EUROPEAN SOIL WASHING FOR U.S. APPLICATIONS

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ABSTRACT

The purpose of this paper is to present the details of the introduction of a new soil treatment technology to the U.S. market. For the purposes of this presentation, I would like to introduce a concept of three tiers of contaminated soil treatment; traditional treatment technologies, alternative treatment technologies and emerging treatment technologies. Traditional treatment consists of landfilling, incineration, and stabilization. Alternative technologies consist of low-temperature thermal treatment, bioremediation, vapor extraction, and physical screening and separation to achieve volume reduction...the essence of soil washing. Emerging technologies currently include in-situ vitrification, RF processes, dechlorination, and possibly some extraction techniques. This paper focuses on the alternative soil technologies. One of the most important lessons we have learned over the past decade is that no single technology provides a broad enough capability to solve all the soil situations that we encounter - - the key to feasible and cost-effective site solutions is the ability to optimize the use of reasonable alternatives in a site-specific matrix of use.

The Environmental Protection Agency (EPA) has recognized this need and particularly with SARA, emphasized the importance of "on-site" treatment technologies. This policy was initially stimulated through the development of the SITES program and most recently expanded by the formation of the Technology Innovation Office.

Still, all technologies have their limitations. The limitations that are most commonly encountered are:

- The volume of soil is too big or too small.
- The contaminants species and/or concentration is not process-compatible.
- Organics and inorganics cannot be handled in the same treatment train.
- The process has little or no commercial operations experience.

This document is intended to provide a description of a commercial soil-washing facility operating in Holland for the past seven years and to demonstrate how many of these limitations can be overcome with this system.

BACKGROUND

About the same time as the EPA began an active review of European technologies, Geraghty & Miller, Inc. conducted a review of the European remedial market and found significant success in the use of soil washing in Holland. This review led Geraghty & Miller to establish a Joint Venture with the Dutch firm of Heidemij Reststoffendiensten, headquartered in Arnhem, The Netherlands to make this soil washing system available in the United States. Heidemij currently operates bench scale, pilot, and commercial soil-washing facilities in The Netherlands, and last year treated more than 150,000 tons of contaminated soil. The system consists of screening, separation, froth flotation, sludge treatment, and residuals management. The process, its strengths and limitations will be discussed in this paper.

PROCESS DESCRIPTION

Particle Size/contaminant Relationship

The Heidemij Soil Wash Process is based upon the fact that a discrete relationship exists between soil particle size and contaminant residence. The first step in evaluating the potential application of soil washing at a particular site is to quantify this particle size/contaminant relationship. Generally, remedial site soils will exist in five primary "fractions":

- **Gross Oversize.** This material is >8" and consists of concrete rubble, tree stumps and branches, scrap steel, and tires.
- **Oversize.** Material in this fraction is >2"(500mm) but <8". This fraction will consist of gravel, cobbles, shredded wood, and slags.
- **Large, Coarse-Grained Soils.** This material is in the range of 1/4" to 2" and is composed of sands and gravels.
- **Coarse-Grained Soils.** This material resides in the range of 40-60 microns up to 1/4" and is sand.
- **Fine-Grained Materials.** Clays and silts with an average particle size of less than 40-60 microns.

Once these particle size fractions have been identified and quantified, the "percent finer" particle-size distribution curve is constructed. Each resulting target fraction is then analyzed chemically for appropriate contaminants. The selection of the analytical menu, of course, will be dependent upon existing information, the history of the site, and understanding of the contaminants of concern. The worst case, where no information exists, will require a full quantitation of each of the particle-size fractions. The data is reviewed and then an overlay of the data on the particle-size distribution curve is prepared. The understanding of this step is the real key to soil washing, for in most cases, at least one of the fractions will not be contaminated. The challenge and capability of the soil wash system is to separate the uncontaminated fraction(s), and then to direct appropriate treatment at the contaminated fractions.

PROCESS OVERVIEW

The process is constructed completely of standard, proven equipment, most of which has been used for decades in the mining business. The waste pile is excavated and a working pile is created. The Gross Oversize and Oversize fractions are separated individually using mechanical screening techniques, while the coarse and fine-grained split is obtained with the creative use of hydrocyclones. If required, the coarse-grained materials (the sands and gravels) are treated by froth-flotation techniques. The fine-grained materials are more difficult to treat and will be handled by dewatering, biological, or extraction processes.

The basic soil-wash treatment plant is modular, and easily transportable. The "basic" plant has a throughput capacity of 20 tons per hour (tph) and in a full treatment mode requires about 1.5 acres of laydown space. On a typical site, the facility area will be graded, a liner placed on the plant area, and run-on and run-off controls provided. The plant does not require any special foundation or support work. The plant's primary utility requirements are water and electrical power. Water is completely recycled in the system, and therefore no discharge is required, but make-up water at the rate of approximately 25 gallons per minute (gpm) is necessary. The 20 tph plant has approximately 1,000 connected horsepower and can operate from an organic mobile generator if commercial 440, 3-phase power is not available.

The soil wash system can be used on a very wide range of contaminant species, including heavy metals, semi-volatile organics, including PCBs and pesticides. If volatile organics are included in the waste stream, the material will either be pre-treated by removing the VOCs with a thermal screw, or the entire system may be operated in an enclosed working space with complete air emissions control.

The plant consists of four major sub-systems: 1) Screening, 2) Separation, 3) Froth Flotation, and 4) Sludge Management. A schematic diagram of the plant is attached as Fig. 1. Also, remember that the plant will be generating three residual products that will be managed:

1. Oversize and Gross Oversize material (usually clean)
2. Clean sand (to be beneficially reused)
3. A sludge cake to be appropriately disposed at a permitted Treatment Storage and Disposal Facility (TSDF). The sludge cake is where the contaminants finally reside.

THE SECRET IS TO RECYCLE THE OVERSIZE, REUSE THE CLEAN SOIL, AND TO KEEP THE SLUDGE CAKE VOLUME AS SMALL AS POSSIBLE

Each of the sub-systems will now be explained.

Screening

As mentioned above, a working pile is excavated in the field. This working pile must first be screened to remove the Gross Oversize fraction. This will normally be accomplished using a hopper mounted with a vibrating Grizzly. If annoying hopper blockage results, it may be necessary to substitute a Kombi screen or Trommel screen to provide a more uninterrupted step. Gross Oversize material is periodically removed from the hopper area and staged for recycling. The "fall through", or the material that is now < 8", is conveyed to the next mechanical screening unit, which will generally consist of a double-decked vibrated screen with stacking conveyors. The double-decked screen will have two flow paths: 1) an oversize material that is > 2" and, 2) a fall-through that is directed by conveyor to the wet-screening unit.

Wet screening is applied to the stream of soil < 2". High-pressure water nozzles attack the influent stream, breaking up small clods, dropping out pea-sized gravel, and forming the slurry that is now pumped to the Separation Sub-system.

Separation

The heart of the Heidemij soil wash system is the creative use of hydrocyclones. The influent soil/water slurry is pumped to the cyclone and the slurry enters tangentially. In the cyclone, open to atmospheric pressure, the coarse-grained sands are spun out of the bottom, while the fine-grained materials and water are ejected from the top of the unit.

Several details need to be pointed out regarding the special use of the hydrocyclones in this system. First, the cyclones have field-adjustable cone and barrel components such that the "cut-point" interface between coarse and fine-grained materials can be modified consistent with treatment needs. This is extremely important in achieving the smallest volume of sludge cake requiring off-site disposal. Secondly, the hydrocyclones can be arranged in many flow-path configurations depending upon the interface needs and the goal of minimizing coarse-grained carryover into the fines.

Depending upon the soil to be treated, it may also be beneficial to utilize gravity separators on either or both of the coarse/fine fractions. Typical applications might include the removal of a floating organic layer or, at the other end of the density spectrum, dropping lead out from the soil-treatment stream.

Coarse Fraction Treatment

The underflow from the hydrocyclones contains the coarse-grained materials. When treatment is required for this fraction, it is accomplished using proven air-flotation treatment units.

The first important decision that must be made in this sub-system is the selection of a surfactant. The selection, made from scores of alternatives, has one objective: the surfactant, when contacted properly with the contaminant/soil mass, reduces the surface tension binding the contaminant to the sand and allows the contaminants to "float" into a healthy froth which is then removed from the surface of the air-flotation tank. The selection of the appropriate surfactant is made during the treatability study at the bench-scale level.

Two streams, the overflow froth, and the underflow sand, are the effluents from the treatment unit. The froth is concentrated and usually directed to the sludge management belt filter press where it is dewatered into a 50-60% solids cake. If, however, the contaminants from the coarse and fine-grained fractions are not compatible, then it may not be wise to send the froth to the filter press, but to manage it separately. The underflow from the flotation unit (the sand) is now directed to sand dewatering screens - the dry sand represents the "clean" material that will be reused, the water is recycled back to the wet screening section.

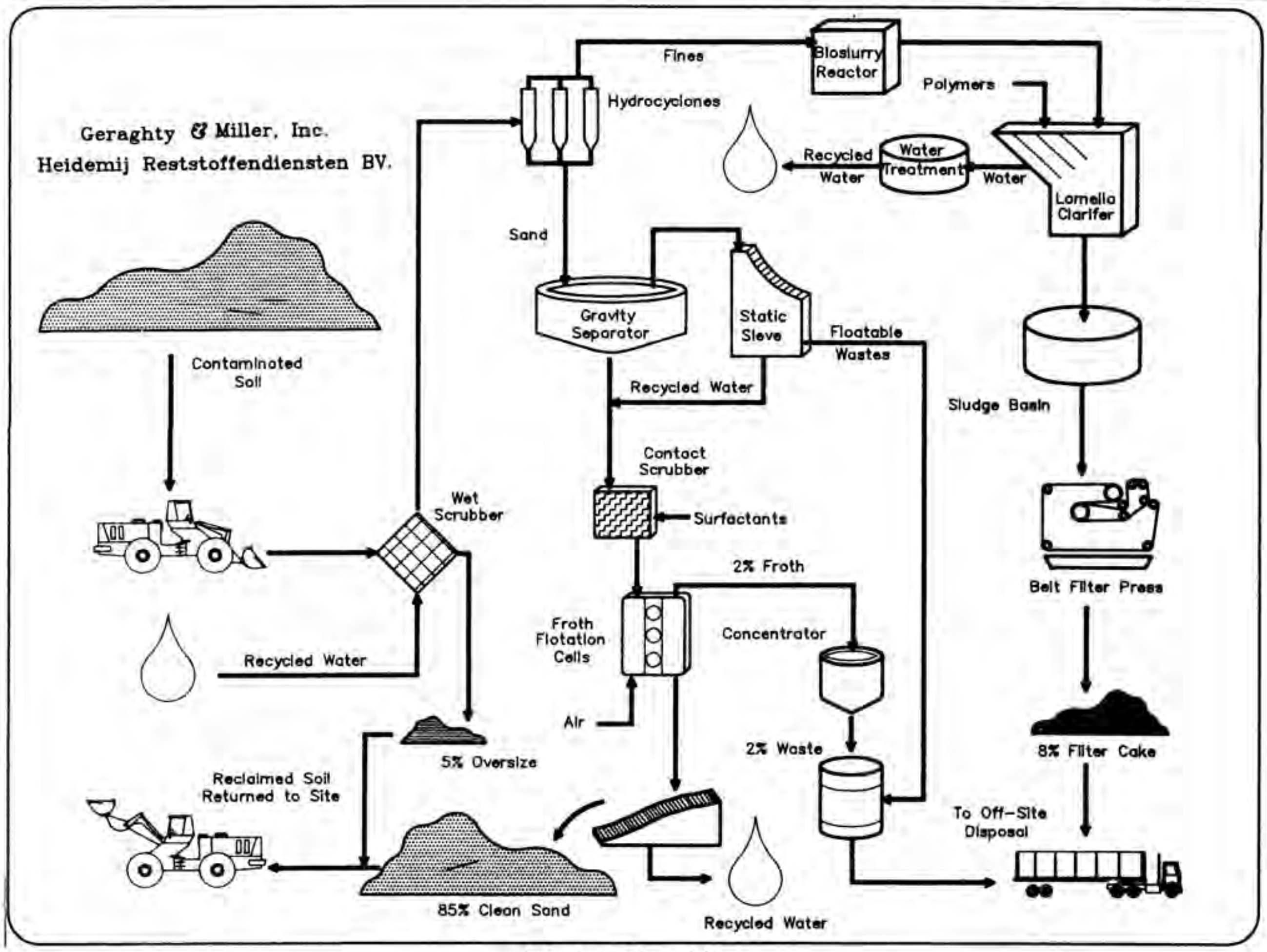

Fig. 1. Soil washing.

Sludge Management

The overflow from the hydrocyclone, consisting of fine-grained materials and water is now pumped to the sludge management sub-system. As mentioned earlier, the fines represent the most difficult fraction to treat, as a result of complex binding and attachment dynamics and mechanisms. If the distribution of fines to coarse is favorable, it is feasible to simply treat the fines similar to a wastewater sludge by polymer addition, sedimentation, thickening, and dewatering. If the fines/coarse ratio is not that favorable, it may be necessary to consider more sophisticated treatment. Of course, this upgraded treatment will depend upon the contaminants of concern, but it may include biological degradation or metals extraction.

In the primary case (simple treatment), the hydrocyclone overflow is pumped to the sedimentation area, currently consisting of banked Lamella clarifiers. An appropriate polymer has been selected in lab jar testing, and is dosed prior to introduction to the Lamella. The clarified solids are directed to a sludge thickener, while the water overflow is returned to the wet screening area for reuse. The thickened solids are then pumped to a pressurized belt filter press. A 15-20% solids influent is converted into a 50-60% dry solids filter cake. This cake contains the target contaminants and therefore must be managed by disposal at a properly permitted off-site disposal facility.

Residuals Management

There are three primary residuals to be handled:

- The Oversize and Gross Oversize Material
- The Clean Coarse-Grained Material (The Sand)
- The Fine-Grained Material (The Sludge Cake)

For the oversize material, efforts will be taken to reuse the material. The clean sand can be used as select backfill, and can usually be returned directly to the area of excavation. The fine-grained materials, recall that here is where the contaminants reside, will require disposal off-site at a permitted RCRA TSDF.

OPERATIONS AND STAFFING

The soil wash plant is relatively easy to operate. A plant can be operated on a 5 days per week/2 shifts per day basis. Preventive and routine maintenance is performed on Saturday and the plant is shut down on Sunday. If schedule or production requires, however, 7 days per week/3 shifts per day schedules can be worked.

The field operation is headed up by a Plant Manager, who is supported by a Plant Engineer, Site Safety Officer, and a mechanical/electrical technician, the four of whom work the day shift. The shift crews (two or three depending upon production requirements) each consist of a Shift Foreman, a flotation unit operator, a belt filter press operator, and two laborers.

THE REGULATORY SITUATION

The success of soil washing will be measured by the ability of the *system* to meet specific treatability/cleanup standards. Projects will be regulated, in most cases, by either CERCLA, RCRA, or specific state law. In the case of CERCLA, no specific permit is required, but all the normal requirements of a permit must be documented and met. When the soil-washing remedy is specified in the Record of Decision (ROD) the permits form no barrier to implementation.

RCRA projects have recently become much more flexible to the use of innovative technologies through the Corrective Action Program. An owner/operator can apply for a temporary permit to use an innovative method for 180 days and renew for another 180-day period. (Most projects can be completed in this one year period.)

TREATABILITY STUDIES

Every project will commence with a treatability study. The purpose of the study is to understand the particle size/contaminant relationship, to confirm a process for the treatment of the waste of concern, and to price the service. The treatability study consists of four phases:

Phase I: "Representative" samples are collected from the site. This determination of representativeness is important to the client and contractor since this agreement is the basis of treatment and pricing decisions. Where possible, we believe that it is very useful for the client and the contractor to participate mutually in this "representativeness" decision. The samples are managed with proper controls, and can be analyzed at the client's facility if the proper staff and resources are available, at the Geraghty & Miller Treatability Laboratory in Tampa, Florida, or at the Heidemij Treatability Laboratory in Waalwijk, The Netherlands. The analyses to be performed include, first, the sieve analysis and the construction of the Percent Finer Curve. Then, the target particle-size fraction samples are chemically analyzed for the required contaminant menu. The Phase I results represent a good "Go/No Go" point, for this information will allow a reasonable decision to be made regarding the feasibility of soil washing.

Phase II: The next step is to perform bench-scale investigations to confirm specific unit operations. Specifically, screening, hydrocycloning, air flotation, and filter pressing studies will be conducted to select treatment units, and to determine surfactant, polymer, flow rate, and throughput requirements. This phase of the treatability study will be conducted in The Netherlands. In this phase of work, direct equipment and professional support will be provided by the Mineral Processing staff and the extensive facility at the Technical University of Delft (TUD), The Netherlands. This is a long-term, funded relationship between Heidemij and TUD that has proven invaluable in keeping the team at the forefront of soil treatment. This study will generally take about four weeks to conduct, will result in the confirmation of a process flow diagram, confirmation of treatment capabilities.

Phase III: When necessary, a pilot treatment plant will be tailored from existing plants at two locations to run the specified treatment train with actual site soils. The pilot plant facilities consist of the full range of required treatment units and have the capacity to run studies at the level of one ton per hour. While these studies will be normally conducted in Holland, the EPA has anticipated the need to ship soils out of the U.S. and has provided guidelines and requirements in 40 CFR 263. (PCB materials cannot be shipped out of the U.S.) The scope of the pilot study and the location where it will be conducted depend directly on the size and complexity of the project. Where a site situation matches closely to current experience, it may not be necessary to even conduct a pilot level study. The team can, where necessary, assemble a pilot treatment facility at the U.S. site.

Phase IV: After the completion of the required studies, a report will be prepared documenting the investigation activities and providing conclusions regarding the findings. The report will provide the confirmed process *flow diagram* and the general specifications for the actual facility. The report will commit to a unit treatment price and specify any particular contractual qualifications. The document is intended to provide all the technical information required to negotiate a services agreement.

COSTS

Comparison costs of other forms of on-site treatment are shown in Table I. A summary of the unit treatment price, broken down by major cost components, and at several different volume points, is presented in Table II.

BENEFITS OF SOIL WASHING

The benefits of soil washing are substantial and are:

- The system is exceptionally cost-effective since it can focus treatment only on the appropriate fractions, rather than treating the entire waste stream.
- The system can treat both organics and inorganics in the same treatment stream.
- The soil washing system is a true volume reduction option and directly supports the recycle and reuse of site materials.
- The system is consistent with current EPA directives and policies requiring on-site, innovative treatment.
- Since there is no air emission or wastewater discharge, the system is easier to permit than traditional remedial alternatives.

WHAT DO YOU NEED TO DO TO GET STARTED?

Please contact Mr. Michael J. Mann or Ms. Jill Besch at (800) 676-1921 to discuss your specific site situation. We will be happy to provide direct information regarding your needs, arrange a site visit, if appropriate, and respond in writing to requests for proposal. As stated above, each site requires a treatability study, a study that can be tailored to the needs of your project, conducted in a staged process, and by using existing site information.

TABLE I

Comparison of on-site Remedial Technologies

	Waste Handled			
	Cost/yd^3	Organic	Inorganic	Permitting
Incineration	600-2000	Yes	No	RCRA, air and NPDES
In-situ vitrification	350-400	Yes	Yes	Land ban restrictions
Low temperature thermal treatment	200-250	Yes	No	Air
Chemical treatment, (solvent extraction, BEST, KPEG)	250-300	Yes	No	NPDES
Soil washing	100-200	Yes	Yes	None
Bioremediation	75-100	Yes	No	None
Stabilization/solidification	20-100	Yes	Yes	Land ban restrictions
Vapor extraction/soil venting	2-5	Yes	No	Air

TABLE II

Soil Washing Costs
($ Cubic Yard)

	Volume (cubic yards)			
Item	20,000	40,000	60,000	100,000
Capital Depreciation	65	38	28	20
MOB/demob	5	3	2	2
Labor	25	15	12	9
Back-up	3	2	2	1
Chemicals	15	15	15	15
Maintenance	8	4	4	3
Equipment upgrade	12	9	8	7
Safety equipment	3	3	3	3
Utilities	6	6	6	6
Material handling	5	5	5	5
Management/engineering	20	13	10	8
Overhead	9	8	5	3
Process testing	22	11	8	4
Off-site disposal	15	15	15	15
Site preparation	0	0	0	0
TOTALS	**$213**	**$147**	**$123**	**$101**