Determination of Hydrophobicity Index: Standard and Mini Disk Infiltrometers

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Abstract

Soil hydrophobicity drastically impacts water infiltration, retention and transport. Hydrophobicity index, a ratio of the sorptivity of water to ethanol, is a common measure of soil hydrophobicity. The sorptivity may be measured using the disk infiltrometer. The standard disk infiltrometer is large, cumbersome and expensive while the mini disk infiltrometer is compact and readily accessible. The objective of this study was to determine if the mini disk infiltrometer is comparable to the standard disk infiltrometer as a means of analyzing the soil hydrophobicity index. The soil hydrophobicity index was calculated from the sorptivities of water and ethanol as determined by both infiltrometer methods. Results indicate no statistical difference between soil hydrophobicity indices calculated from the standard and mini disk infiltrometer methods.

Introduction

Soil hydrophobicity is the reduced adhesion between soil and water. This includes severe cases where water will not infiltrate the soil surface but is most often observed as a reduction in infiltration rate (Tillman et al., 1989). This is a widespread and naturally occurring phenomenon (DeBano, 2000). A major cause of soil hydrophobicity is organic coating of soil particles. Coarse textured soils are far more susceptible to hydrophobicity (Woche et al., 2005). High degrees of soil hydrophobicity may affect soil erosion rates and water storage capacity.

The infiltration rate of a liquid into soil is related to its sorptivity; the cohesion between the soil and the liquid. Philip (1969) describes sorptivity as:

$$S = \frac{i}{\sqrt{t}} \tag{1}$$

where S is sorptivity (cm hr $^{-1/2}$), i is infiltration (cm) and t is time (hr). This is conveniently the slope of the cumulative infiltration plotted against the square root of time.

Water infiltration is impeded by soil hydrophobicity, while ethanol infiltration is not . In a soil that has no hydrophobicity water and ethanol will infiltrate at a similar rate; however, in a soil that is hydrophobic infiltration of water will be slowed and ethanol will be unaffected by the hydrophobicity. Thus the ratio of the sorptivities of water and ethanol provide an indication of the degree of soil hydrophobicity. The hydrophobicity index (HI) (Tillman et al., 1989) is calculated as:

$$HI = \frac{S_E}{S_W} \tag{2}$$

where S_E and S_W are the sorptivities of ethanol and water respectively (cm hr $^{-1/2}$). The hydrophobicity index is more sensitive than other measures of soil hydrophobicity, such as molarity of ethanol droplet test and water droplet penetration time test (Wallis et al., 1991). A hydrophobicity index higher than one indicates that soil hydrophobicity is present.

Sorptivity may be measured by the disk infiltrometer (Perroux and White, 1988). The disk infiltrometer infiltrates liquid into the soil at a negative tension. The soil has to 'suck' the liquid out of the instrument. The effect of gravity is not driving infiltration. Thus this is an appropriate measure for the infiltration into unsaturated soil and the sorptivity of the liquid being infiltrated.

The standard disk infiltrometer is a large, expensive piece of equipment, but is adaptable both in the range of tensions and the disk sizes available. It is cumbersome for in situ measures and larger volumes of liquid needs to be transported to study sites. The mini disk infiltrometer is more compact and requires less liquid, but is less adaptable in tension and disk size. The standard disk infiltrometer uses a 30µm nylon mesh tightly drawn over disks of interchangeable sizes as the membrane between the liquid and the soil, while the mini disk infiltrometer uses a 4.5 cm sintered steel disk. The standard disk infiltrometer is able to infiltrate larger volumes into the soil and as such, requires greater time in the field.

If the mini disk infiltrometer is comparable to the standard disk infiltrometer for measuring soil hydrophobicity index, then the hydrophobicity index may be used at higher frequency with greater ease. The objective of this study was to determine if the mini disk infiltrometer is comparable to the standard disk infiltrometer for in situ measures of soil hydrophobicity.

Materials and Methods

Study Sites

The study was carried out in the summer of 2008 on six sites in western Canada (Table 1). Five were sandy textured sites located in the grey luvisol and organics soil group of Northern Alberta. Of these, three were undisturbed A ecosites (SV10, SV27 and A ecosite 1) and two were reclaimed from open pit oil sands mining (AlbianSands Instrumented Slope and Suncor Coke Cover). The sixth site was an undisturbed grassland on clay textured soil located in the brown soil zone of Saskatchewan (St. Denis). Measurements were taken between June 26 and October 10, 2008.

Table 1. Study sites

Site	Description	Soil Texture	Location
SV10	Undisturbed A ecosite in northern Alberta	96% Sand 3% Silt 0.8% Clay	N 63º 25' E 04º 63'
SV27	Undisturbed A ecosite in northern Alberta	90% Sand 7% Silt 3% Clay	N 63º 73' E 04º 73'
A ecosite 1	Undisturbed A ecosite in northern Alberta	88% Sand 12% Silt 0.5% Clay	N 57º 16' W 111º 33'
AlbianSands Instrumented Slope	Mineral-peat mix over tailing sand in northern Alberta	68% Sand 19% Silt 21% Clay	N 63º 46' E 46º 84'
Suncor Coke Cover	Mineral-peat mix over coke in northern Alberta	56% Sand 22% Silt 21% Clay	N 57° 36' W 111° 30'
St. Denis	Grassland in central Saskatchewan	29% Sand 42% Silt 29% Clay	N 52º 13' W 106º 05'

Methods

Five points at each site were selected. At each point both tap water and 95% ethanol were infiltrated using the standard and mini disk infiltrometers. An area of approximately $1m^2$ was cleared of vegetation and leveled with a hand shovel and straight edge. Care was taken to minimize compaction.

Measurements from the standard infiltrometer were taken for 20 minutes at each 10, 7, 5 and 3 cm tensions via a 20 cm disk consisting of 30 μm nylon mesh membrane. Measurements were taken at all tensions without moving the equipment. Samples were collected before and after for initial and final moisture contents.

Measurements from the mini disk infiltrometer were taken for 10 minutes at 6 and 3 cm tensions via a 4.5 cm disk consisting of a sintered steel disc.

Early time sorptvities for were calculated from the 3cm tension readings from each treatment as in eq. 1. The sorptivity was calculated from the first two measurable movements in liquid level then averaged.

Results and Discussion

Table 2 shows the difference between the measured water sorptivity between the two disk infiltrometer methods. The mean difference between the methods was -.0798 cm $hr^{-1/2}$. The range of differences was small and there was no clear trend of one method being consistently higher or lower than the other.

Table 3 and Figure 1 illustrate the differences in the hydrophobicity indices calculated from both methods. The mean difference between the methods was -0.365 cm $hr^{-1/2}$. There was no statistical difference between the methods.

Table 2. Sorptivity (cm $hr^{-1/2}$) of water as measured by the standard and mini disk infiltrometers.

Site	Standard Infiltrometer	Mini Infiltrometer	Difference
AlbianSands Instrumented Slope	1.65	1.40	0.25
Suncor Coke Cover	1.77	6.50	-4.73
SV27	1.69	1.41	0.28
SV10	1.97	2.66	-0.69
A ecosite 1	1.02	0.88	0.14
St. Denis	0.89	0.93	-0.04

Table 3. Hydrophobicity Index as measured by the standard and mini disk infiltrometers.

Site	Standard Infiltrometer	Mini Infiltrometer	Difference
AlbianSands Instrumented Slope	2.67	3.24	-0.57
Suncor Coke Cover	1.68	1.16	0.52
SV27	4.18	3.57	0.61
SV10	1.18	0.66	0.52
A ecosite 1	6.70	12.63	-5.93
St. Denis	3.64	0.98	2.66

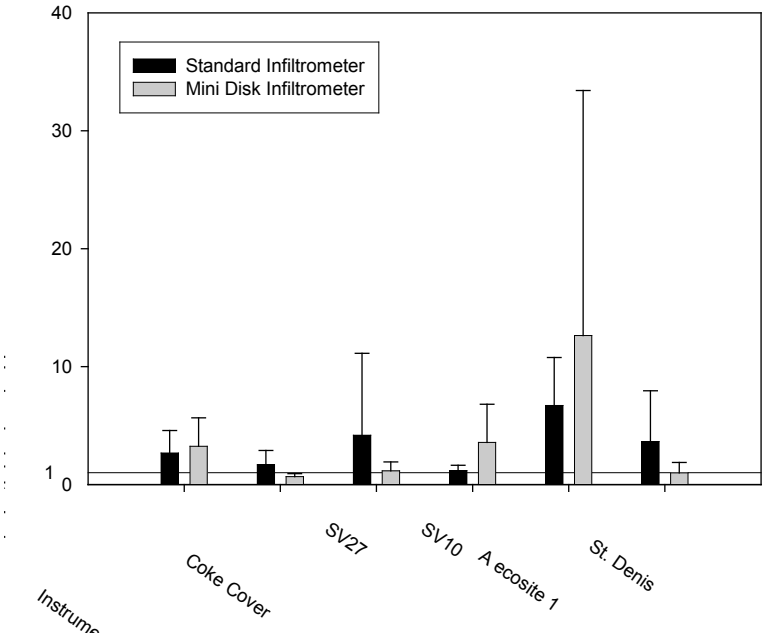

Figure 1. Hydrophobicity index

There was no significant difference between the standard and mini disk infiltrometer methods (p=0.800). This study concludes that the mini disk infiltrometer is comparable to the standard disk infiltrometer for in situ measures of soil hydrophobicity index. This may aid in maximizing the breadth of studies on hydrophobicity. The mini disk infiltrometer may be widely applied with confidence in its measures.

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