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MODELING OF SOIL HUMIDITY EFFECTS UPON ORGANIC COMPOUND  
SORPTION DURING SOIL VAPOR EXTRACTION

By

CHRISTOPHER LYNTON BAILEY, B.E.

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

Civil Engineering Department

THE UNIVERSITY OF TEXAS AT EL PASO

July, 1997


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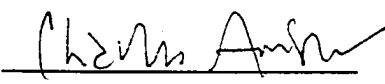
Department of Civil Engineering

APPROVED:

  
Dr. John Walton, Chair

  
Dr. Soheil Nazarian

  
Dr. Richard Langford

  
Associate Vice President for  
Graduate Studies

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## **CHAPTER 1**

### **INTRODUCTION**

Soil Vapor Extraction (SVE) has been effectively utilized to remediate vadose zone soils contaminated with volatile organic compounds. Organics, less susceptible to volatilization, have also been successfully treated with variations on traditional SVE such as bioventing (Suthersan, 1996).

The process of SVE or soil venting involves the generation of air flow in the subsurface by application of a vacuum within a vapor extraction well screened throughout the depth of the contaminants. The vapor effluent can be routed through a treatment system, such as granular activated carbon or a catalytic oxidation unit situated above ground prior to discharge.

The efficacy of soil venting is dependent upon various parameters including the amount of contaminant partitioned into the vapor phase, the ability of air to travel in the subsurface - i.e. the permeability of the soil, and diffusion rates from stagnant zones (Pederson and Curtis, 1990). Stagnant zones occur where air flow preferentially by-passes low permeability soils, curtailing advective transport, limiting cleanup to diffusion based vapor transport.

Compound vapor pressure or vapor concentration increases exponentially with temperature. Efforts to enhance soil venting utilizing this phenomenon have met with some success. Due

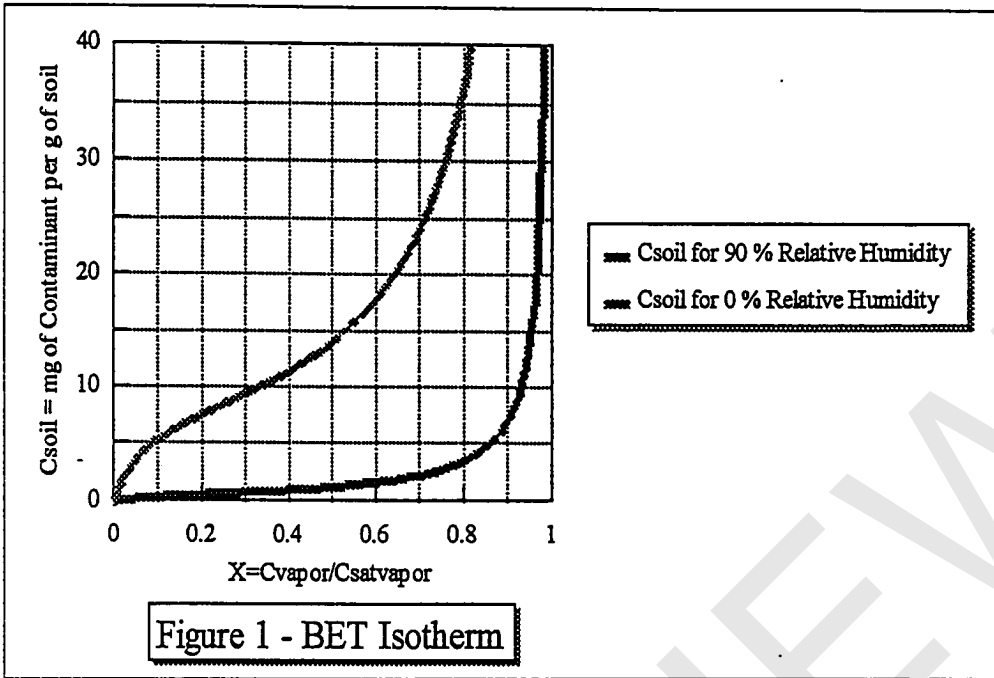
to the high heat capacity of soil, a significant amount of heat energy must be applied to the subsurface before a temperature rise will be observed.

Water content has opposing implications upon SVE. Increasing soil moisture decreases air permeability for both advection and diffusive transport, however, higher moisture contents are more productive for biodegradation (Suthersan, 1996, Roderick, 1997). In addition, vapor phase sorption of organics is highly dependent upon moisture content (Peterson et al, 1988, Poe et al, 1988, Valsaraj and Thibodeaux, 1988, Pennell et al, 1992). Pennell et al (1992) indicate that the capability of mineral soil surfaces in the vadose zone to adsorb organic compounds is heavily influenced by the humidity of the soil atmosphere. Further, commonly used saturated partitioning functions applied to unsaturated conditions produce misleading results in VOC transport calculations (Peterson et al, 1988).

Several researchers have conducted work to quantify sorption of organics in the vadose zone. Pennell et al (1992) fit p-Xylene laboratory sorption data with various relative humidities by a least-squares procedure to the following linear form of the Type II BET (Brunauer, Emmett and Teller) isotherm (Brunauer et al, 1938).

$$\frac{X}{S(1-X)} = \frac{1}{S_M C} + (C-1) \frac{X}{S_M C}$$





Where

X is equal to the vapor concentration divided by the vapor concentration at saturation of the compound -

$$X = \frac{C_{Vapor}}{C_{Sat Vapor}}$$

$$C_{Vapor} = \frac{\text{Mass of Contaminant in Vapor Phase}}{\text{Air Filled Porosity}} = \frac{M_{Vapor}}{V_{Vapor}}$$

S is the mass of the compound per mass of soil (multiplied by 1000) -

$$S = \frac{1000 * \text{Mass of Contaminant Adsorbed}}{\text{Soil Mass}} = \frac{1000 * M_{Soil}}{\text{Soil Mass}}$$

$S_M$  is a constant equal to the nominal monolayer sorption capacity

C is a constant related to the heat of adsorption

Constants  $S_M$  and C were determined for experimental data collected from several soils and relative humidities.

For organic compounds in soil, until very low concentrations are realized, the bulk of the total contaminant is in Non-Aqueous Phase Liquid (NAPL). Using the partitioning described by the BET isotherm as developed by Pennell et al (1992), NAPL phase can be represented as adsorbed to soil.

A brief analysis of the isotherm presented in Figure 1 indicates that a humid soil atmosphere with approximately five milligrams (mg) of compound per gram (g) of soil can have vapor concentration near 0.9 of the saturation vapor concentration. Five mg of contaminant in a dry soil atmosphere will result in vapor concentrations close to 0.08 of the saturation vapor concentration. This demonstrates that a dry soil may retard vapor extraction cleanup by a factor of ten.

In addition to temperature effects on the compound vapor pressure, temperature also affects partitioning between the dissolved and vapor phases of a compound, i.e. Henry's Law constant. In moisture/vapor environments without NAPL phase, temperature effects can be important.

The focus of the work presented here is to determine the effect of the wide differences in organic compound sorption under humid and dry conditions for soil venting. As described above, organic compound sorption will vary greatly depending upon the relative humidity of the soil environment. A ten fold decrease in vapor concentration from humid to dry soil atmosphere environments can result. Quantification of soil humidity influenced vapor sorption has allowed this phenomenon to be explored in numerical modeling.

Other studies have shown that cooling and drying of soil can occur during soil venting due to latent heat energy expenditure (Casey, 1996, Anker, 1995). Evaporation of the adsorbed organic and moisture cools the soil, while reducing moisture contents. Soil venting applied at arid region sites can decrease moisture in soils, most significantly adjacent to the extraction well and at the perimeter of the air recharging zone (Casey, 1996). An existing computer model was modified to observe the increased sorption phenomenon changes during soil venting and examine possible remedies.