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Extreme Soil Water Repellency: A Materials View Incorporating Granularity and Super-Hydrophobic Effects

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Wettability of materials is known to depend upon both the surface chemistry of the material and the topography of the surface. Within soil science increased soil water repellency causes enhanced run-off and erosion. Soil water repellency is promoted by drying of soil, and can be induced by fire or intense heating of soil containing hydrophobic organic matter which causes organic compounds to be redistributed within the soil profile. Understanding water repellency is a common concern across many scientific and engineering problems from textiles to building construction. However, the language and techniques used to investigate and describe common aspects of these problems are often different. Within soil studies water drop penetration time (WDPT) and molarity of ethanol droplet (MED) tests are used widely, whereas within materials work contact angle studies are common. The differences in techniques deployed are necessitated by the need for in-situ fieldwork and the potential ambiguities that occur when field samples are prepared for laboratory work or when idealized models are created in the laboratory. However, transferring understanding between model studies and the field, and between disciplines is important. Outside of soil science recent studies have shown how enhancement of the natural water repellency of materials due to the surface chemistry can be induced by surface topography. The enhancement can be dramatic with an almost complete roll-up of water droplets occurring (i.e. a greater than 150 degree contact angle indicating super-hydrophobicity). The roll-up of water droplets can occur in several ways leading to “slippy” surfaces from which water rolls-off or “sticky” surfaces from which water does not easily roll-off. In this work, the creation of a range of surfaces and materials (surface textured, porous and granular), which demonstrate extreme water repellency, is described. The similarities

between these super-hydrophobic materials and observed properties of water-repellent sandy soil are discussed from a non-soil scientist materials-based perspective. To illustrate how these ideas might be relevant to soil science, a simple quantitative model for a hydrophobic granular surface is provided. Such a surface could be produced by the volatilization of organic compounds and their re-condensation onto suitable size and shape grains within the soil profile. It is shown that this model can provide a mechanism for enhancement of soil water repellency through the relative size and spacing of grains and pores. The model provides a possible explanation for why soil water repellency should be more prevalent under dry conditions than wet. Consequences for water run-off, raindrop splash and soil erosion are discussed.