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DISCUSSION

A numerical investigation of landfill hydraulics using variably saturated flow theory

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Experimental data (e.g. Beaven & Powrie, 1995) show that both the saturated permeability and the density of typical municipal solid wastes vary significantly with vertical stress, and hence with depth of burial in a landfill. For example, the saturated permeability of a crude domestic waste was reduced from 3.5×10^{-5} to 10^{-7} m/s on increasing the vertical effective stress from 40 to 600 kPa. For pulverized waste, the saturated permeability decreased from 3.6×10^{-5} to 3.5×10^{-9} m/s over the same stress range. Depending on the as-placed density, an orders-of-magnitude variation in saturated permeability could occur even within a landfill only 10 m deep. Furthermore, the suction–moisture content curve might also be expected to vary with vertical effective stress and/or waste density.

The authors appear to have assumed that the same saturated permeability, suction–moisture content relationship and possibly density apply at all depths within the landfill. Is their model capable of taking into account the likely real and significant variations in these parameters with effective stress/depth of burial, and what would be the effect on the results of their analyses?

Authors' reply

The authors appreciate the comments made by Professor Powrie and welcome the opportunity to enlarge upon some of the background to their original paper.

Professor Powrie correctly notes that the flow model descibed represents a non-deforming porous medium and as a consequence a single set of hydraulic parameters, i.e. saturated permeability, suction–moisture content relationship and relative permeability function, is adopted throughout the waste region. Whilst the authors agree that the hydraulic parameters will vary with effective overburden stress, the model in its present form is not configured to accommodate such a variation. The reasoning behind this is twofold.

Firstly, we have presented a preliminary investigation of landfill hydraulics which accounts for both boundary moisture transfers occurring during active infilling and subsequent redistribution. It is during the active phase that waste import and climatic conditions establish the initial distribution of moisture within a landfill site. A combination of sequenced disclosure of waste elements of known moisture content and transfer of boundary rainfall conditions have been used to control the spatial and temporal introduction of moisture. However, numerical solutions of variably saturated flow models are sensitive to time and mesh discretization particularly where transient boundary flows occur. The simplifications highlighted by Professor Powrie were considered advantageous in verifying that boundary fluxes were reliably controlled and mass was being conserved.

Secondly, the simplified hydraulic analysis was pursued because of the complications associated with a long term mechanical analysis of landfilled waste. The experimental data presented by Beaven & Powrie (1995) elucidates the hydromechanical processes occurring within waste refuse and is clearly invaluable with regard to a more realistic interpretation of landfill behaviour. We would hope to incorporate their findings into future model developments. However, as noted by Beaven & Powrie (1995), the mechanical response to self weight constitutes only part of the overall volumetric behaviour. An equally significant contribution occurs as a result of biodegradation (Sowers, 1973; Wall & Zeiss, 1995), a process which has been thought to be affected by moisture history (e.g. Farquhar & Rovers, 1973; Leckie, Pacey & Halvadakis, 1979). A more comprehensive analysis of landfill behaviour might therefore utilize the hydraulic regime as a controlling factor in landfill settlements, although prior to a suitable method of coupling being determined, the authors chose to continue testing of the simplified hydraulic formulation.

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