Integrated modeling and up-scaling of landfill processes and heterogeneity using stochastic approach

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Introduction

Municipal solid waste landfills are a very complex and heterogeneous systems. The waste in a landfill body is a heterogeneous mixture of a wide range of materials containing high levels of organic matter, high amounts of salts and a wide range of different organic and inorganic substances, such as heavy metals and organic solvents.
A range of processes of different nature occur within landfills. Bio-geochemical processes in a landfill body lead to the development of landfill gases, a mixture of predominantly methane (CH4) and carbon dioxide (CO2) and smaller amounts of trace gases. Water flow through the landfill is the main driving force for biodegradation and leachate generation. This induces loss of matter via leachate and gas generation hence a new pores become available for water flow and settlements take place.
An estimation of the remaining emission/contaminating potential of the landfill under different landfill management scenarios is the main goal of our research. This can give valuable information on when it is "safe" to release the landfill from active aftercare and what actions need to be done in order to reach this threshold earliest.

Methodology

The main idea is to apply stochastic approach and transfer functions to model water/leachate residence time in the landfill body. This time may then be used together with the amounts of water infiltration through the landfill as an input to the biodegradation model coupled with the settlement model. Biodegradation and settlement will in turn affect water/leachate flow through the waste.
The objective of research requires integrating models of water flow; bio-geochemical reactions; reactive transport and settlement on the landfill body (see Fig. 1). Understanding of processes at a small scales occurring within a landfill (biodegradation of organic matter) is needed in order to model large scale processes (landfill gas and leachate generation as well as settlements). However high heterogeneity cannot be modeled precisely using deterministic approaches. Therefore stochastic approach to handling heterogeneity is applied.
We assume that a landfill is divided into a large number of columns which may be considered as flow paths. Each column has its own random hydraulic properties and chemical composition, although is considered to be a homogeneous itself.
All water coming into the landfill body is split into small amounts each with a random travel time defined by a travel function. A flow model is being developed which will allow defining the probability distribution for "travel times" of water through the landfill. This model considers the presence of impermeable layers (such as plastic sheets) which induces large rates of preferential flow. The model will be calibrated and validated using LeachXS database and results obtained from measurements at a column scale and full scale landfills.