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Numerical modelling of pressure and runoff conditions of a capillary barrier

Summary of PhD Thesis

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Abstract

The closing of landfills is a very topical issue in Europe, with many European countries already scheduling the end of waste disposal at these sites (Biele, 2007). A capillary barrier is one option for surface closure of landfills. For covering landfills of municipal waste, European regulations require that surface sealing for class 2 waste be made up of two independent components. In most cases, this is satisfied by the combination of an artificial and a mineral sealing. The next development stage of the capillary barrier is the combined capillary barrier (Wohnlich, 2006a), intended as an alternative to conventional combined sealing. Prof. Dr. Stefan Wohnlich and his team at Ruhr-University Bochum undertook a series of laboratory experiments simulating capillary barriers in a tipping trough. The German association LAGA was made aware of the conducted research. The research should be focused on the combined capillary barrier and should particularly answer questions concerning the pressure and runoff condition of a combined capillary barrier.

During my research, I revisited numerically two tipping trough experiments carried out at Ruhr-University Bochum in order to find conditions under which it is possible to replace laboratory-based investigation of a capillary barrier by its numerical modelling. For all the numerical modelling presented in this thesis I used the programs S2D_dual nebo S1D_Console 10 (Vogel, 1999). It was found that in the case of soils applicable in capillary barriers, the hydraulic characteristics determined by the tension-apparatus method according to Havlíček and Myslivec (1965) are quite suitable for numerical models. The obtained results suggest that using such hydraulic characteristics, the outcomes of the numerical model are quite reliable. According to this evidence of reliability, it was possible to investigate capillary barriers by means of numerical simulations.

The obtained hydraulic characteristics were further utilized in an investigation of the influence of failures in the impermeable sheeting on the efficiency of a combined capillary barrier. It was found that even fine fissures (of 1 mm width) in the impervious sheeting can result in significant leakage through the capillary boundary. On the other hand, the breakthrough of a combined capillary barrier (with sheeting) should never exceed that of a capillary barrier with no sheeting at all in the applied model. It was also found that the relative position of the drain and the rupture of impervious sheeting affect the efficiency of the barrier considerably. Taking into account that the position of a failure cannot be predicted, the results suggest that the combined capillary barrier should be equipped with the same drainage system as a simple capillary barrier. The numerical model successfully provided answers to the questions originally intended for laboratory research.

Two different capillary barriers were considered with the aim of studying efficiency of a capillary barrier from the viewpoint of applied materials. The impact of hysteresis of the retention curve on numerical simulations of the capillary barrier was discussed. A new criterion of capillary barrier efficiency was found and presented. It was found, that the efficiency of a capillary barrier is closely related to the distance between retention curves of materials of the capillary layer and capillary block. The efficiency of a barrier increases with increasing value of $\Delta h_{\inf l}^{barrier}$ (Equation 43). When comparing the efficiency of two capillary barriers, the difference in pressure head values of retention curve inflection points is a more suitable indicator than the difference in hydraulic conductivity. The behaviour of water within the capillary barrier is affected by hysteresis. If the retention curve's hysteresis is discounted and only the drying branch of the retention curve used, the efficiency of the capillary barrier is overestimated.

A capillary barrier is not the sole component of the sealing of a landfill surface, which also includes an overburden of a recultivation layer. During the tipping trough experiments the capillary layer is irrigated directly; in a real landfill profile water has to cross the recultivation layer to approach the capillary barrier. If the interaction of capillary barrier and recultivation layer is examined and understood it would therefore help with assessment of the suitability of materials for the landfill covers. The data needed for extension of the numerical model and implementation of the recultivation layer have been collected during my research fellowship at University of Applied Sciences Zittau/ Görlitz, namely in the research facility in Bautzen/Nadelwitz, led by Prof. Dr.-Ing. J. I. Schoenherr and Prof. Dr.-Ing. habil. J. Engel.

Ten lysimeters of different recultivation layer layout were used to estimate material parameters of a numerical model of the recultivation layer. This allowed subsequent extension of the model of the capillary barrier so that it included an overlying recultivation layer. This new model was then used in investigations of the interaction between the recultivation layer and the capillary barrier with regard to the materials used in their construction. It was found, that a recultivation layer improves the sealing capability of a capillary barrier by reducing the amount of water infiltrating the actual sealing system, provided that it is not damaged and that preferential flow paths do not develop. With a carefully chosen material composition, the recultivation layer contributes to drainage function and lowers the amount of water infiltrating into the underlying capillary barrier.