

MIXED WASTE SOIL WASHING USING ENVIRONMENTALLY BENIGN CHEMICAL SOLVENTS

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ABSTRACT

Treatment of soils contaminated with radionuclides and heavy metals presents a considerable technical challenge. Soil Washing is effective for remediation of soils with a high content of large particle size material (> 90% sand and gravel) (1,2). Chemical extraction methods used to date have been non-selective, yielding relatively large waste volumes compared to the volume of contaminants to be treated (1). Chemical extraction uses strong acids, which when neutralized also yield large volumes of waste, and in some cases hazardous material salts. Effective soil treatment requires a solvent that is selective for the contaminants to be treated, uses environmentally benign chemicals, is dilute, and preferably regenerable. This paper describes such a solvent which has been demonstrated for treating uranium, plutonium, americium, thorium, radium, barium, and lead to levels that meet current cleanup standard requirements.

INTRODUCTION

Removal and/or treatment of contaminated soils is a major problem facing the US DOE and the US EPA Superfund program. The US DOE has identified many of its sites with contaminated soil resulting from past disposal and waste burial practices. In terms of the volume of contaminated material, a few examples will illustrate the magnitude of this problem: 1) at the Mound site, the total estimated volume of soil to be recovered or treated is approximately 280 000 m³; 2) at INEL, the total volume of contaminated soil in the Radioactive Waste Management Complex is approximately 280 000 m³; and at the Fernald site, the total estimated volume of contaminated soil and waste is estimated to be 850 to 1 400 000 m³. Other sites with significant soil contamination problems include Hanford, Rocky Flats, and Savannah River Site to name a few.

The EPA Superfund site list (1) is comparable in magnitude with sites such as: 1) Maywood Chemical Company site in New Jersey with 200 000 m³; 2) Montclair/West Orange Radium Plant in New Jersey with 270 000 m³; and United Nuclear Corporation Church Rock Site in New Mexico with 3 600 000 m³.

Treatment methods for organic contamination have recently been demonstrated. Approaches for organic treatment include thermal desorption, air stripping and catalytic oxidation.

Treatment approaches for radionuclide and heavy metal contamination have included removal to a controlled burial site, soil washing and chemical extraction. In treating contaminated soil, the desired objective is to remove the contaminants to levels which meet the EPA acceptance standards, allowing the treated natural soil to remain in place. The desired treatment process would be selective (i.e., recover only contaminants, leaving non-hazardous minerals with the treated soil), would produce low waste volumes (ideally close to the volume of contaminant recovered), would not produce secondary wastes, would use environmentally benign solvents, and would allow recovery of the contaminants for recycle or disposal with relative ease. Removal to a controlled burial site, soil washing and the chemical extraction methods reported to date do not meet this objective.

Bradtec has developed and tested a dilute, aqueous based, extraction process that meets these objectives. The process can be applied either ex-situ or in-situ. Testing to date has demonstrated the ability to treat soils to levels < 1 300 Bq/kg for uranium, and < 930 Bq/kg for plutonium. The process can also be used to treat materials other than soil, including large process vessels (e.g., enrichment plant components), hot cells, or military vehicles contaminated with depleted uranium.

PROCESS DESCRIPTION

The Bradtec process (the ACT*DE*CON process, patent pending) combines dissolution with dilute selective solvents, contaminant recovery, and solvent regeneration to provide a continuous recirculating treatment process for the treatment of soils to remove strontium, cesium, technetium, radium, actinides (uranium and transuranics), barium and lead. Other contaminants may be treatable, but testing has not been performed to verify the performance in the recovery of other contaminants.

Ex-situ Soil Treatment

The solvent chemistry combines well established carbonate recovery chemistry with a chelant and an oxidant. A variety of chemistries can be utilized. One example is the Peroxide Bicarbonate Process (3). This formulation is composed of Hydrogen Peroxide, Sodium Carbonate, Sodium Bicarbonate, 8-Hydroxyquinoline and EDTA. Other chemistries have been reported where bubbling CO₂ gas into the solvent can be used to replace the sodium carbonate and/or sodium bicarbonate (4).

The oxidant is required to raise the oxidation state of the contaminant. For example, when uranium is present in an oxidation state lower than (VI), the oxidant is required to raise the oxidation state to (VI) to allow formation of uranium carbonate complexes, UO₂(CO₃)₃⁴⁻. The function of the chelant is not fully understood, but is expected to be an important factor in the formation of the carbonate complexes.

For treating soils ex-situ, the soils would be recovered and fed to the treatment process. Figure 1 provides a flow diagram for the ACT*DE*CON process applied ex-situ for soils.

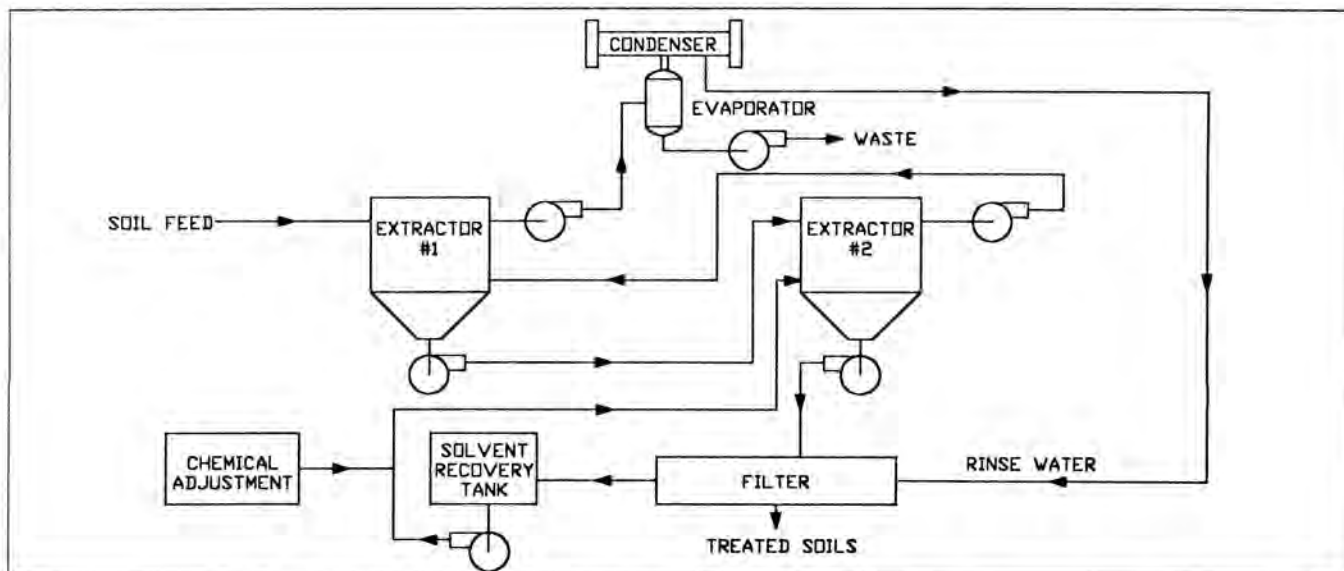


Fig. 2. Typical ACT*DE*CON treatment system with evaporation recovery.

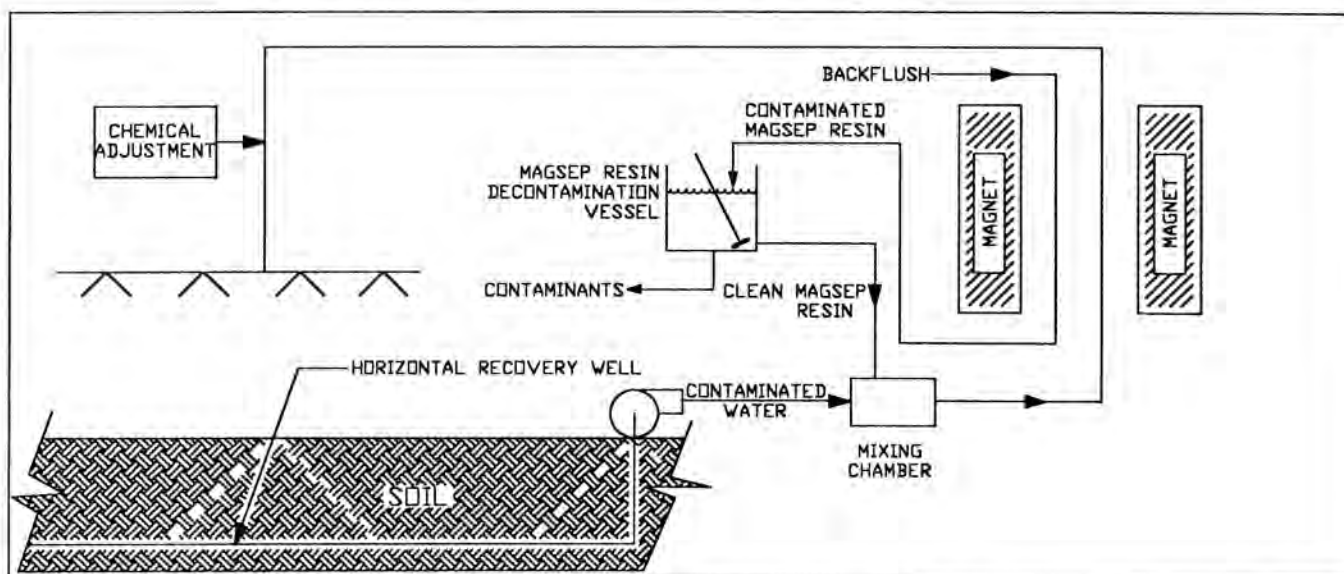


Fig. 3. Typical in-situ ACT*DE*CON soil treatment system.

uranium and < 930 Bq/kg plutonium) are achievable. We have also determined that the levels of uranium achieved following treatment are lower than the background levels in the soil prior to testing.

HEALTH & SAFETY CONSIDERATIONS

The only special health & safety considerations required (beyond those necessary as a result of the contaminants), would be confinement provision when treating soils in-situ. This can be accomplished by using either cryogenic barriers, barriers consisting of vitrified material, or combinations of either of the above with concrete confinement walls.

COSTS

The specific costs associated with any remediation project will vary depending on the contaminant(s) to be treated (e.g., uranium vs. plutonium can be a significant difference based on confinement requirements and building codes re-

quired), the concentration of contaminant(s), and the treatment system capacity. Current costs for removal and burial are \$1,236 per m³ for burial at the Nevada Test Site.

For comparison purposes, we have evaluated removal and burial, soil washing, strong acid extraction and ACT*DE*CON extraction for a hypothetical remediation of a site containing 85 000 m³ of soil contaminated with uranium at levels of 37,000 Bq/kg. The cost assumptions used are as follows:

- Excavation costs are equivalent and therefore ignored;
- Treatment system costs are \$2,000,000 for each of the treatment system approaches;
- The cost of treatment equipment is written off over the project;
- Equipment decontamination cost is \$500,000;

TABLE I

Dissolution Test Results For Soil Type I

Parameter	Pre-Test Value	Post-Test Value	DF
Clay Fraction	5%	5%	
Silt Fraction	87%	87%	
Uranium Test 1	360 mg/kg	12 mg/kg	30
Uranium Test 2	1033 mg/kg	20 mg/kg	51.6
Uranium Test 3	893 mg/kg	30 mg/kg	30
Plutonium Test 4	94.75 Bq	8.75 Bq	10.83
Americium Test 4	61.03 Bq	1.99 Bq	30.67
Lead Test 5	19.2 mg	0.6 mg	32

TABLE II

Dissolution Test Results For Soil Type II

Parameter	Pre-Test Value	Post-Test Value	DF
Clay Fraction	17%	17%	
Silt Fraction	60%	60%	
Thorium Test 1	3.93 Bq/gm	0.49 Bq/gm	8
Radium Test 1	348 Bq/gm	0.09 Bq/gm	> 3500
Radium Test 2	348 Bq/gm	0.14 Bq/gm	> 2400

- Disposal of wastes following treatment cost \$1,236 per m³; and
- Disposal of boxed soil costs \$1,236 per m³.

Two soil types are considered; high clay content soil (50% clay and silt) and low clay content soil (15% clay and silt). For soil washing, the fine fraction recovered by the separation of fines and coarse materials is assumed to be the clay and silt fraction (1,2). In treating soil by strong acid dissolution, the acid extractant is applied at the rate of 250 kg per ton of soil, and caustic for neutralization is applied at a rate of 1.18 kg of caustic per kg of acid.

In comparing soil washing and strong acid extraction technologies to the ACT*DE*CON process, ACT*DE*CON utilizes equipment similar to that required for strong acid extraction. This equipment consists of a closed

system of tanks and pumps, and is generally smaller in size and less costly than soil washing equipment (including auxiliary systems). The primary advantages provided by ACT*DE*CON are reduced chemical costs and waste volume generation (and the associated waste volume disposal costs).

Table III summarizes the key data regarding this analysis. As seen from these data, dilute, selective extraction provides savings between 117% and 1150% compared to the alternatives.

CONCLUSIONS

Remediation of soils contaminated with heavy metals and actinides and their daughter products is a major activity facing the US DOE and the US EPA. Treatment processes used to date are inadequate, as they produce large waste volumes due

TABLE III

Treatment Cost Comparison

Parameter	Remove & Bury	Soil Wash 15% Fines	Soil Wash 50% Fines	Acid Dissolution	ACT*DE*CON
Capital Cost		\$2,000,000	\$2,000,000	\$2,000,000	\$2,000,000
Decon Cost		\$500,000	\$500,000	\$500,000	\$500,000
Chemical Costs				\$55,700,000	\$2,750,000
Waste Volume (m ³)	85,000	12,744	42,480	17,360	2,550
Disposal Cost	\$105,060,000	\$15,752,000	\$52,505,000	\$21,457,000	\$3,152,000
Total Cost	\$105,000,000	\$18,252,000	\$55,005,000	\$79,657,000	\$8,402,000
Percent Over Base	1150%	117%	556%	848%	Base

to the non-selectivity of the treatment approach. Bradtec has developed a dilute aqueous based treatment process that is: selective for the contaminants of concern, uses environmentally benign chemicals, and is regenerable. Tests performed to date have confirmed the effectiveness of the process, and the ability to meet current treatment standards proposed for DOE and EPA sites. The costs of application of this process provide savings compared to existing treatment methods.

REFERENCES

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