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Density-driven instability during infiltration and redistribution in effluent-irrigation induced water-repellent soils

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Recently, we found that prolonged application of treated sewage effluents on certain soils has led to development of water repellent soils at the soil surface layer. The development of repellency under these conditions has not yet been described in the scientific literature. Soil water repellency adversely affects infiltration, spatial and temporal water distribution in the soil profile, therefore negative repercussions for plant growth and vadose zone contamination are expected. As a result, the irrigation systems' design should be adjusted to the changes in soil hydrophobicity. Since drip irrigation has been widely used for irrigation with treated sewage effluents, we were motivated to examine in more detail the changes that soil water repellency impose on spatial and temporal moisture distribution in the soil profile from a point source. An experimental study of the dynamics of water penetration, infiltration and redistribution in soils of different water repellency degree is present in this paper. The soil samples were taken from an orchard that has been irrigated with treated effluent for many years. The water repellency of these soils was attributed to the prolonged irrigation with effluents. The examined soils were packed in a transparent chamber of height 32.5 cm, width 20 cm and interior thickness of 1-cm. Spatial and temporal distributions of moisture content in the soil profile during water application and subsequent redistribution was tracked by a high-resolution CCD camera. Water was applied to the soil surface at three application rates by a point source that simulates drip irrigation systems that are widely used for effluent irrigation. High resolution calibration between the grey-values in the CCD images and moisture content in the chamber enabled to follow after temporal and spatial variations of moisture content in the chamber. The experimental runs indicated

that the combination of water-repellency degree and water application rate determine the height and width of the temporary pond formed on the soil surface at early times, on the plume size and shape, and on the spatial water distribution within the plume. The plumes in the non-repellent soil expanded radially form the point source with high moisture content underneath the point source that had decreased with distance from this point. The plume in the repellent soil had a finger-like shape owing to the limited lateral expansion of the plume beyond the pond width. The higher moisture content at the finger tip, relative to its tail (saturation overshoot) indicates that density-driven instability was formed during the infiltration into the repellent soils. Moisture flow beyond the wetting plume during redistribution was limited, and took place primarily in the vertical direction. These observations can be readily used for drip-irrigation design, e.g., dripper discharge, distances between drippers and from one dripper line to another, in water repellent soils in general and in fields irrigated with treated sewage effluents in particular.