of each unit operation. The highly turbulent mixing of fluidisation provides for particle wetting and interparticle scouring to allow high pulp densities, low residence times, and resulting high capacities. Augmenting the physical intensity of fluidization with applied soil contaminant chemistry enables the metals and hydrocarbon contaminants to be desorbed from the soil particle surfaces. Exploiting the washout velocity of the soil particles, a classifier provides the basis to segregate the separated contaminants from the clean portion of the soil. Pressure filtration dewaters the contaminants to yield a dry cake with the hot filtrate plus excess surfactant returning back to the fluidized bed. The system is mechanically simple with resulting low operating and capital costs. The high specific capacity of the system enables it to be mobile rather than requiring a permanent fixed site.

TREATABILITY TESTING

The suitability of the ChemTech soil treatment technology is evaluated for a particular contaminated soil by measuring the contaminant concentrations of the segregated (uncontaminated) soil, the percent of raw soil which reports to the uncontaminated portion, the processing time required, and the estimated commercial scale operating and capital costs.

Bench treatability assessments are needed to establish the efficacy of the process for each particular soil and contaminant. In general terms, optimizing the soil segregation unit involves matching the operating conditions with the type and concentration of various soils and contaminants to optimize their removal. Parameters that are assessed for the bench scale performance testing include: surfactant selection and dose, pH, temperature, solids concentration, air velocity, fluid velocity, and residence time.

Following an analysis of the results of bench scale testing, we transport our mobile pilot plant to the site. The mobile pilot plant which comprises the soil segregation system and water treatment unit, is mounted on a trailer which measures 8 ft x 16 ft. The daily processing capacity ranges from 2 to 5 tonnes, depending on the soil and contaminants. The unit requires a supply of fresh water, compressed air and electrical power.

An on-site pilot plant demonstration utilizes the chemistry established at the bench scale, continues the performance testing to establish the kinetics of the remediation, and fine tunes the operating conditions for commercial remediation. Pilot scale performance testing establishes the appropriate solids concentration, air velocity for fluidization, fluid velocity for elutriation, and solids residence time. A pilot scale demonstration would typically run for five days plus a day for set up and take down.

A sampling plan characterizes the original contaminant concentrations, the extent of contaminant removal, and the residual contamination for each operating condition performed at each site. Previous site characterization is used as a guide for where to excavate samples for processing. Confirmation testing is conducted to characterize the types and levels of contamination at the test site and to characterize the treated soil. Field duplicates, equipment blanks, trip blanks and field blanks samples are run as per established QA/QC procedures.

Bench and pilot scale treatability testing can be expected to identify the optimum the soil segregation operating conditions to remove a range of metals and heavy hydrocarbons from the site, estimate process kinetics to size a commercial scale soil segregation system, determine the operating and capital costs for commercial scale remediation for the soils and contaminants, and add technical credibility with site owners, regulators, and financiers.

RESULTS

Bench and pilot scale studies of the ChemTech soil treatment process have shown it to be an efficient method by which metals and petroleum hydrocarbons can be removed from contaminated soils. Results of this test work for a number of different soils after 5 minutes of treatment are summarized in Table 1.

Table 1 Segregation of Metal and Hydrocarbon Contaminants From Soil

CONTAMINANT	CONCENTRATION UNITS	FEED SOIL CONC.	SEGREGATED SOIL CONC.
Diesel	ug TEH */g soil	41,000	170
Kerosene	ug TEH/g soil	1,340	20
Motor Oil	ug TEH/g soil	213,170	1,350
PAH	ug TEH/g soil	1,620	80
Creosote	ug TEH/g soil	44,500	4,780
Arsenic	ug/g soil	45	17
Barium	ug/g soil	2,015	750
Cadmium	ug/g soil	12.0	1.5
Chromium	ug/g soil	59	38
Copper	ug/g soil	202	114
Manganese	ug/g soil	1,875	525
Nickel	ug/g soil	133	48
Lead	ug/g soil	1,950	550
Strontium	ug/g soil	1,538	269
Zinc	ug/g soil	6,525	802

* TEH = total extractable hydrocarbons

Table 1 indicates that effective decontamination of soils can be achieved rapidly with a minimum of inputs. Increased processing time or staged segregations can be expected to further improve performance.

Volume reductions exceeding 95% have been demonstrated for some soils. The extent of volume reduction depends upon the nature of both the soil and the contaminants, as well as on the soil/contaminants interactions. Soils which are largely clay or organic matter will demonstrate lower segregation while those soils which are mainly sand will demonstrate higher segregation.

Process viability for each site depends upon the soil type, the types and concentrations of the contaminants, and how the contaminants associate with the soil. These factors in turn dictate the optimum operating conditions, process kinetics, quantity of residuals, and operating costs.

PROCESS ATTRIBUTES

The ChemTech process offers comprehensive soil remediation capability: it is effective to concurrently remediate a mix of metal and petroleum hydrocarbon contaminants. Rapid soil treatment decreases the duration of negative environmental or health impacts due to contaminated soil; is compatible with excavation or dredging operations; decreases the costs on-site for assays and permitting; and decreases the risk of land development by shortening the interval between starting remediation and land use. A key attribute to the ChemTech approach to soil remediation is the ease of adjustment of operating conditions to segregate the contaminants from the soil matrix Adaptability is gained through readily adjusting the operating conditions such as air velocity of the fluidized bed, fluid velocity in the classifier, surfactant type or dose, pH, temperature, solids concentration in the fluidized bed, and solids residence time to respond to the varying properties of both soils and contaminants within a site.

PROCESS LIMITATIONS

Effective soil segregation is essential to process viability but may be difficult for: some types of hydrocarbon contamination due to the chemical characteristics of the contaminant and/or the permissible concentration as specified in contaminated site regulations (chlorinated organics for example), some particularly cohesive soils, and soils where "contamination" is intrinsic to the soil (as in mine tailings) rather than concentrated in the organic or clay fractions following spillage. This case would be unusual and not related to industrial contamination of soils.

CHEMICAL AND POWER COSTS

Chemical and power costs approximate SCA 20 to 25 per tonne of contaminated soil. Depending on the soil type, the contaminants, and the scale of the remediation project, the added costs for labour, residuals management, permitting, profit and amortization of the capital costs could result in total operating costs to be double this estimate. Such costs could be considered to be attractive when compared to the option of landfilling contaminated soil.

PATENTS

A US patent application (MOBILE SOIL TREATMENT APPARATUS AND METHOD, serial no. 08/527,750) of the ChemTech soil treatment system was filed on September 13, 1995. The patent claims center around the use of a fluidized bed for soil segregation, and describe the use of an associated metals extraction unit and a water treatment system. It is expected to require less than 12 months to process this application.

REGULATORY ISSUES

The ChemTech soil treatment process concentrates metals and/or petroleum hydrocarbon soil contaminants into a small portion of the soil. It does so by means of chemical engineering unit operations and involves neither incineration nor the use of hazardous chemicals.

Once segregated, the majority of the soil should be suitable to return to the ground as uncontaminated. This portion could be all of the soil, less the contaminants. Our limited practical experience indicates that this can be as high as 95% of the original soil. The concentrated contaminants typically constitute from less than 5 to 20% of the mass of the originally contaminated soil. This soil cake would require storage prior to analysis and disposal.

Large volumes of air are used in the process and this air is scrubbed of contaminants for recycle back to the blower. In addition to not venting the process air to the environment, warm air recycle decreases the heating requirements of the process. Demobilizing; the unit results in draining the unit operations. This process water is treated by means of coagulation and/or high density sludge process in order to meet discharge to sewer regulations. A small quantity of a lime/metals sludge is produced from water treatment which requires disposal. The quantity of sludge depends upon the pH of the soil segregation system. The lime/metals concentrate is stable, easily dewaterable and non-leachable.

CONCLUSIONS

The ChemTech soil segregation process is effective to concurrently remediate a mixture of metal and petroleum hydrocarbon contaminants. Results to date at the bench and pilot scales indicate that the rapidity of the process can be expected to decrease the duration of public and worker exposure to the soil contaminants, be compatible with excavation or dredging operations, and decrease clean up costs. It is readily adaptable to respond to the varying soils and contaminants within a site through adjusting the process operating conditions. The process does not generate important quantities of solid wastes or contaminated liquid effluent or air emissions. The estimated costs are SCA 20 to 25 per tonne of contaminated soil for chemicals and power, with costs for costs for labour, residuals management, permitting, profit and amortization of the capital costs dependent upon scale of the clean up project.

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