Geophysical Research Abstracts
Vol. 17, EGU2015-10231, 2015
EGU General Assembly 2015

Bacteria-mineral interactions in soil and their effect on particle surface properties

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Interactions between bacteria or their residues and mineral surfaces play an important role for soil processes and properties. It is well known that bacteria tend to grow attached to surfaces and that they get more hydrophobic when grown under stress conditions. In addition, bacterial and fungal biomass residues have recently been shown to contribute to soil organic matter formation. The attachment of bacteria or their residues to soil minerals can be expected to modify the surface properties of these particles, in particular the wettability. We hypothesize that the extent of the effect depends on the surface properties of the bacteria, which change depending on environmental conditions. As the wettability of soil particles is crucial for the distribution and the availability of water, we investigated the effect of both living cells and bacterial residues (cell envelope fragments and cytosol) on the wettability of model mineral particles in a simplified laboratory system. We grew *Pseudomonas putida* cells in mineral medium either without (unstressed) or with additional 1.5 M NaCl (osmotically stressed). After 2 h of incubation, the cells were disintegrated by ultrasonic treatment. Different amounts of either intact cells, cell envelope fragments or cytosol (each corresponding to 10^8, 10^9, or 10^{10} cells per gram of mineral) were mixed with quartz sand, quartz silt or kaolinite. The bacteria-mineral associations were air-dried for 2 hours and analyzed for their contact angle. We found that the surfaces of osmotically stressed cells were more hydrophobic than the surfaces of unstressed cells and that the bacteria-mineral associations had higher contact angles than the pure minerals. A rather low surface coverage ($\sim$10%) of the mineral surfaces by bacteria was sufficient to increase the contact angle significantly, and the different wettabilities of stressed and unstressed cells were reflected in the contact angles of the bacteria-mineral associations. The increases in the contact angles were similar for intact cells and cell envelope fragments, whereas they were even more pronounced if the minerals interacted with the cytosol. Based on these results we conclude that bacterial cells and their residues play an important role in controlling soil particle surface properties, in particular wettability. This process can explain the development of water repellency in soils, which has a major impact on the distribution and availability of water in soils at the microscale.