Geophysical Research Abstracts
Vol. 17, EGU2015-15093, 2015
EGU General Assembly 2015

Fluorescent probes for understanding soil water repellency: the novel application of a chemist's tool to soil science

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Food security and production is one of the key global issues faced by society. It has become essential to work the land efficiently, through better soil management and agronomy whilst protecting the environment from air and water pollution. The failure of soil to absorb water - soil water repellency can lead to major environmental problems such as increased overland flow and soil erosion, poor uptake of agricultural chemicals, and increased risk of groundwater pollution due to the rapid transfer of contaminants and nutrient leaching through uneven wetting and preferential flow pathways. Understanding the causes of soil hydrophobicity is essential for the development of effective methods for its amelioration, supporting environmental stability and food security.

Organic compounds deposited on soil mineral or aggregate surfaces have long been recognised as a major factor in causing soil water repellency. It is widely accepted that the main groups of compounds responsible are long-chain acids, alkanes and other organic compounds with hydrophobic properties. However, when reapplied to sands and soils, the degree of water repellency induced by these compounds and mixtures varied widely with compound type, amount, and mixture, in a seemingly unpredictable way.

Fluorescent and phosphorescent probes are widely used in chemistry and biochemistry due to their sensitive response to their physical and chemical environment, such as polarity, and viscosity. However, they have to-date not been used to study soil water repellency. Here we present preliminary work on the evaluation of fluorescent probes as tools to study two poorly understood features that determine the degree of wettability for water repellent soils: (i) the distribution of organics on soils; (ii) the changes in polarity at soil surfaces required for water drops to infiltrate.

In our initial work we have examined probes adsorbed onto model soils, prepared by adsorption of specific organics onto acid washed sand. Studies using steady-state and μs time-resolved emission spectroscopy, together with fluorescence microscopy and image analysis, of probe lifetime, spectra, and spatial distribution have been used to 'map' the emission characteristics of probes when adsorbed, and also to examine how the distribution of hydrophobic compounds changes during contact with materials used for treating hydrophobic soils (e.g. clays, biochar).

Furthermore, while it has been suggested that during soil wetting the water droplet induces changes in conformation, orientation and arrangement of a hydrophobic layer of organics adsorbed to the soil surfaces, there is little direct evidence for this, and so we are also exploring the use of fluorescent/phosphorescent probes adsorbed on the soil surface to determine any changes in environment polarity, viscosity or hydrophobicity at the soil surface during the wetting process.