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Effect of Hydrophobicity on Splash Erosion by a Single Drop Impact: From Model Soil to Real Soil

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Splash erosion is soil loss caused by raindrop impacts and can be a dominating process in low precipitation events or on barely vegetated slopes. Water repellent soils have been reported to have greater splash loss by multiple drop impacts than wettable soils either due to effects of a water layer (Terry and Shakesby 1993) or a wet crust (Fox et al. 2007) generated by accumulation of water. In previous work, using homogeneous glass beads as model soil material, we found that the impact of a single water drop results in significantly different splash behaviour between hydrophobic and hydrophilic particles (Ahn et al. 2012). Natural soils are more variable in particle shape, surface texture and morphology than the model material used. The aim of the study presented here was to examine to what degree this difference in splash behaviour between hydrophobic and hydrophilic spherical glass particles applies to natural sandy soil material.

Splash behaviour of beach sands was compared with that previously obtained for the model material (glass beads) using the same single drop impact test procedure (Ahn et al. 2012). The sand particles were in the same size range (350∼400 μm diameter) and chemically modified with HCl and chlorotrimethylsilane in the same method applied to glass beads. A single water drop was released from 40 cm above the target and its impact was recorded using a high-speed video camera (976 fps). Overall, the amount of splash detachment was significantly lower (50∼80%) for the beach sand than for glass beads in both hydrophobic and hydrophilic cases. However, the difference in the amount of splash detachment between hydrophobic and hydrophilic sand was 3 times larger than that of glass beads.

Potential factors for lower net detachment and higher contrast, of sand compared to glass beads, might be (i) particle mobility and (ii) enhanced water repellency on rougher surfaces, respectively. Mobility experiments (angle of repose and flowability) showed that sand particles had significantly less mobility than glass beads (angle of repose: beads: 21.3 ± 0.7 °, sands: 37.3 ± 0.9 °, $p < 0.001$, dF = 17), and that sands took longer to flow through a funnel (beads: 1.88 ± 0.02 s, sands: 2.05 ± 0.13 s, $p = 0.002$, dF = 9). This lower mobility of sands may well be an important factor in the smaller amount of overall splash detachment for sands than beads. Secondly, the water repellency of hydophobized sands, measured by water contact angle (CA) and the Molarity of Ethanol Droplet test (MED), was greater than for identically hydrophobized glass beads (beads: CA 119.6 ± 5.1 °, MED 33%; sands: CA 137.0 ± 2.0 °, MED 36%). This is probably due to the enhancing effect of surface roughness on hydrophobicity. This amplified hydrophobicity can help to explain the enhanced contrast in splash behaviour between hydrophobic and hydrophilic sands.

The results show that the enhanced splash detachment observed for hydrophobic model materials in our previous study occurs to an even greater degree in real sands. The findings also suggest that surface roughness and amplified hydrophobicity in real sands need to be considered when translating findings from model materials to real soils. Finally, the results of this study confirm that particle hydrophobicity leads to a greater susceptibility of sands to splash erosion in the initial stage of rain or irrigation events.

References: Ahn S, et al. 2012. ESPL. DOI: 10.1002/esp.3364; Fox DM, et al. 2007. Hydro. Proc. 21: 2377-2384; Terry JP and Shakesby RA. 1993. ESPL 18: 519-25

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