<u>Using a hydro-bio-mechanical (HBM) model for landfill stabilisation and completion</u>

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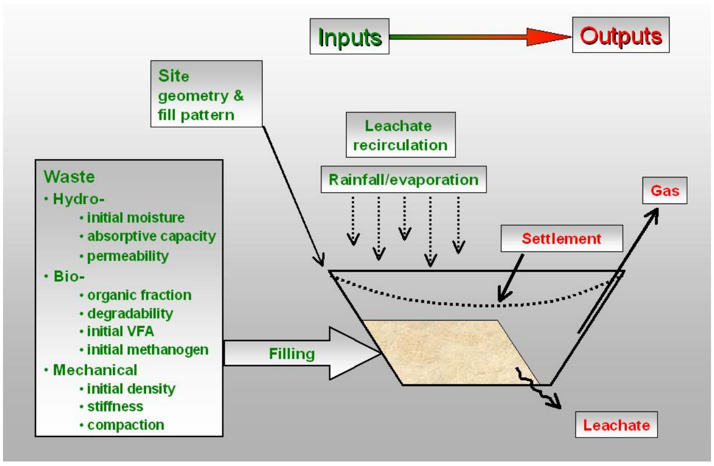
Understanding and predicting the influence of organic decomposition and mechanical biological pre-treatment on landfill stabilisation and settlement.



Case for Support

The Landfill Directive, by diverting a percentage of organic matter away from landfill, will have a significant impact on waste management options. It is vital that the environmental consequences of the new priorities are fully understood and managed.

The science and engineering of the wastes deposited in landfill, be they MSW mechanically biologically pre-treated waste or incinerator residues will be a complex mix of hydraulic, biochemical and mechanical processes. At field scale, these processes and their interdependence are poorly understood; at best, they are accounted for using highly empirical methods and not usually addressed by the waste management industry in any quantitative fashion. They are nevertheless, issues which SEPA must consider. This proposal seeks to build on existing developments of a computational method for assessing the hydraulic, biodegradation and mechanical behaviour of landfilled waste, and to develop a graphical user interface that will allow regulators and operators alike to use the computer model. In this way, the selection and management of different waste management options is improved.

Over the last 10 years, researchers at Edinburgh Napier University have been developing a coupled hydraulic-biodegradation-mechanical (HBM) model with which to analyse the behaviour of decomposable materials such as landfilled waste. The modelling project was funded from various sources, including EPSRC.

The research proposed herein will allow user definition of various landfill scenarios. For example site geometry, waste type, organic fraction, filling rate and sequence, incident rainfall can all be controlled. The evolution of leachate discharge, both quantity and quality, landfill gas potential, and surface settlement can then be simulated. Through a graphical user interface, the model will be usable by regulators, landfill operators and designers with relatively little training.

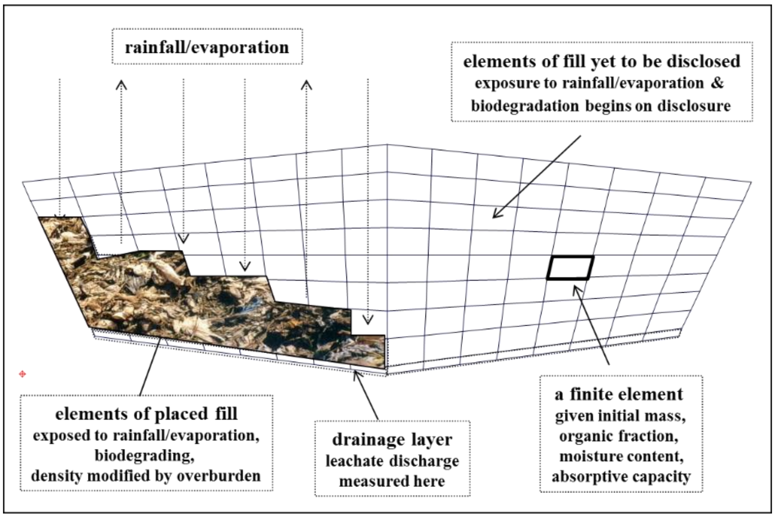
The Science and Engineering: Conceptual Framework

The HBM model provides a framework for the integrated analysis of the hydraulic, biodegradation and mechanical behaviour of landfilled waste or other degradable soils.

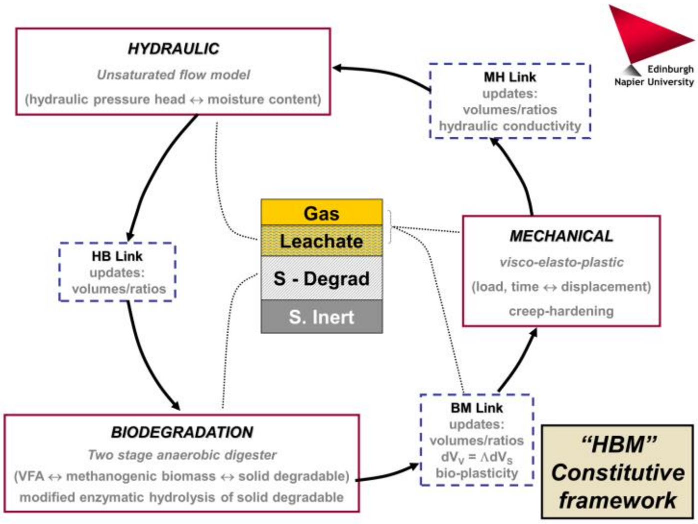
Building on individually-proven models of hydraulic, biodegradation and mechanical behaviour, the HBM model gives a synergistic interpretation of landfill behaviour with relatively light input parameter requirements.

The HBM model fulfils two roles. Firstly, it is illustrative. Fundamental links between hitherto disparate phenomena allow users to explore the consequences of input parameter changes upon the wider landfill system. Secondly, it is predictive. For a given scenario, with a representative set of input values, the model provides quantitative predictions of future performance.

The HBM model is implemented using the finite element method with which it is possible to account for material and operational features such as complex section geometry, waste heterogeneity, anisotropic hydraulic conductivity and simulation of the filling phase.



The HBM model comprises three main system models: hydraulic, biodegradation and mechanical, and link routines, through which the algorithm passes, as shown in the figure below. It is in the link routines that the most recent system variable values are used to update the conditions within each system model.



The three main constitutive descriptions and coupling are shown schematically in the figure above and described more fully below. System variables are used within the link routine continually to update the wider context within which each module operates. In this way, a more representative condition at each stage of the simulation is obtained.

Hydraulic module

The hydraulic model is an unsaturated flow model that enables the distribution of moisture and flow to be determined in a user-defined two dimensional landfill section under given infiltration and drainage conditions.

Biodegradation module

The biodegradation model is a simple two-stage anaerobic digestion model in which indicative volatile fatty acid and methanogenic biomass concentrations control the mineralisation of organic matter. Spatial and temporal distributions of all field variables and related properties are available. Some key modifications have been made to reflect more realistically the enzymatic hydrolysis of solid organic matter including dependence on moisture content, product inhibition and the changing digestibility of the decomposable fraction. These modifications are described in detail in McDougall & Pyrah (2001). A number of natural phenomena and operational treatments can then be simulated, e.g. souring due to acid accumulation, addition of methanogenic inoculum, clean water flushing or leachate recirculation.

Mechanical module

The mechanical model combines load, creep and biodegradation-induced effects to analyse and predict landfill settlement. In the HBM model, biodegradation-induced effects are not treated as a simple time dependent process, instead they are rate-limited. This means decomposition is constrained by a maximum rate. Within that rate, under the influence of acid accumulation or moisture/nutrient addition for example, decomposition may slow down, accelerate, or stop completely.

A key component of a more fundamental analysis of landfill biodegradation is the interpretation of the mechanical consequences of decomposition. In other words, how does solid phase loss translate into changes in phase composition and the associated mechanical condition? A constitutive relation between two volumetric state variables, the void phase volume V_V and solid phase volume V_S, handles the impact of decomposition on the mechanical state. This relation is given by:

$$dV_V = \Lambda \, dV_S \quad (1)$$

where Λ is the decomposition-induced void change parameter. A full derivation and description of Λ can be found in McDougall & Pyrah (2004).

A more complete description of the model can be found in McDougall (2007).

If you have any interest in this work or would simply like to talk to me about it, even try the model (I can send a sample version to you on a CD), please email me on j.mcdougall@napier.ac.uk .

References

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