Transport Phenomena in the Conversion of an Anaerobic Landfill Into an Aerobic Landfill

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Abstract

The world's landfills are beginning to fill up due to the growing human population. Landfills require land and there will come a time when there will be no land to be used for landfills. A solution that is gaining attraction is the conversion of traditional "dry-tomb" landfills (used for storage) into bioreactor landfills. Dry-tomb landfills have many associated problems such as methane production (25 times more harmful than carbon dioxide as a greenhouse gas (Huber-Humer et al., 2011) and the production of harmful leachate that if left untreated can infiltrate the water table causing serious environmental and potential health problems.

Conversion of dry-tomb landfills into bioreactor landfills is done by recirculating leachate providing an even distribution of bacteria and nutrients, accelerating the biodegradation process (Kulkarni and Reddy, 2012). If left on their own landfills will become anaerobic as oxygen inside the landfill is quickly used by aerobic bacteria. Once injected with air, the dominant bacteria shift back to aerobic. Aerobic bioreactor landfills have added advantages including: (1) faster degradation time compared to anaerobic, (2) due to air injection, less leachate production, and (3) significantly decreased production of methane (Omar and Rohani, 2015). Studying landfills experimentally takes months to years to collect data and draw conclusions.

Waste is a porous medium requiring heat transfer, fluid flow and reactions through porous media to be considered in any modeling attempt. The reacting flow in porous media and heat transfer in porous media interfaces were used. Biological kinetic equations are not included in COMSOL Multiphysics® software and as a result mathematics physics interfaces had to be used to include the kinetic equations in the form of distributed ordinary differential equations and coupled to the chemical kinetic equations.

The model showed that the initial aerobic biomass concentration was a significant factor in the conversion process (Figure 1(a)-(c)). Due to the dependence of biomass growth on biomass concentration, the less aerobic biomass present, the slower the growth. However, too high an initial biomass concentration causes the temperature to increase rapidly, killing the aerobic bacteria. Another significant factor in the biodegradation process is the leachate recirculation, shown in Figure 2(a) and (b). Aerobic biodegradation is an exothermic process, affecting the rate of biodegradation. Without the leachate recirculation, the temperature of the waste will continue to increase until the biomass begins to die. The biomass concentration will be near 0 causing very slow biodegradation and it will take long for the heat to dissipate and the biomass to grow and

reach the previous initial concentration. The leachate recirculation provides a heat sink for the heat generated which otherwise would go towards heating the waste mass.

This model provides the framework for determining how different factors (e.g. pH, moisture content, etc.) affect the conversion of anaerobic landfills to aerobic landfills and the efficiency of the subsequent aerobic biodegradation. Valuable operational information can be gained from using this model. Gathering this data experimentally can take months (even multiple years) whereas this model can provide the same insight in days.

Reference

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M. Huber-Humer, P. Kjeldsen, K.A. Spokas. Special issue on landfill gas emission and mitigation. Waste Manag., 31, 821–822(2011).

Figures used in the abstract

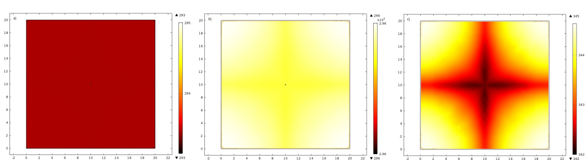

Figure 1: Landfill Temperature After 1 day at Aerobic Biomass Concentrations of: (a) 0.1 kg/m^3; (b) 1 kg/m^3; (c) 10 kg/m^3

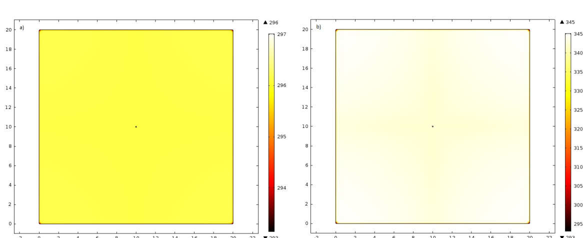

Figure 2: Landfill Temperature After 1 Day: (a) With Leachate Recirculation; (b) Without Leachate Recirculation