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**USE OF ACTIVATED CARBON IN VACUUM REMOVAL OF VOC'S
FROM CONTAMINATED SOILS**

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INTRODUCTION

As awareness to environmental issues increases and public and governmental pressures to clean up these problems grow, an increasing number of remediation techniques have been developed to remove volatile organic chemicals (VOC's) from soils contaminated by leaking underground chemical storage tanks, gasoline tanks, and from landfills, spills and sites contaminated by indiscriminant dumping.

Vacuum removal is one of the newest and fastest growing techniques for the remediation of these problems. Activated carbon plays a key role in this process, by both providing capture and ultimately destruction of the VOC's removed. This paper analyzes the role of carbon in this technology, and defines the information needed by the carbon system supplier so that it can provide the best, most effective system available.

PROCESS DESCRIPTION

The principle underlying soil vacuuming is relatively simple. Once an assessment of the spill or contamination has been made, by drilling, testing or estimation, a well or wells are drilled into the contaminated soil. A vacuum device (rotary blower, vacuum pump) is connected to the well or wells to draw air/VOC's from the surrounding soil. Prior to releasing the now contaminated air to the environment, the VOC's must be removed or destroyed.

Activated carbon has long been known and used to remove VOC's from air streams. Its affinity for a broad spectrum of organic compounds and its ability to function well under conditions of varying flow and organic concentration make it an ideal material for the capture and concentration of VOC's discharged during soil remediation.

The subjects to be discussed include:

- * Site - Spill
- * Carbon Performance
- * Carbon Systems
- * Costs

SPILL

Although the conditions surrounding the actual contaminated site are usually the concern of the remediation engineer or contractor, a few site considerations influence the design and operation of the carbon system.

Age of Spill

Natural aeration, oxidation and bacterial action contribute to changes in the composition of the organic constituents. Therefore the organic materials to be removed may be radically different than those comprising the original spill.

Soil

The permeability of the soil can vary dramatically from site to site, controlling the rate at which air flows, and the rate at which VOC's can be removed.

Water Content

Water, if present in the soil, will be removed, and the resulting moisture in the air stream can influence design of the system.

Type of VOC

Low molecular weight easily volatilized compounds are easier to remove than heavier, less volatile compounds. This will result in changes in VOC content of the air stream with time over the life of the project. Actual analysis of the composition of VOC's in the air stream makes carbon system estimation and design much easier.

CARBON SYSTEMS

Systems employed have varied from the use of single small (200 lbs.) canisters to those employing multiple, large canisters (1000lbs.)

For the most part, Westates has recommended and employed

systems utilizing coconut shell carbons as the adsorbate. Because of its naturally high surface area and fine pore structure, fluctuations in VOC concentration have minimal effect on the overall adsorption capacity of this type of carbon, and desorption during periods of reduced VOC content can be minimized.

Generally, because of air pollution concerns, systems are designed to employ two carbon canisters in series. Monitoring of discharge at the exit of the first bed provides essentially 100% breakthrough and almost complete exhaustion of the carbon with the second bed providing back-up capture of organics on breakthrough.

Carbon has been employed on both the vacuum and pressure sides of the system. Each position has its benefits and disadvantages.

Vacuum	<ul style="list-style-type: none"> *Leakage is into system *Carbon on cool side, providing higher capacities 	<ul style="list-style-type: none"> *Lower total system pressure, lowering carbon capacity *system needs vacuum designed vessels *Water saturated, and reduced efficiency, lengthened mass transfer zones
Pressure	<ul style="list-style-type: none"> *With cooling of gas, efficient carbon utilization *Reduces effect of moisture 	<ul style="list-style-type: none"> "Needs air cooler *Must be tight to prevent leaks

CARBON PERFORMANCE

Estimates of carbon consumption can be made from preliminary data provided by soil samples and/or pilot wells. When employing carbon adsorption isotherms, it is possible to estimate the capacity of activated carbon for a particular organic or family of organic compounds.

The amount of material that can be adsorbed is dependent on the physical and chemical characteristics of the organic constituents, their concentrations in the gas stream, and the system temperature, pressure and humidity. To maximize capacity, a system should be operated at the lowest practical temperature.

Although water is weakly adsorbed, moisture can have an

effect on capacity and mass transfer zones at high humidity (+50% RH). Water can have a significant effect on capacity for low molecular weight organics, such as vinyl chloride, and relatively little on strongly adsorbed organics such as benzene or toluene, but may increase the mass transfer zone significantly.

The following example is typical of gasoline spill clean up systems:

Flow rate	-	50 scfm
Temperature	-	60 F
Pressure	-	4" Hg Vacuum
Benzene	-	.3 lbs./day
Toluene	-	.96 lbs./day
Xyiene	-	1.43 lbs./day
Ethylbenzene	-	.14 lbs./day
Hexane	-	9.28 lbs./day

Based on the above parameters an estimate of carbon capacity would be 10-14%.

As is usually the case with relatively new technologies, significant quantities of long term data is not readily available. The long term effects of flow rate, VOC concentrations and changes in VOC composition can not be separated at this time.

Data was collected from four actual clean up sites providing the following information:

<u>INSTALLATION</u>	<u>CARBON LOCATION</u>	<u>TYPE ORGANIC</u>	<u>AVERAGE % VOC ADSORBED</u>	<u>AVERAGE % H2O</u>
1	Vacuum	Chlorinated	13.8	16.2
2	Vacuum	Mixed	22.7	.33
3	Pressure	Gasoline	23.6	1.8
4	Pressure	Gasoline	21.9	4.4

As can be seen from this data, substantial quantities of VOC's can be picked up and retained by carbon in this service, even in the face of highly saturated gas streams, No. 1.

Installation No. 4 provides operational data from the facility for which the sample capacity calculation was performed. As can be seen, substantially more VOC has been adsorbed than anticipated. Since actual influent data is not presently available, we can only conclude that the actual VOC concentrations are significantly higher than those anticipated.

COSTS

Costs associated with activated carbon treatment vary with each system and clean up, but essentially consist of similar elements;

1. Capital cost will vary with the type of system used. Self regenerable systems are most capital intensive and disposable canisters are least costly. For sites which can be remediated over a fairly short period of time, rental and lease of systems is a viable option. Costs vary from \$20 to \$75 per pound of VOC recovered.

2. Regeneration of the carbon provides the user with the "final solution" ultimate destruction of the organic contaminants, and cost benefits by reuse of the regenerated carbon. Costs vary from \$8 to \$15 per pound of VOC.

3. Freight costs for carbon disposal or regeneration are frequently overlooked, but they are a potentially costly component. Since spent carbons are generally considered a hazardous waste transport by a licensed waste hauler is required. With carbon consumption generally being less than supplied with the capability, 4000 - 6000 pounds over the life of the clean-up, the use of a carbon system supplier with the capability to accumulate and service multiple installations can substantially reduce costs. Costs here vary \$1 to \$2 per pound of VOC.

As we have seen, soil vacuuming and carbon adsorption are a proven, reliable remediation technique. However substantial quantities of data remain to be collected and analyzed before prediction of system capacities and designs become routine.