Abstract

PREFERENTIAL FLOW THROUGH EARTHEN LANDFILL COVERS:
FIELD EVALUATION OF ROOT ZONE WATER QUALITY MODEL (RZWQM) AND
LABORATORY VALIDATION OF LATTICE BOLTZMANN METHOD (LBM)

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May 12th 2014, 9-11 am
Room 3540 Engineering Building

In order to impede the infiltration into the waste, earthen landfill covers are constructed once a landfill reaches its capacity. Formation of macropores and flow through these relatively large pores can significantly increase the percolation through earthen landfill covers during service. Most commonly used water balance models that are used for predicting percolation through earthen cover are based on Richards’ equation that simulates only the micropore flow. Hence, a model that can simulate the micropore and macropore flow is required to simulate the long term hydrology of the earthen covers. Validation of the Root Zone Water Quality Model (RZWQM) using data collected form an instrumented field test section and development of a model capable of simulating macropore flow using lattice Boltzmann method were carried out in this study.

The instrumented field-scale test section of earthen landfill cover, 1.5 m thick compacted clay overlain by 0.3 m topsoil, was constructed at a landfill and monitored for about four years. Measured annual percolation increased by an order of magnitude during the second and the third year of service. Controlled irrigation tests conducted on the test section confirmed macropore dominated flow through the test section. Estimated effective field hydraulic conductivities of the test section increased by an order of magnitude during the 4th year of service compare to the 1st year of service. Field methane tracer tests confirmed the presence and locations of macropores.

Water balance of the field test section was simulated using the RZWQM and a commonly used numerical model UNSAT-H. For the first year data, both models simulated percolation relatively accurately. However, the numerical predictions of percolation were not accurate for the second and the third year when the effect of macropores was ignored. The macropore parameters required for RZWQM were calibrated using the irrigation test results. The RZWQM simulations using calibrated macropore parameters yielded relatively accurate prediction of percolation for the second and the third years of the field data.

Measurement of macropore flow through clay in lab-scale samples is relatively challenging due to the effect of confining walls and size of the sample. A new technique was developed to consistently fabricate clay samples containing macropores. High resolution X-ray CT images of compacted clay specimens were taken to visualize the 3D structure of macropores. A 3D lattice
Boltzmann based model (LBM) that can simulate saturated flow through micropore and macropore flow was developed. Verification of the LBM was carried out using analytical solutions. The LBM was validated using laboratory measurement of saturated hydraulic conductivities \( (k_{\text{sat}}) \) of compacted clay specimens containing macropores. A prediction equation is formulated to predict the rate of flow of an arbitrary shape and tortuous macropore using the flow rate of straight vertical cylinder. Comparison of the predicted \( k_{\text{sat}} \) using the proposed formulation and calculated \( k_{\text{sat}} \) using the LBM were showed excellent match.