疎水性有機化合物，粘土，含水比が比較的乾いた土の撥水性に及ぼす影響

Effects of Hydrophobic Organic Compounds, Clay, and Water Content on Water Repellency of Relatively Dry Soils

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INTRODUCTION

Water repellency is supposed to be caused by low energy surfaces resulting in weak attraction between solid and liquid phases. It may break down when exposed to water for long time. Clay additions have long been used as an effective way to reduce water repellency in sandy soils. Kaolinitic clays were the mostly used to increase the wettability of soils.

Many researchers world wide have studied the relationship between water content and soil water repellency. Many have reported that water repellencies increased with decreasing water content. They have found that soil become readily wettable above a particular water content, which is called critical water content. Conversely, Doerr et al. (2002) have reported that water repellency of air dried soils increased with increasing relative humidity (RH). It means water content is directly related to water repellency at relatively dry state. They have explained this as an effect caused by expansion of hydrophobic parts into pore spaces as organic-mineral bonds disrupted by energy released from water vapor condensation. de Jonge et al. (1999) have reported different behaviors of soils with water content including two maximum repellencies with first peak at complete dry condition. This first peak was explained as a result of drying samples at 60ºC. Some soils did not vary with soil water content. Yet, considering available literature, it is possible to decide that there are two readily wettable limits in soil with maximum repellency between them (Figure 1).

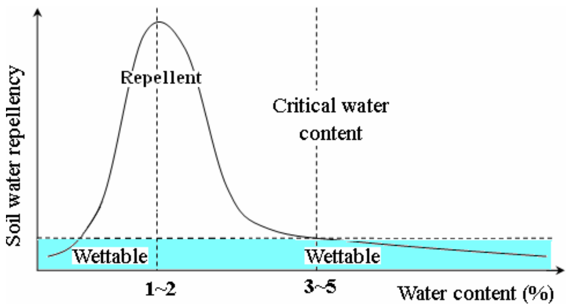

Figure 1. Relationship between water content and water repellency.

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土の撥水性，疎水性有機化合物，粘土，含水比

As water repellency seems sensitive to many variables in natural soil, findings often have contradictions. Studying effects of individual soil components on soil water repellency is important to clarify these phenomena. Thus the objective of this study is to determine effects of hydrphobicity of organic materials, clay content, clay type, and water content on water repellency of relatively dry soils.

MATERIALS AND METHOD

Fine silica sand with 94% of mass is between 53~150 μm was used as a model soil. Effects of kaolinite and Na-montmorillonite on soil water repellency under different RH levels were assessed with and without hydrophobic organic compound. To prepare samples with hydrophobic organic compound, sand was mixed with 0.1% stearic acid (molecular weight 284.5). Since stearic acid is insoluble in water, it was dissolved in diethyl ether and mixed with sand. Samples were allowed for volatilization and kept for one day. Sands were mixed with kaolinite or montmorillonite to obtain 1%, 2% and 5% clay contents. Nearly 5 g of each sample in three replicates were exposed to RH levels of 33%, 57%, 75%, 94% and 100% at 25ºC for 20~22 hours. Wettability or repellency of samples was estimated using water drop penetration time (WDPT) test. One drop of distilled water with 50±1 μl volume placed on the soil surface using a burette at approximately 10 mm height. Time taken for complete penetration of the water drop was measured. Average penetration time of three replicates was taken as the WDPT for the particular sample.

RESULTS AND DISCUSSION

Water content of samples increased with the amount of clay only in case of montmorillonite (Figure 2B). This might be due to higher water adsorption of montmorillonite than kaolinite. Water content of samples after exposure to each RH was not affected by presence or absence of 0.1% stearic acid, which means hydrophobic compound might not affect the adsorption of water vapor.

Water repellency of stearic acid treated sand increased with clay addition and decreased again with increasing clay content (Figure 3). When

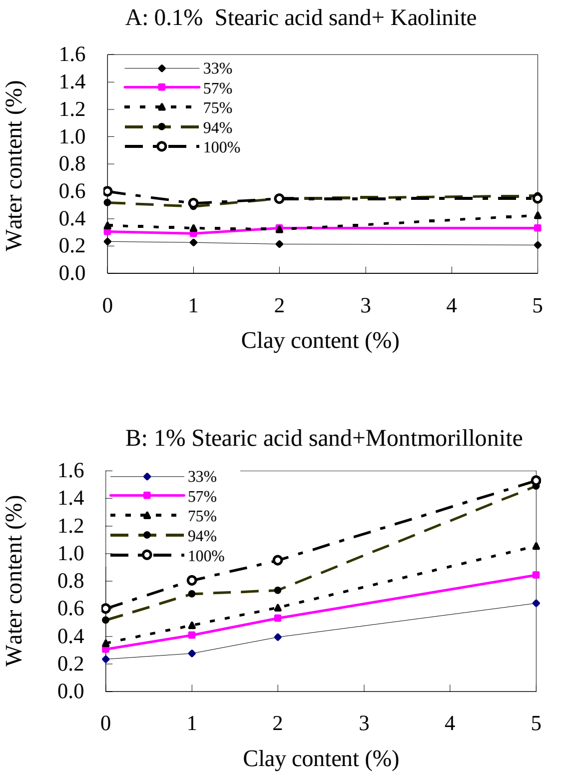

Figure 2. Effects of clay content on soil water content of stearic acid sand under different relative humidities.

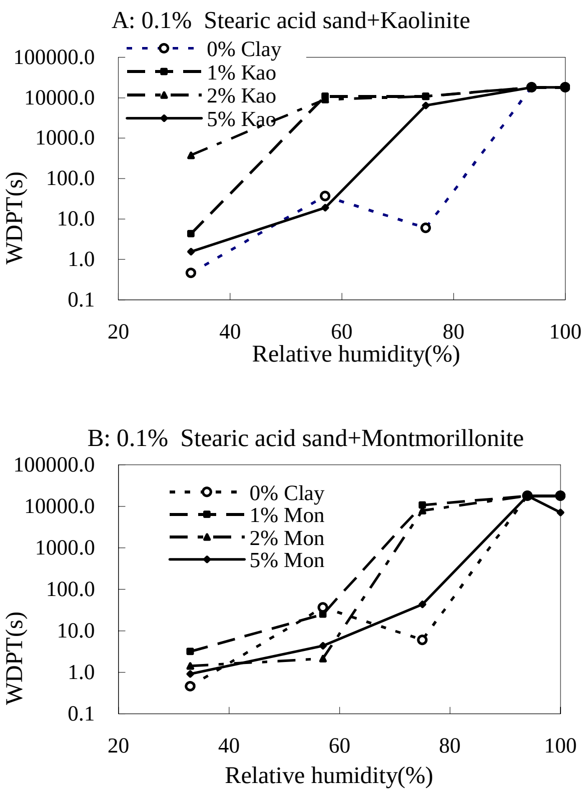

Figure 3. Effects of relative humidity on water repellency of stearic acid sand at different clay contents.

stearic acid was mixed, sand might be covered with hydrophobic organic coating and repel water from sand surfaces. With addition of clay, smaller clay particles might block pores limiting the available pore spaces for water entry, which might result in reduced wettability (increased repellency). However clays are originally wettable and thus soil may tend to adsorb more water with increasing clay content, especially in case of montmorillonite. WDPTs of all samples without stearic acid were less than one second regardless of clay type, clay content, and water content, suggesting that soils free of hydrophobic organic compound might be wettable at any state.

Stearic acid treated samples were wettable at low RH and repellency increased with increasing RH (Figure 3). At higher water content above a certain value, repellency might decline again.

Samples equilibrated at low RH have lower water potentials resulting in readily wettable soils. With increasing RH, surface tension of soil will be lowered. Young's equation relates surface tensions to contact angle:

$$\cos\theta = \frac{\gamma_{SG} - \gamma_{SL}}{\gamma_{LG}}$$

where θ is the contact angle, γ_{SG}, γ_{SL} and γ_{LG}, are surface tensions (Jm^{-2}) of solid/gas, solid/liquid and liquid/gas respectively. As γ_{SG} decreased, numerator decreases and consequently reaches a negative value, reducing wettability and making soil repellent. Conversely, with increasing water content, cohesion force increases and at a certain point, it might overcome the surface repellency. Water content at this point is called critical water content in literature and above this point any soil become readily wettable. Between these readily wettable limits, integrate effect of above two phenomena might give the apparent water repellency of soil (Figure 4).

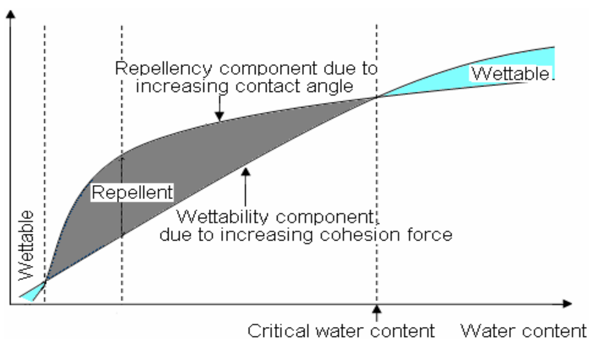

Figure 4. Integrate effect of repellency component and wettability component.

REFERENCES

1. S. H. Doerr et al. 2002, Soil Sci. Soc. Am. J. 66: 401-405.
2. de Jonge et al. 1999, Soil Sci. Soc. Am. J. 63:437–442.