A STUDY OF SOIL WATER-HOLDING PROPERTIES AS AFFECTED BY TPH CONTAMINATION

[1]S.R. Burckhard, [2]D. Pirkl, [2]V.R. Schaefer, [3]P. Kulakow, and [4]B. Leven

[1,2]Civil and Environmental Engineering Department, Box 2219, South Dakota State University, Brookings, SD 57007; [1]Phone: (605) 688-5316, [1]E-mail: suzette_burckhard@sdstate.edu; [3]Department of Agronomy, 2004 Throckmorton Plant Science Center, Kansas State University, Manhattan, KS 66506; [3]Phone: (785) 532-7239, [3]E-mail: kulakow@ksu.edu; [4]Great Plains/Rocky Mountain HSRC, 101 Ward Hall, Kansas State University, Manhattan, KS 66506; [4]Phone: (785) 532-0780,[4]E-mail: baleven@ksu.edu.

ABSTRACT

The measurement of soil water content is one of the most common kinds of soil analysis performed. The potential effects of the soil water content on the behavior of soil make it an important measurement in every type of soil study. The relationship between soil water content and metric suction is known as the soil-water characteristic curve. The soil-water characteristic curve is often used for calculating unsaturated hydraulic values. The introduction of petroleum hydrocarbons into an unsaturated soil, due to a spill, alters unsaturated hydraulic properties of the soil, but current computer modeling of flow in unsaturated soil does not account for this change in unsaturated hydraulic properties. This presentation will present results from a laboratory experiment measuring the hydraulic properties of contaminated soils.

Key words: *petroleum hydrocarbons, contaminated soil, soil physical properties*

INTRODUCTION

The measurement of water content is one of the most common kinds of soil analysis performed. The potential effects and/or influence of soil water content on the behavior and application of soil makes it an important measurement in every type of soil study (Carter, 1993). Over the past ten years or so, interest in the vadose zone (unsaturated zone) of soils has been increasing. This interest has been fueled by public concerns about diminishing quality of groundwater and soil (van Genuchten et al 1991). Hydraulic properties of soil, such as hydraulic conductivity are affected by soil physical properties such as soil texture. As soil physical properties change, so does the soil-water characteristic curve and the hydraulic conductivity. The main goal of the research conducted was to measure the change, if any, in the water-holding capacity of a soil contaminated with petroleum. The results are intended to act as a stepping stone for future research in the hydraulic properties of contaminated soil.

Before describing the experimental setup, a few definitions are needed.

Soil-Water Characteristic Curves: The soil-water characteristic curve shows the relationship between water content and soil suction in the vadose zone.

Soil Water Content: The term soil water content is defined as the amount of water incorporated within soil pores. Soil water content can be defined as either gravimetric water content, or volumetric water content. Gravimetric water content is defined on a mass of soil basis. Volumetric water content is defined as a percent by volume of soil basis.

Gravimetric water content, ω, is calculated as follows:

$$\omega = \frac{M_W}{Ms} \quad (1)$$

where M_w symbolizes the mass of the water and M_w symbolizes the mass of the soil.

Volumetric water content, q, is calculated as follows:

$$\theta = \frac{(W_W - W_d)}{(dV_s)} \quad (2)$$

where d is the density of water, and V_s is the contained volume of the sample. The wet weight of the soil and the sample container ring is W_w, and the dry weight of the soil and the container is W_d.

Soil Suction: The soil water potential, or soil suction, is an energy level of the soil water. Matric suction was used during the course of this study. Matric suction can be defined as the pore-air pressure minus the pore-water pressure. When an unsaturated soil becomes more saturated, matric suction decreases.

DETERMINATION OF SOIL-WATER CHARACTERISTIC CURVES

Determination of the soil-water characteristic curve is accomplished by establishing equilibrium between a body of water of known potential and the soil water in the sample. A Five-Bar Pressure Plate Extractor, shown in Figure 1, from Soil Moisture Equipment Corporation (Santa Barbara, CA) was used to establish equilibrium at the following suction levels: 0.00, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.11, 0.22, 0.34, 0.45, and 1.00 bars. Operating instructions for the Pressure Plate Extractor can be obtained from Soil Moisture Equipment Corporation (Santa Barbara, CA) and they are also described in detail in Pirkl (1999). The soil used for this experiment was Ottawa sand. The sand was contaminated with 10W30 motor oil to varying degrees: 0.0%, 0.2%, 0.4%, 0.6%, and 1.0% by weight. The method used to homogeneously contaminate the soil is described in detail in Pirkl (1999). Quadruplicate samples were used for statistical purposes. After the samples reach equilibrium, volumetric water content is calculated and is plotted versus the matric suction at equilibrium to establish a data pair.

RESULTS

The effect of varying oil contamination on the hydraulic properties of the Ottawa sand was analyzed during the collection of the data needed to construct the soil-water retention curves. Contamination levels were varied at a constant rate from no contamination to 1.0% contamination by weight. Procedures were followed to minimize the differences, not associated with level of contamination, in the samples.

To construct a soil-water retention curve, data pairs of volumetric water content and matric suction were plotted. These data pairs were then used to construct the soil-water retention curve for the soil being tested. Figure 2 shows that there were mutually exclusive soil-water retention curves for each level of contamination. The soil-water retention curves indicated that at low suction values, the uncontaminated soil sample has a higher water-holding capacity than the contaminated samples. This is indicated by the higher water content of the

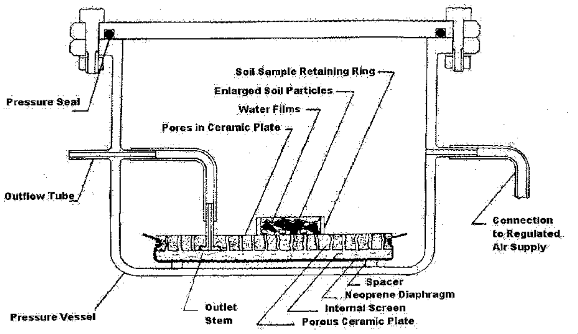

Figure 1. Diagram of Five-Bar Pressure Plate Extractor.

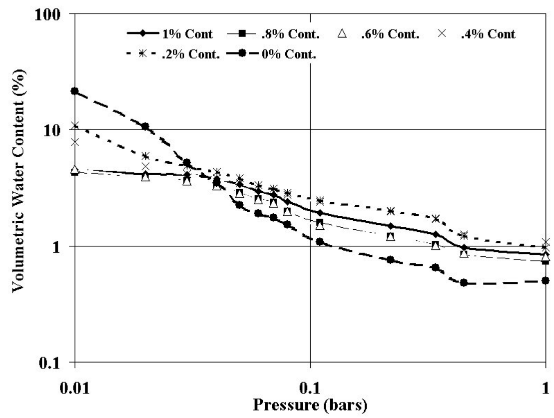

Figure 2. Volumetric Water Content Versus Pressure for Various TPH Levels.

uncontaminated soil sample relative to the contaminated samples at the lower suction values. This development was unexpected. An orderly progression relative to the percent oil contamination and final water content could not be deduced from the data.

DISCUSSION

The results of this data show that at higher suction values, the water-holding capacity of Ottawa sand increases due to presence of oil contamination. This may cause a problem when designing a pump-and-treat, soil-vapor-extraction, or air-stripping remediation system to clean up oil-contaminated soils. If the soil properties are changed due to the presence of the contaminant, a residual product may remain even after; theoretically, the soil treatment should be complete. Many computer-modeling programs do not account for the fact that the physical properties of the soil may change due to the contamination present. This could cause a substantial underestimation of the amount of work required to remediate a site.

CONCLUSIONS

Soil-water characteristic curves for oil-contaminated Ottawa sand constructed during this study were different from the soil-water retention curve of clean Ottawa sand. The soil-water retention curves indicate that the introduction of a relatively low amount of oil contamination inhibits the movement of water. The results of this research indicate that the introduction of petroleum hydrocarbons to a soil changes that soil's hydraulic properties. At higher suction values, the contaminated samples had a higher water- holding capacity. This should raise concerns with the accuracy of most computer models used to evaluate fluid-flow through soils. Further studies are suggested to better understand the relationship between the effects of soil contamination and the hydraulic properties of the soil.

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REFERENCES

Carter, M. R. (1993) Soil Sampling and Methods of Analysis, CSSS, Canadian Society of Soil Science, Lewis Publishers, Boca Raton, FA.

Pirkl, D. R. (1999) Petroleum Hydrocarbon Residual Product Effects on Soil-Water Retention Curves, A Master's Thesis, South Dakota State University, Brookings, S.D.

Van Genuchten, M. Th., and D.R. Nielsen (1985). "On Describing and Predicting the Hydraulic Properties of Unsaturated Soils." Annales Geophysicae, 3(5), 615-628.