

## **EVALUATION OF THE POTENTIAL UTILITY OF FLUID ABSORBER MAPPING OF CONTAMINANTS**

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### **ABSTRACT**

The SEAMIST™ method of installation and retrieval of absorbent collectors has made the use of absorbers very easy for sampling of pore fluids in the vadose zone. This paper addresses the question of how well the method can be used to map contaminants in soil and rock. The issues are: how much liquid can be obtained; how long must the absorber be emplaced; are the samples representative; what are useful absorber materials; how can the samples be analyzed; what handling precautions are required; where has the method been used; and what were the results? Typical absorbed water volumes are 25-100 percent of the absorber mass. The length of time required ranges from several hours in coarse grained soils to many days in fine grained materials. Ten absorber materials were analyzed for characteristic curves, permeability and imbibition rates and volumes. The method has been successfully used at the DOE LANL, LLNL and WIPP sites. Calculations of the mass flow with the LANL TRACR3D model generally agrees with the laboratory tests. Sample analysis has been done with the purge and trap technique. Tests of the acoustic IR method are in progress. Tests at LLNL show that VOC's can be collected with a consistent concentration of about 70 percent of the in situ value. Historical use of absorbers has shown promise of both vapor and liquid collection, but measurements of capillary tension are plagued by the question of equilibrium times. The use of electrical monitoring can help that problem. Very interesting possibilities exist in the use of absorbers to infer relative vapor and liquid permeabilities.

## **INTRODUCTION**

This paper describes the method of fluid sample collection in the vadose zone using an absorbent material to wick the fluid from the wall of a borehole. The general physical processes of absorber placement, absorption, and absorber retrieval are described. The current experience with this technique is summarized. The calculated evaluation of the process was performed for a variety of conditions to determine the limits of the method. Those results are then related to field experience. The range of potential applications is discussed and the measurements required to advance the art are described.

## **BACKGROUND**

The common experience of sponging up milk from a carpet or soaking up spilled wine from one's shirt-front with a napkin are simple examples of wicking a fluid into an absorbent material from another more saturated material. The red stain on the napkin is the fluid sample of wine. When the shirt is washed with soap and water, the wine is re suspended and flushed from the fabric. Can these same processes be used to collect pore fluids from deep holes? Would the absorbed fluid in the "napkin" be as useful as a core fluid sample? Would it cost less? How can it be analyzed?

When we wished to collect a liquid sample from fractures of relatively impermeable rock deep in a borehole, the SEAMIST<sup>1</sup> system was invented as a means of emplacing and retrieving the absorbers without touching the borehole with the absorber at more than one discrete location. The SEAMIST pneumatically driven, everting membrane is shown in Figure 1 as it is emplaced with several attached absorbers numbered 1-3. The retrieval process follows the reverse path, so that the absorbers are inverted into the ascending membrane, well protected from any subsequent contact with the borehole. The process is described in more detail in earlier papers presented at NWWA conferences (Ref. 1-3). Based upon the successful use of absorbers emplaced with SEAMIST in mapping a tritium plume at LLNL (Ref. 4), one wonders what the limitations are in the process and if it can provide much of the information on pore fluids obtained from core samples in the vadose zone.

The absorber geometry may be patches as illustrated (Figure 1), or a continuous strip attached to the outside of the membrane, or a complete covering of the membrane. The installation and retrieval mechanism is the same.

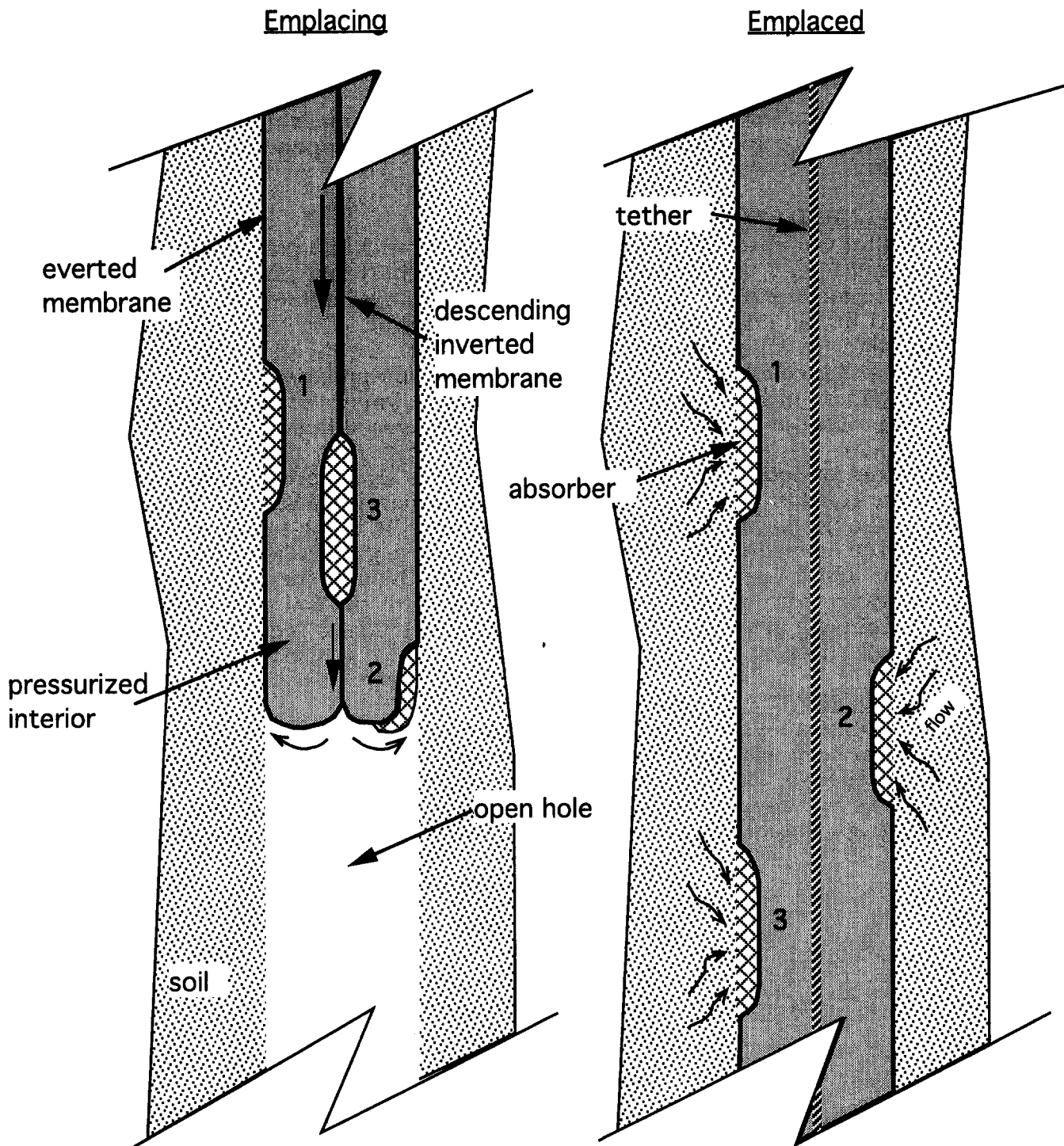
## **THE ABSORPTION PROCESS**

The absorber shown in Figure 1 is overlain by the pressurized, impermeable membrane and pressed against the hole wall with a typical pressure of 1-3 psi. That may seem like a modest pressure, but it is equivalent to a 2-6 inch thick, lead brick lying on a flat surface. The pore space is well compressed in soft absorbers such as cotton felt, cotton cloth or polypropylene felt (baby diaper type material), or other such common absorbent materials.

If the absorber is relatively dry (a characteristic to be discussed) and the material of the hole wall is moist, the absorber will wick moisture from the hole wall if several conditions are met as follows:

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<sup>1</sup> The SEAMIST™ system (pat. no. 5176207) was invented by the author and the patent and trademark are currently owned by Eastman Cherrington Environmental.



**Figure 1.** The pneumatic emplacement of three absorbent pads mounted on an impermeable coated fabric (membrane).

- The capillary tension in the absorber is larger than the capillary tension of the geologic medium (a necessary and sufficient condition); and,
- The absorber is in contact with the pore liquid (a helpful and sometimes necessary condition).

Measurements have shown that dry absorbers can collect moisture from soils with capillary tensions much larger than 1 bar, well beyond the operating limit of suction lysimeters.

### **VAPOR AND LIQUID TRANSPORT**

The reason that the absorber need not be in contact with the pore liquid is because some pore liquid (e.g., water) can be absorbed from the vapor phase. The common example is a cigar humididor. It can increase the moisture content of a cigar by maintaining a humid environment surrounding the cigar. The relative humidity is the critical factor in vapor absorption by the absorber. Liquid and vapor absorption can occur simultaneously. In most soil characterization processes such as porous plate measurement of saturation vs. capillary tension, vapor vs. liquid transport is often ignored. That is a potential problem to be discussed later.

The significance of both vapor and liquid transport to an absorber depends upon the use of the sample. Vapor transport to the absorber will dilute the dissolved solids in any liquid flow into the absorber. However, the vapor transport may have no effect on the concentration of volatile compounds (e.g., VOC's) in the absorbed liquid. In the limit of extremely long contact times, the absorber vapors and liquids can be expected to reach nominal equilibrium with the soil pore liquid and vapor via the diffusion process. The diffusion process tends to reduce concentration gradients of all kinds.

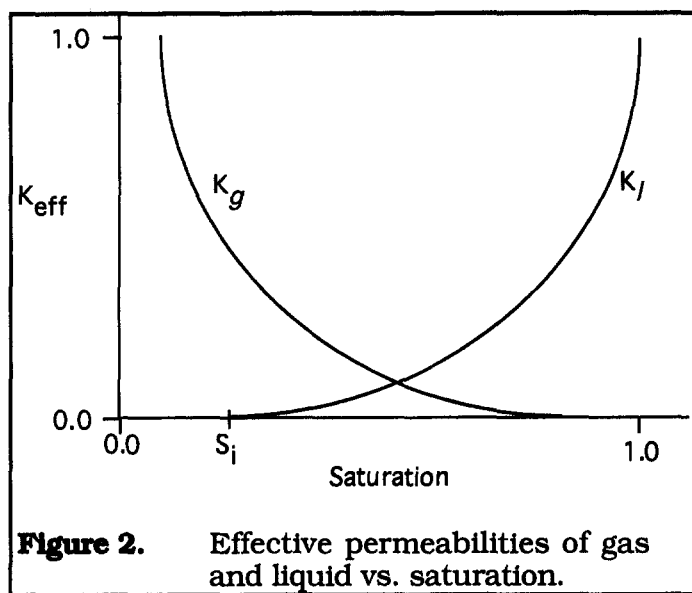
### **RELATIVE TRANSPORT RATES**

Vapor and liquid transport to the absorber will proceed until the capillary tensions are equal. How soon will that occur? Or, how long must an absorber be emplaced? As usual, "it depends." The simple Darcy flow equation for porous flow velocities is often written as two coupled equations. One treats liquid transport and the other treats vapor (e.g., water) and gas (e.g., air) transport. The simple equation is:

$$Q = A \cdot v = A \frac{K}{\mu} \frac{dp}{dx}$$

Where:	$Q$	=	The volumetric flow (cc/sec).
	$A$	=	The area traversed by the flow.
	$v$	=	The volumetric velocity (not the actual liquid or gas velocity).
	$\mu$	=	The viscosity of each phase.
	$K$	=	The permeability of each phase.
	$\frac{dp}{dx}$	=	The "pressure" gradient.

The permeability  $K$  is the intrinsic permeability of the medium  $K_i$ , multiplied by the "effective permeability" for the liquid or gaseous phase  $K_l$  or  $K_g$ . The effective permeability ranges between 1.0 and 0.0 depending upon the saturation. Figure 2 shows the two effective permeabilities as a function of saturation. As the soil goes



from wet (sat. = 1.0) to dry (toward sat. = 0.0), the soil pores are more open to gas flow ( $K_l$  goes down). The effective permeabilities are very sensitive to the saturation. At the saturation labeled  $S_i$ , the pore liquids are not zero, but they become disconnected so that the liquid flow stops. At low saturations, the "pressure" gradient for liquid water may contain a high capillary tension component. This capillary tension gradient is what controls the "wicking" process, but above 2 bars (i.e., 2-3 bars) the effective permeability of water is very low and the flow is extremely slow.

At very high capillary tensions (dry conditions), the pore water vapor in contact with (and in equilibrium with) the pore water will have a significantly lower relative humidity. A way of thinking of it is that the high capillary tension "sucks" some of the water vapor from the air. Hence a relatively dry rock (or dry absorber) has a lower relative humidity. If that drier material is placed near a wetter material, the dry material will draw water vapor from the wetter pore space. Hence the relative humidity gradient can transport pore vapor from the soil to the absorber. The rate of transport depends upon the effective gas permeability.

Subsurface, the relative humidity is generally very high compared to surface air or a "dry absorber." However, in South Carolina, the surface relative humidity can be near 100 percent. That means that an air dried absorber can be heavy with moisture (cigars don't need humidors). In New Mexico, the reverse is true, much of the time. The calculations described hereafter use a very detailed model of the liquid and vapor phase transport to calculate the rate at which vapor and liquid are absorbed in a absorbent collector. The effective permeabilities are deduced from measurements of the soil and absorber characteristics. The gradients evolve as the absorption process progresses. The questions addressed are:

- How much of the absorbed sample is due to vapor vs. liquid transport as a function of the soil saturation and intrinsic permeability?
- How long must an absorber be in contact with the soil before the capillary tension is near equilibrium?

- How long before a diffusion equilibrium can be expected?
- Can the absorbed water be a measure of the soil capillary tension (i.e., a larger absorbed sample for a lower capillary tension)?
- How quickly will an absorbed sample wick along the length of an absorber?
- How do the calculated results compare to the field experience and lab tests?

In the extremes of saturation, one would expect a quick and large liquid sample from a wet soil and a slow, all vapor transport sample from a dry soil.

There are a number of other interesting sampling procedures for dry soils. If, for example, the wine stain described above had dried before a napkin was applied, no wine would soak into the napkin. But, if one applied a wet cloth behind, or next to, the wine stain, water would re dissolve the dried wine and stain the napkin a pink color. Likewise, can one re dissolve precipitated metals or leachate solids and detect their presence with an absorber?

Finally, when the sample is retrieved to the surface, what are the requirements for handling the sample? How quickly are volatiles lost and what can be done to preserve the sample recovered by the SEAMIST procedure? Also, how can the absorbed sample be analyzed?

#### **ADVANTAGES**

Why bother with such an analysis? Because the absorber installation is quick and relatively inexpensive. The absorber can recover liquid samples in soils too dry for suction lysimeters. The use of a full hole length absorber allows a profile of the entire hole. This is especially useful in horizontal holes. The currently evolving vapor analysis methods allow rapid inexpensive analysis of the absorbed materials. The absorber can be left in place to detect an episode of high transport such as fracture flow after a rain shower. Electrical monitoring can detect the time of the episode's flow. The absorber method is especially amenable to monitoring of old and new landfills in the vadose zone. Specially manufactured absorbers (e.g., the Goresorber™) can be used to detect trace amounts of VOC's or other inhabitants of the pore space such as radio nuclides or bacterial population.

#### **DISADVANTAGES**

There are some obvious limitations of absorbers for fluid (i.e., gas, vapor and liquid) collection. The hole must remain open. The sample recovered is sometimes small. The depth of sampling in the hole wall is small unless a flow of the pore fluid is in progress (e.g., a fracture). Many samples are easily obtained and add to the analytical costs. The method is less useful under the water table.

The following description of actual field and laboratory measurements using absorbers is offered as guidance to the appropriate use. Subsequent evaluations are suggested to enhance the utility of the approach.

#### **ACTUAL FIELD AND LABORATORY MEASUREMENTS**

The report by T. C. Rasmussen and D. D. Evans (Ref. 5) summarizes the use of absorbers (mainly filter paper) to wick moisture from soils and rock to measure the capillary tension of the geologic material. The absorbers were presumed to equilibrate with the capillary tension of the geologic sample and the absorber was then measured in a thermocouple psychrometer chamber for its capillary tension (via

relative humidity). The geologic sample was then measured in the same psychrometer. Several conclusions were reached about the process of tension measurements. It is difficult to develop a known tension in a soil or rock sample since the psychrometer measurement and pressure plate measurement often give different results. Within these uncertainties the filter paper absorbers needed to be protected from evaporation, but in general, the filter paper and soil or rock samples compared well if the psychrometer measurement alone is used. But the most important result was that filter paper absorbers wick from 25 percent to 100 percent of their dry weight in the tension range of 10 bars to 0.1 bars. Furthermore, absorbers in contact and absorbers only near the sample often absorbed comparable quantities of water.

More recent uses of the absorber method have provided measurements of contamination concentrations in the absorbed fluids that have compared very well with the "actual value."

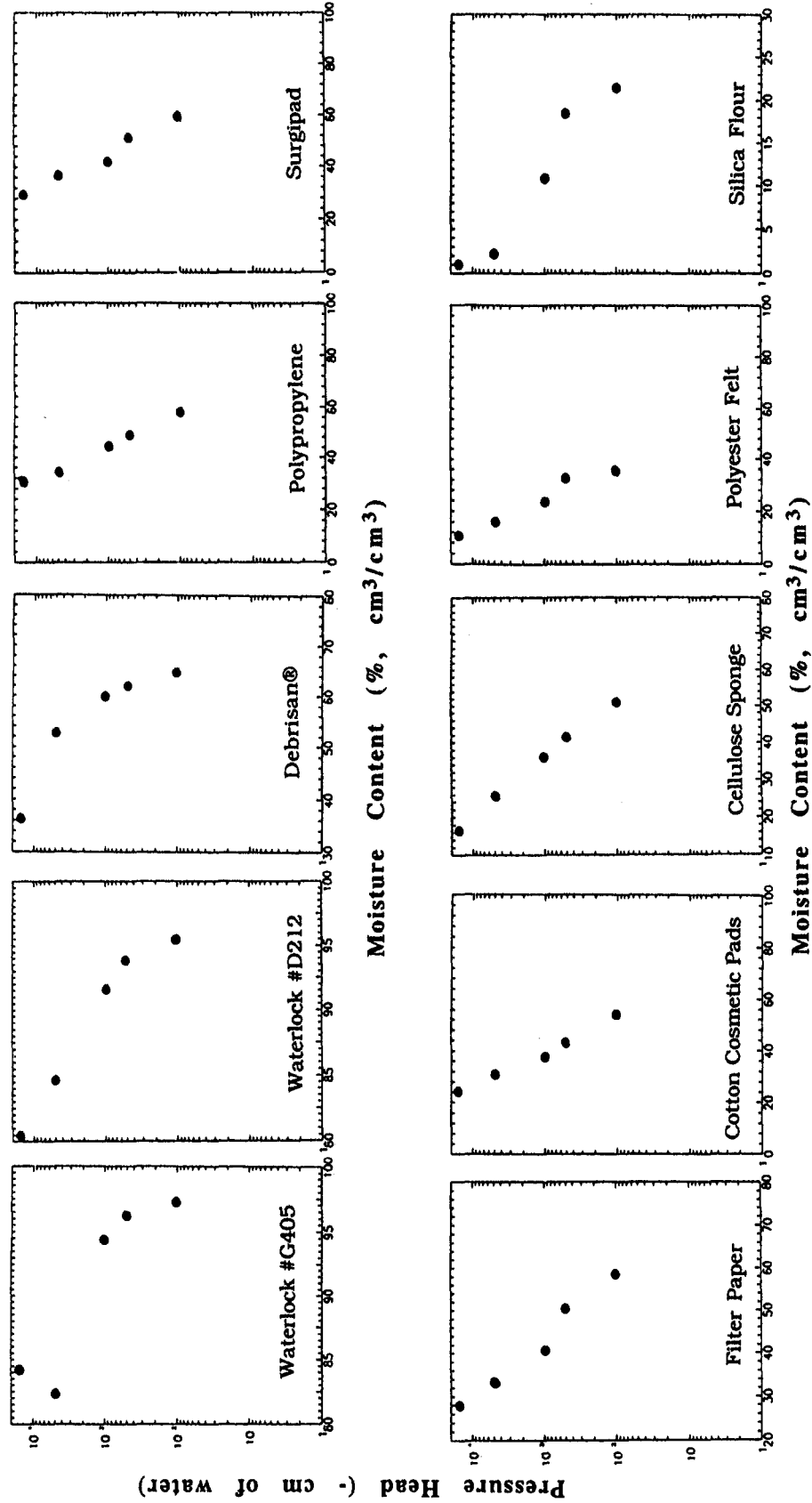
Mallon, et al, presented a paper (Ref. 4) at the 1992 NGWA Outdoor Action Conference which showed the very similar concentrations of tritium in cores, absorbed samples, and in pore vapors extracted from the walls of uncased drill holes. The measurements of  $T^3$  in the core fluids were within 20 percent of the measurements in water wicked from the hole wall a month later. Absorbers have also been used for the collection of  $T^3$  and VOC's by Steve McLin at LANL. The absorbers were installed with SEAMIST via horizontal holes under a low level radiation waste site.

S. Martins, et al, reported measurements of the effect of absorber handling on the measured concentrations in blown polypropylene and cellulose absorbers (Ref. 6). Over a wide range of TCE concentrations and air exposure times, the results were strangely similar. Essentially, 70 percent of the initial TCE contaminant was measured in the absorbed fluids for all the parameters varied.

Measurement of absorbers using the acoustic IR technique is being tested at Ames Lab at Iowa State University (Ref. 7).

As part of a DOE funded program, the characteristics of a wide variety of absorbers were measured by Dan Stephens Associates under contract to Science and Engineering Associates (Ref. 8). The absorbers are described in Appendix A. The characteristic curves (capillary tension vs. saturation) obtained, are shown in Figure 3. The wide range of behavior is impressive. The less aggressive absorbers (e.g., polypropylene and filter paper) are actually the preferred material for several reasons. The very aggressive absorbers (e.g., Waterlock #G405) can collect large quantities of vapor when not in contact with the soil (Table 1). That may be useful for some situations, but they were also found to produce relatively large amounts of dissolved solids from their own components. (Table 1) shows the conductivity measured in 50 ml of water added to each of the materials. The ions contributing to the higher conductivities were not identified. They may not interfere with some contaminants wicked from the hole wall. There is clearly a need for a more rigorous analysis of the absorber materials, but the measurement of the water absorbed by each material (Table 1), when placed on soil samples with 1.0, 5.0 and 15.0 bar capillary tension, shows that one can obtain a substantial fluid sample in the five selected absorber materials. The last four materials were not fully measured, because they either absorbed much less water or were not easily obtained in pure form.

Figure 3. Characteristic curves measured for 10 absorbent materials.



**Caution:** The abscissa as reported in Ref. 8 ( $\% \text{ cm}^3/\text{cm}^3$ ) is actually  $\frac{\text{MassH}_2\text{O}}{\text{MassH}_2\text{O} + \text{MassAbsorber}}$ .

Because the absorbers swell during absorption, percent saturation is an elusive concept. The calculational model used the abscissa as the percent water by volume.

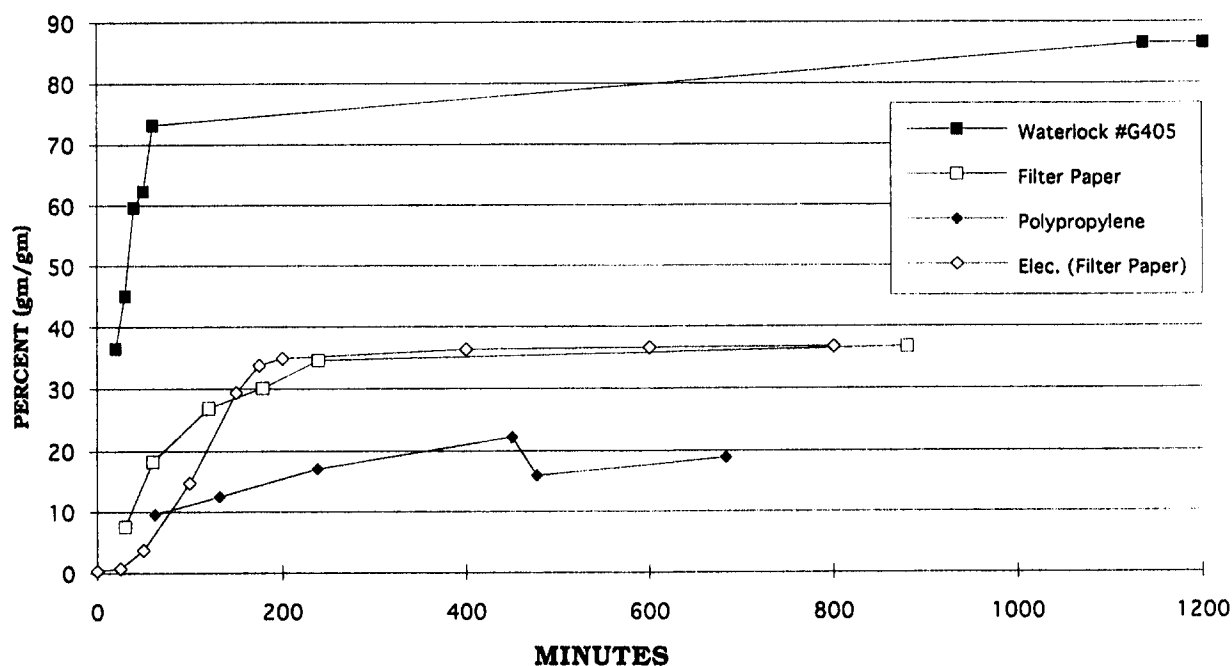


**TABLE 1**

Absorber	Dry Wt. (gm)	Vapor Conductivity Absorption in 50ml (% Dry Mass) Water	Water Absorbed from Soil (ml/gm)			
			-15 Bar	4.9 Bar	1.0 Bar	
Waterlock #G405	0.84	117.9	206.0*	5.37	4.66	16.71
Waterlock #D212	0.85	97.6	336.0*	N.A	N.A	N.A
Debrisan®	4.72	51.5	17.4	0.56	1.32	1.88
Polypropylene	0.72	6.9	11.4	0.53	1.11	1.84
Surgipad	0.88	5.7	24.8	0.43	3.65	4.57
Filter Paper	0.88	25.0	4.8	0.75	0.91	2.16
Cotton Cosmetic Pads	1.09	9.2	9.0	N.A	N.A	N.A
Cellulose Sponge	4.17	27.8	256.0	N.A	N.A	N.A
Polyester Felt	0.97	0.0	4.4	N.A	N.A	N.A
Silica Flour	3.50	0.0	31.2	N.A	N.A	N.A

\* Conductivity measured in 100 ml of water.

Another measurement to characterize the absorbers was the rate of fluid uptake when placed upon a silty, coarse, angular sand at 0.3 bar tension. Figure 4 shows some of the water absorption volumes vs. time. Electrical conductivity measurements were made in the absorbers, using a simple wire pair between the absorber and soil, during the absorption process to determine if the electrical measurement was a practical indication of the approach to equilibrium and therefore the time required before retrieval of the absorber. The electrical measurement agreed very well with the absorbed mass measurement. In Figure 4 the approach to 90 percent of the apparent asymptote occurs at 150 minutes for the electrical measurement (vs. ~160 minutes for the mass absorption) for a filter paper absorber. The details of the measurements are described in (Ref. 8). Measured vs. calculated absorption rates are discussed later. One must be careful of the concept of equilibrium based upon short time measurements.



**Figure 4.** Absorption rate.

This brief review of absorber behavior shows that there are a wide range of characteristics from which to choose. More exotic absorbers, such as litmus paper, which react in a special way with the pore fluids, are the subject of future research and evaluation.

**CALCULATIONS OF THE ABSORPTION PROCESS**

A variety of calculations were performed using the Los Alamos National Laboratory code called TRACR3D (Ref. 9). The TRACR3D code includes the essential porous flow model features of the vapor and liquid flows from the soil to the absorber. The absorbers chosen were the polypropylene/cellulose and filter paper absorbers discussed above. The soil characteristics were of several kinds to determine how they might affect the absorption rate and total sample size collected. One dimensional calculations were done to allow faster computation and to avoid geometric effects.

The combinations of absorber, soil type, and soil conditions calculated are tabulated in (Table 2). The SL, LS and SC soil types are those used in the paper by A. Bumb, et al, in a study of lysimeter spacing (Ref. 10). The absorber properties and Hanford soil properties were those reported in Reference 8. The absorbers initially had the moisture content characteristic of a 40% relative humidity.

**TABLE 2**  
**Calculational Matrix and Material Parameters**

<b>Absorber</b>	<b>Soil</b>	<b>Soil Sat. Permeability</b>	<b>Initial Soil Saturation</b>	<b>Initial Soil Tension</b>
Filter Paper <sup>1</sup>	Hanford	21md	0.49	0.3 Bars
Polypropylene <sup>2</sup>	Hanford	21md	0.49	0.3 Bars
"	LS (Loamy Sand)	15md	0.203	0.3 Bars
"	SL (Silty Loam)	2md	0.52	0.3 Bars
"	SC (Silty Clay)	.3md	0.72	0.3 Bars

**NOTE:** 1d = One Darcy =  $\sim 10^{-3}$ cm/sec. for water.

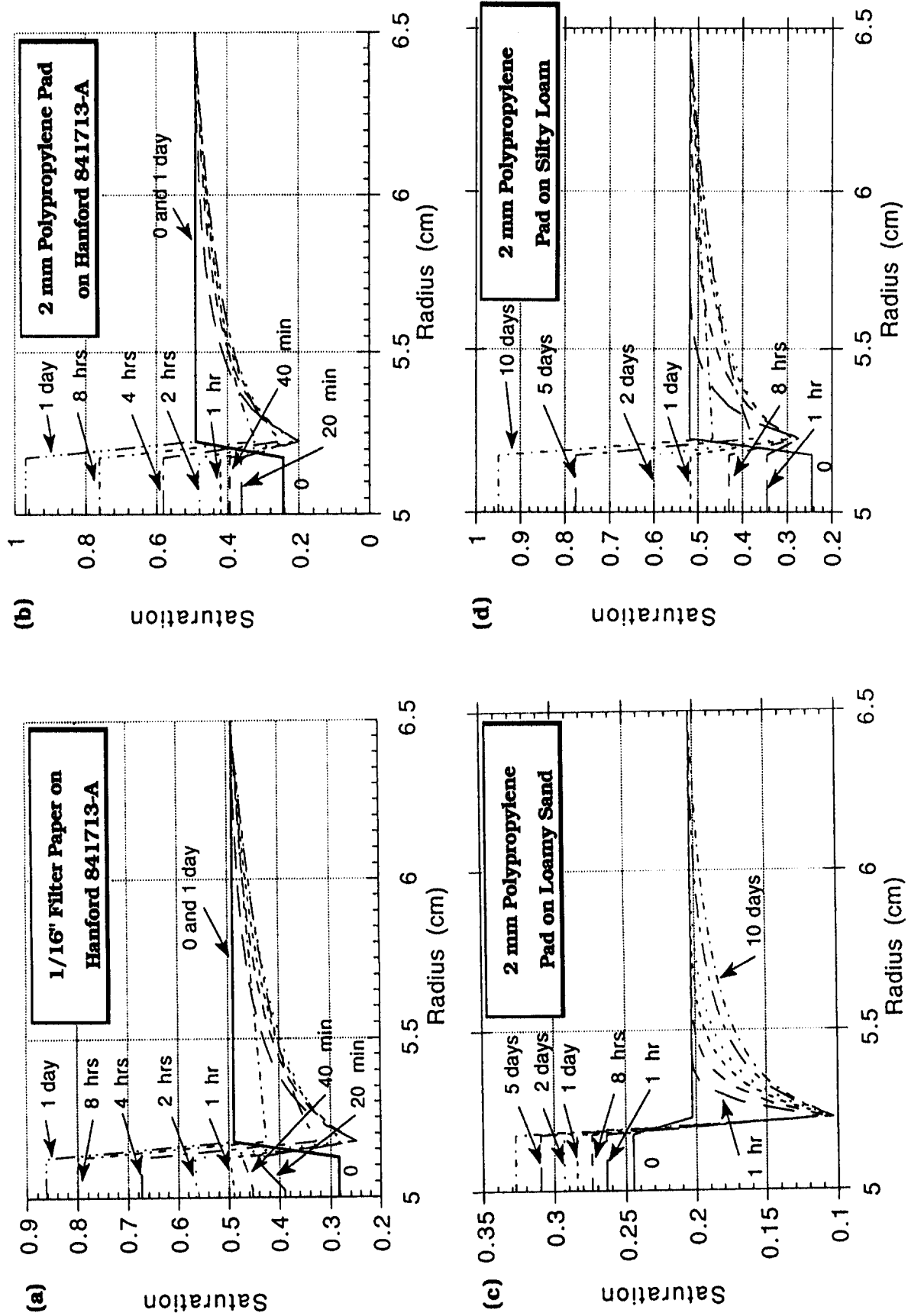
<sup>1</sup> Filter paper saturation permeability = 13md, saturation = 0.283 (40% relative humidity).

<sup>2</sup> Polypropylene saturation permeability = 19d, saturation = 0.245 (40% relative humidity).

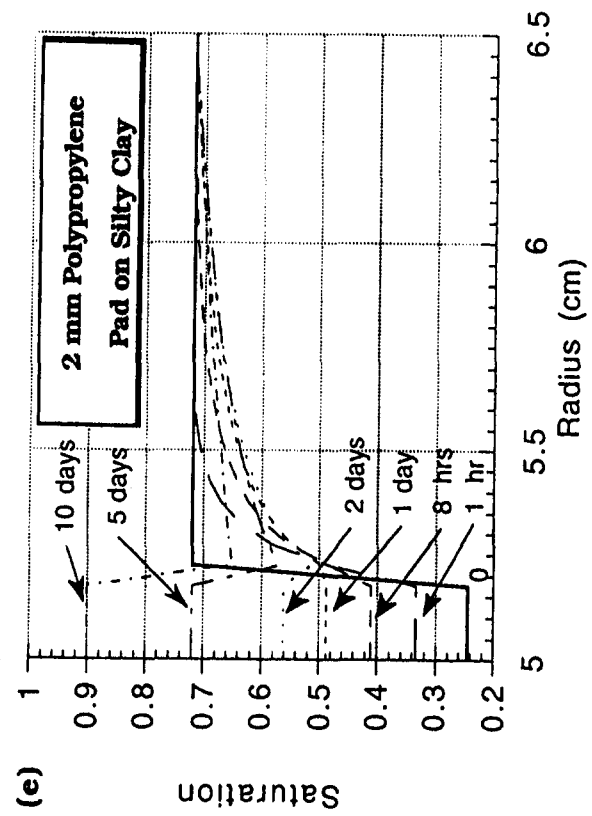
The absorption from Hanford soil was measured with both filter paper and polypropylene absorbers and can be compared directly to the calculations. The comparison of behavior according to soil type is possible for the polypropylene absorber calculated on all four soils.

The calculation results at first glance (shown in Figure 5(a-e)) were surprising. The amount of water absorbed in the filter paper and in the polypropylene from the Hanford soil was almost exactly that measured in absorbers on the porous plate at 0.3 bars (the initial soil tension). It was more water than absorbed from the Hanford soil at 0.3 bars. The reason is that the characteristic curve used was the drainage curve measured on the porous plate. The imbibition curve of the Hanford soil was not measured. However, the imbibition curve might be inferred from the imbibition measurements had they been conducted at several soil saturations.

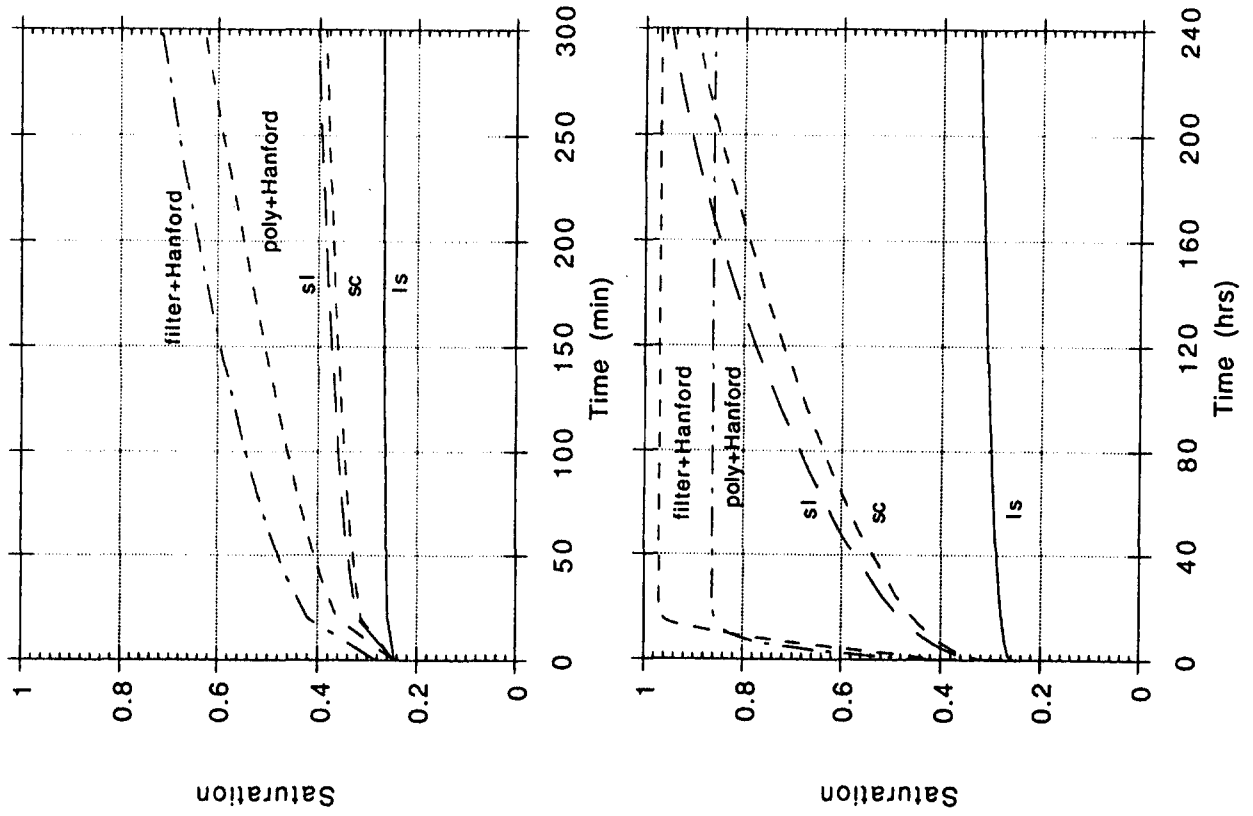
**Figure 5.** Saturation distribution in the absorber and soil at indicated times.



**Figure 5 (cont.).** Saturation distribution in the absorber and soil at indicated times.



**Figure 6.** The saturation increase versus time for the five calculations of Table 2.



The calculated rate of absorption for the filter paper (shown in Figure 6) was slower than the measurements shown in Figure 4. Whereas about 90 percent of the water was actually absorbed in the filter paper by 160 min., the 90 percent increase in saturation was not calculated to occur until near 360 minutes. That was only a small surprise compared to the calculated absorption from the loamy sand (LS) soil. Figure 6 shows the three very different rates of absorption calculated. The surprise is that the Hanford soil and the LS soil have nearly the same permeability (Table 2). How can they behave so differently? The clue is in the initial saturation plot of Figure 5(c). Only the LS soil starts with an initial saturation below that of the absorber even though all the soils were at 0.3 bar tension. The immediate drop of the soil to near its irreducible saturation (8%) drives the effective water permeability to near zero. Unlike the other soils, the LS saturation stays depressed near the absorber for the following ten days. It is likely that the polypropylene absorption is mainly due to vapor transport. In light of the strong effect of the effective permeability on the transport and the approximate nature of the Brooks-Corey relationship used to calculate effective permeabilities, the Hanford soil calculations are pretty good.

One of the very tempting aspects of this work is to try to use the absorbers to deduce the effective permeability vs. saturation for soils.

This review paper does not allow space for a thorough discussion of the calculational results, but one must conclude that the fine grained soils like SL and SC may be more easily sampled with absorbers than a more coarse grained soil like LS. The Hanford soil described as "a silty, coarse, angular sand" happens to be the easiest to sample. The uncertainty in absorption rate makes the use of electrical monitoring of absorption (described earlier) the more useful.

## **CONCLUSION**

Measurements of absorber characteristics and absorption rates coupled with calculations of the absorption process have shown that fluid samples can be obtained in reasonable volumes and times for many, but not all, soils. These results provide guidance on the selection of absorbers, thickness of absorbers, emplacement times and potential pitfalls. However, there are a number of promising extensions of the work reported here. Those can be listed as follows:

- Improve the speed (reduce the cost) of absorber analysis.
- Extend the calculations with parameter variations and the use of tracers in the vapor to obtain more understanding of vapor versus liquid transport.
- Calculate and test the ability to increase the absorption rate for dry soils by liquid injection near the absorber.
- Further evaluate the effects of sampling and sample handling procedures.

This brief paper is meant to better define the growing results and useful direction of subsequent research rather than to answer all questions. But the method of absorber collection is already very useful as a contamination mapping technique. The work on absorber analysis at Ames Lab may make it inexpensive as well as fast.

## REFERENCES

1. C. Keller and B. Lowry, "**A New Vadose Zone Fluid Sampling System for Uncased Holes,**" Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, pp. 3-10, May 4-17, 1990, Las Vegas, Nevada, presented by the Association of Ground Water Scientists and Engineers (division of NWWA).
2. C. Keller, "**So, What is the Practical Value of SEAMIST?**" Proceedings of the Fifth National Outdoor Action Conference on the Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, May 1991, Las Vegas, Nevada.
3. C. Keller, "**A Serious Vadose Defense of Ground Water from Landfill Contamination - New Concept, Old Principles**" Proceedings of the Sixth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods in May 1992, Las Vegas, Nevada.
4. B. Mallon, S. A. Martins, J. L. Houppis, W. Lowry, D. C. Cremer, "**SEAMIST™ Soil Sampling for Tritiated Water: First Year's Results,**" Proceedings of the Sixth National Outdoor Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods in May 9-13, 1992, Las Vegas, Nevada.
5. T. C. Rasmussen, D. D. Evans, "**Unsaturated Flow and Transport Through Fractured Rock Related to High-Level Waste Repositories,**" Department of Hydrology and Water Resources, University of Arizona, NUREG/CR-4655, Prepared for U.S. Nuclear Regulatory Commission.
6. S. A. Martins, G. L. McQueen, R. E. Martinelli, M. C. Jovanovich, "**Factors Affecting Trichloroethylene (TCE) Recovery from SEAMIST™ Pads,**" Presented at the American Geophysical Union, 1992 Fall Conference, Lawrence Livermore National Laboratory Report No. UCRL-JC-110604.
7. John McClelland. Ames Laboratory, Iowa State University, personal communication, , January 1993.
8. S. M. Narbutovskih, "**The Use of Absorbent Materials to Collect In Situ Vadose Zone Liquids,**" Science and Engineering Associates, Inc., Topical Report, Task 3.1 Perfect the Absorbent Collector System of Contract No. 02112408, Argonne National Laboratory, March 14, 1992, Santa Fe, New Mexico.
9. B. J. Travis, K. H. Birdsall, "**TRACR3D: A Model of Flow and Transport in Porous Media,**" Report No. LA-11798-M, Los Alamos National Laboratory, April 1991.
10. Bumb, C. Amar, McKee, R. Chester, Evans, B. Roy, and Eccles, A. Lawrence, "**Design of Lysimeter Leak Detector Networks for Surface Impoundments and Landfills,**" Landfills, NGWA Anthology, January 1992.

## APPENDIX A

### Absorbent Materials

1. **Waterlock #G405**..... A copolymer consisting of 2-propenamide and 2-propenoic acid with a sodium salt. Particle size is approximately 1 mm.  
Property..... Potential to absorb 400 times its own weight in water.
2. **Waterlock #D212**..... A starch containing grafted side chains consisting of 2-propenamide and 2-propenoic acid, mixed sodium and aluminum salts copolymers. Particle size distribution ranges from 40 to 200 mesh.  
Property..... Potential to absorb 350 times its own weight in water.
3. **Debrisan®**..... A three dimensional network of macromolecular chains of cross-linked dextran. Particle size ranges from 0.1 to 0.3 mm.  
Property..... Absorbs four times its own weight in water.
4. **Polypropylene sorbent**... Polypropylene material pad with some cellulose.  
Properties..... Absorbent, chemically pure, economic, easily packaged for membrane attachment.
5. **Surgipad**..... Cotton with cellulose inner layers, enclosed in a non-woven rayon fabric.  
Properties..... Absorbent, chemically pure, economic, easily packaged for membrane attachment.
6. **Filter paper**..... Whatman #42, low ash, fine grain.  
Properties..... Chemically pure and relatively inert, economic, easily packaged for membrane attachment.
7. **Cotton cosmetic pads**.... thin, circular, 5.5 cm diameter 100% cotton pads.  
Properties..... Absorbent, chemically pure, economic, easily packaged for membrane attachment.
8. **Cellulose sponge**..... A natural wood pulp cellulose.  
Properties..... Absorbent, economic, easily packaged for membrane attachment.
9. **Polyester**..... 100% one inch thick polyester batting.  
Properties..... Absorbent, chemically pure, economic, easily packaged for membrane attachment.
10. **Silica flour**..... 200 mesh silica.  
Properties..... Chemically pure and relatively inert, economic.