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Developing Risk Models of Cryptosporidium Transport in Soils from Vegetated, Tilted Soil Box Experiments

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Transport of *Cryptosporidium parvum* through macroporous soils is poorly understood yet critical for assessing the risk of groundwater contamination. We develop a conceptual model of the physics of flow and transport in packed, tilted, and vegetated soil boxes during and immediately after a simulated rainfall event and apply it to 54 experiments implemented with different soils at different slopes and two different rainfall rates. Using a parsimonious inverse modeling procedure, we show that a significant amount of subsurface outflow from the soil boxes is due to macropore flow. The effective hydraulic properties of the macropore space were obtained by calibration of a simple two-domain flow and transport model that accounts for coupled flow in the matrix and in the macropores of the soils. Using linear mixed-effects regression (LME), macropore hydraulic properties are shown to be associated with soil bulk density and rainfall rate. Macropore flow is responsible for bromide tracer and *C. parvum* transport through the soil into the underlying pore space observed during the 4-hour experiments. We confirmed this finding by conducting a pair of saturated soil column studies under highly packed conditions with no macropores, in which no *C. parvum* transport was observed in the effluent. LME and logistic regression models developed from the soil box experiments provide a basis for estimating macropore hydraulic properties and the risk of *C. parvum* transport through shallow soils from bulk density, precipitation, and total shallow subsurface flow rate. Our risk assessment is consistent with the reported occurrence of oocysts in springs or groundwater from fractured or karstic rocks protected only by shallow overlying soils.