Session Chair Report: "Movement of Liquids in Refuse and Cover Materials"

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Many aspects of landfill operation require an understanding of the movement of liquids in landfills and landfill covers. Bioreactor landfills require knowledge of liquid and gas flow to design optimal systems for leachate recirculation and gas extraction (or air injection). In this session we discussed recent advances and important questions pertaining to liquid and gas movement in landfills and landfill covers. Laboratory, field and theoretical/modeling studies that evaluate liquid flow phenomena were discussed in oral presentations and posters from six contributing speakers.

Three presentations were made on imaging and sensing systems for assessing liquid flow in refuse. Isobe et al. and Rosqvist et al. discussed field applications of electrical resistivity tomography (ERT). Isobe et al. used resistivity sensing to measure the water level in a landfill and to determine the direction of water flow within the landfill in response to the pumpage of leachate. However, the measurements were influenced by changes in the ionic strength of the leachate within the landfill, which made data interpretation more complicated. Rosqvist et al. also discussed applications of ERT in a landfill. In this case, ERT was used to track the movement of injected leachate and to track the path of an injected tracer solution. ERT measurements in this landfill suggested that gas flow had a significant influence on water movement. The movement of biogas within the landfill could be inferred from ERT measurements.

The last presentation in the category of "imaging and sensing systems" was by Khire and Mukherjee. These authors have advanced permeable blankets for the injection of liquids into landfills. The authors discussed the use of these blankets in combination with in situ pressure sensors placed within the blankets. If a known volume of liquid is injected into the blanket and the water pressure measured continuously in the blanket, the data may be inverted to determine the in-place vertical hydraulic conductivity of the waste beneath the blanket. The authors presented data and simulation results supporting this hypothesis and a plan for ongoing laboratory and field experiments to further substantiate their proposed methodology.

The second set of presentations were on flow processes in landfills. Powrie et al. discussed what is really measured when leachate levels are determined in wells placed in landfills. Based on their analyses, they concluded that the best information is obtained from measurements of water levels made in discrete horizons of the landfill, as opposed to measurements from fully screened wells extending across multiple horizons. Abichou et al. discussed their work evaluating landfill covers intended to serve as biocovers (oxidizing methane) and evapotranspiration covers (controlling infiltration of rainwater). They demonstrated how a numerical model that coupled heat, gas, and liquid transport with methane oxidation, evaporation, and transpiration processes could be used to evaluate the long-term performance of bio-evapotranspiration covers. Finally, Imhoff et al. discussed their work developing dual-domain models for the flow of gases and liquids in landfills. They demonstrated how pneumatic pump tests and gas tracer tests in a

bioreactor landfill could be used to determine the fraction of the pore space that was in an "immobile" flow domain. They postulated that dual-domain models could be developed using such field data, and that such models would be required to adequately model fluid flow in landfills.

At the conclusion of the presentations, the audience and presenters addressed four questions:

1. When moisture content is measured in a landfill, what is the measurement primarily used for?
2. What are the questions we want to answer with our models for gas and liquid flow in landfills? What are we modeling?
3. Is there a consensus yet on "best" methods for recirculating liquids in refuse?
4. Are the standard approaches for modeling fluid flow in soils adequate for refuse?

These discussions resulted in interesting insights and some disagreement among those in attendance. Below are bulleted comments that summarize the thoughts and ideas presented in these discussions.

When moisture content is measured in a landfill, what is the measurement primarily used for?

- Control of bioreactors (temp. management, etc.)
- Design of injection systems (select optimal ones)
- Overall water balance for landfills
    - Water distribution within landfill (affects gas and water permeability, pore pressures)
        - Prediction of long-term leaching of solutes
        - Assessing degree of decomposition of waste
- Regulatory requirements

What are the questions we want to answer with our models for gas and liquid flow in landfills? What are we modeling?

- Long term emissions of gas and liquid emissions from caps and liners
- Models for biodegradation of waste
- How can the gas pressures and flow be used to assess landfill gas generation rates?
- Enable us to obtain better conceptual understanding of landfill processes
- Management of liquid and gas in landfills
- Assessing pressure heads on liners and internal points in landfills (slope stability)
- Helping regulators to do their job better
- Relationship between liquid flow, density changes, and settlement

Is there a consensus yet on "best" methods for recirculating liquids in refuse?

- No (vertical well, permeable blankets, and trenches are three possible options)
- Efficiency of systems may depend on the type of landfill (existing landfills may require vertical or horizontal wells)
- Efficiency of moisture distribution in waste is not yet established for permeable blankets

    - May need spatial measurements to establish that preferential flow is not a major weakness of this method
- Data from field tests conducted to date are not adequate yet for complete assessment
- Wick drains (up to 15m deep) have been combined with blankets and seem promising
- Costs comparisons between methods – needed?
- Operational practices might help some methods to work better than others (e.g., the presence of intermediate soil covers may affect the performance of particular injection systems)
- Optimal addition of moisture when waste is landfilled – is this important? (field capacity will depend on the bulk density of waste and location in landfill)