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Unified predictive model for transport parameters and its application to gas and heat transport in landfill cover

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Landfill sites are a significant source of greenhouse gases such as a methane which has a high global warming potential. In addition, toxic gases such as a hydrogen sulfide and volatile organic chemicals can emit from landfill sites and affect surrounding local environments. These greenhouse and toxic gases are typically produced by microbiological processes acting on waste materials under anaerobic conditions. The exothermal reactions also occur due to the microbiological processes in the waste layer. These gases and heat produced in the waste layer move through landfill covers and emit to the atmosphere. Therefore, the understandings of gas and heat transport in the landfill covers are essential for enhancing the landfill site stabilization and reducing the greenhouse and toxic gas emissions. Gas diffusion and thermal conduction are main mechanisms for gas and heat transport in soils. Gas diffusion coefficient and thermal conductivity govern gas diffusion and thermal conduction, respectively.
Gas diffusion coefficient is controlled by air-filled networks, while thermal conductivity is affected by both solid phase configuration and water-filled pore networks. Since the bulk soil-pore structure is composed of the three (air, water, and solid) phase geometries and the geometries for each phase are interrelated, we expect a general analogy and difference between gas and heat transport parameters (i.e., gas diffusion coefficient and thermal conductivity). Such a relation enables to develop a unified predictive models for gas and transport parameters which are promising for simulating simultaneous gas and heat transport in the landfill covers.
In this study, we developed a unified predictive model for gas diffusion coefficient and thermal conductivity considering soil compaction level (i.e., dry bulk density). Numerical simulations of gas (methane, carbon dioxide, and oxygen) and heat transport in a landfill cover were performed using the developed predictive model. The effects of soil compaction level and thickness of the landfill cover on gas and heat transport were investigated. Increase of compaction level enhanced not only heat transport in the landfill cover but also methane gas emissions due to reduced methane gas oxidation nearby soil surface. When the thickness of landfill cover is less than 50 cm, methane gas emissions rapidly increased for variably-compacted landfill covers.

Keywords: mass transport, landfill site