砂質土の撥水性に及ぼす疎水性有機物と親水性有機物の影響

Effects of Hydrophobic and Hydrophilic Organic Matter on Water Repellency of Sandy Soils

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INTRODUCTION

Soil water repellency is increasingly being recognized as a common phenomenon impacting hydrological functions of soil systems. Soil-water contact angle is often being used to explain the soil water repellency.

Water repellency is associated with the content and the composition of soil organic matter (SOM). The degree of hydrophobicity has been reported to be positively correlated with the SOM content. Soil water repellency is widely accepted to be caused by the hydrophobic organic compounds, which is only a fraction of the total SOM content. Hydrophobic organic compounds are thought to be existing as coatings on mineral surfaces.

The ratio between hydrophobic and hydrophilic functional groups in SOM may be used for explaining the water repellency. Theoretically, the contact angle would be increased with increasing hydrophobic/hydrophilic ratio. However, soil type dependent factors may affect the relationship between contact angle and different organic compounds. A relationship between contact angle and hydrophobic/hydrophilic ratio can be obtained by using model soils. The objective of this study is to assess the effects of hydrophobic and hydrophilic organic compounds on water repellency of sandy soils.

MATERIALS AND METHODS

Fine silica sand was used as the base material to prepare model sandy soils. Stearic acid (SA) and guar gum (GG) were used as the hydrophobic and hydrophilic organic compounds, respectively.

Five sample series with each consisted of eight samples were prepared for the repellency measurements.

To prepare the samples with hydrophilic organic compound, GG was dissolved in distilled water and mixed with the sand using a spatula and dried at 30°C for one day. To obtain the samples with hydrophobic organic compound, SA was dissolved in diethyl ether and mixed with the sand in a fume hood. Samples were kept 2 h in the hood to allow volatilization of diethyl ether. To prepare samples with both SA and GG, sand was first mixed with SA, and next mixed with GG. Water repellency was estimated by the sessile drop method (SDM).

A monolayer of sand sample fixed on a glass slide using a double-sided adhesive tape was used for the SDM method. A drop of deionized water with 10-μL volume was placed on the sand surface using a micro-pipette. A digital micro-photograph of the horizontal view of the water drop was taken within 1 with a microscopic camera. Contact angle was measured using the micro-photograph.

Surface free energy of solids, γ_S can be calculated with contact angle data using Eq. (1):

$$\cos\theta = 2\Phi\,(\gamma_S/\gamma_L)^{1/2} - 1 \qquad (1)$$

where θ is the contact angle, Φ is the interaction parameter, and γ_L is the surface tension of the test liquid. Considering water as the test liquid and Φ as 0.6 the surface free energy of solids can be calculated using eq. (2):

$$\gamma_S = 50\,(\cos\theta + 1)^2 \qquad (2)$$

撥水性，有機物，接触角

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RESULTS AND DISCUSSION

Contact angle and soil surface free energy in relation to SA/GG ratio (when the GG content was constant) is presented in **Fig. 1**. Contact angle increased (surface free energy decreased) with increasing SA/GG ratio up to 0.4. Considering the data of our previous experiments, particles were considered to be partially coated with hydrophobic organic material up to this ratio. In samples where the particles were fully coated with hydrophobic material (SA/GG ratio=1) hydrophobic/hydrophilic ratio did not increase the contact angle.

Fig. 2 shows the relationship between SA content and contact angle in the four series of samples containing SA. Contact angle sharply increased with increasing SA content up to 1 g kg^{-1}. At 5 g kg^{-1} SA content, where the particles were considered to be fully coated with SA, contact angle showed slight decrease in samples with both SA and GG. Here, GG might have covered the SA surfaces and increased the net surface free energy. At same SA content, contact angles were roughly comparable except the samples with only SA.

Fig. 3 presents the relationship between total SOM and contact angle. Contact angle sharply increased with increasing total SOM content in the initial stage. However, the results cannot be explained using only the total SOM content. At the same total SOM content, the contact angles of the samples in different series were not comparable.

Results suggest that total SOM content would not provide satisfactory information about the soil water repellency. In addition, the SA/GG ratios would not be sufficient to explain the contact angle data.

These results indicate that compared with the total SOM content and the hydrophobic/ hydrophilic ratio, the hydrophobic organic matter content of soil would be a better indicator of soil water repellency.

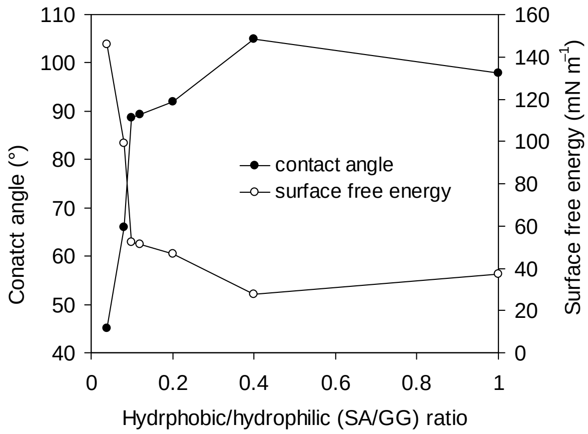

Fig. 1 Contact angle and soil surface free energy in relation to SA/GG ratio. Guar gum (GG) content was constant. SA: stearic acid.

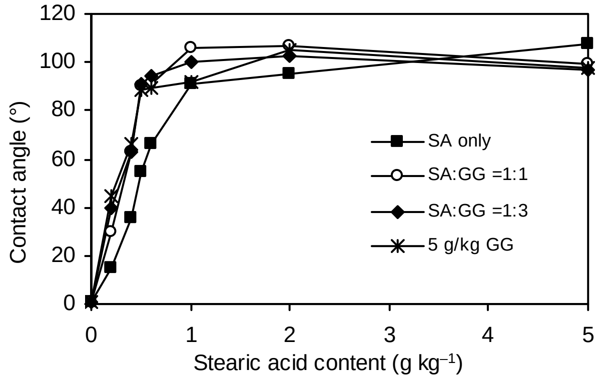

Fig. 2 Relationship between stearic acid content and contact angle. SA: stearic acid; GG: guar gum.

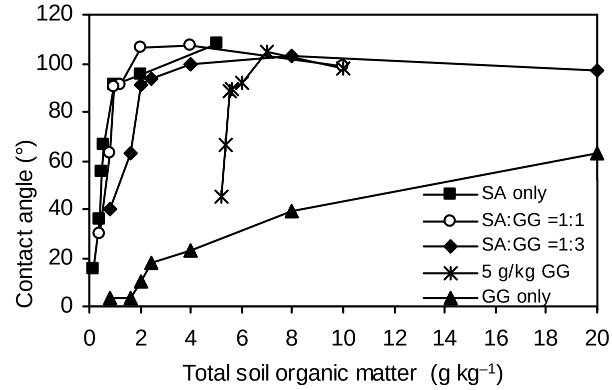

Fig. 3 Relationship between total organic matter content and contact angle. SA: stearic acid; GG: guar gum.

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