Guidance for Bioreactor Design

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Abstract

Waste Management, Inc. and GeoSyntec Consultants recently collaborated on a study that resulted in the development of design guidance related to bioreactor landfills. The collaborative study focused on understanding the design of liquids injection and gas extraction systems for bioreactor landfills, as well as the factors that affect the design, operation, and performance of bioreactor landfills. The study focused on the following three topical areas and the results will be presented at the symposium:

- Liquids Infiltration: A numerical model was developed to simulate liquids infiltration into waste and a parametric study was performed to assess the effects of several parameters on the vertical and lateral movement of the wetting front in the waste mass. Design guidance is provided with respect to the following parameters: (i) infiltration pipe dimensions; (ii) infiltration trench dimensions and properties; (iii) waste hydraulic conductivity; (iv) liquids injection pressure; and (v) liquids injection time.

- Waste Degradation: A numerical model was developed to study waste degradation and the accompanying gas generation mechanisms as a function of waste composition and the liquids injection history in the bioreactor environment. Design guidance is provided with respect to the influence of the amount and type of organic material in the waste stream on the gas generation potential.

- Gas Extraction: A numerical model was developed to simulate gas extraction from the degraded waste. This model was used to assess the vacuum requirements in the gas extraction pipe network and the extraction schedule for a given pipe network design. Design guidance is provided with respect to the sizing of the gas extraction and transmission pipes, as well as the phasing of the gas extraction system

The results of the study demonstrate the importance of matching the liquids injection piping network design to the quantity of liquids available for injection into the bioreactor. The role of the distribution pipe diameter, distribution trench geometry and waste hydraulic conductivity was also studied and summarized. The study also provided valuable insight regarding the importance of liquids and waste composition on the gas generation rates. Finally, the study provided guidance regarding the design and operation of the extraction pipe and blower. This presentation will introduce proposed design procedures for bioreactor landfills. Importantly, this presentation will demonstrate the role of critical design components and the effects of improper design consideration. Finally, several specific recommendations are made with respect to performance monitoring that should be implemented at active bioreactors landfills.

Conclusions

There are several significant conclusions related to this study, as briefly summarized.

- Liquids Infiltration: (i) liquids injection system should be operated under pressure; (ii) pressurized operations and initial pipe geometry are important with respect to likelihood for seeps and local instability; (iii) injection rate is largely determined by operating pressure and waste hydraulic conductivity; (iv) liquids tend to flow primarily vertically in homogeneous waste; (v) diameter of the injection pipe and trench are not critical to performance; and (vi) waste homogeneity, waste isotropy, and the presence of a low-permeability daily cover layer play a critical role in the shape of the wetting front.

- Waste Composition: (i) magnitude and time rate of degradation are dependent on composition of waste; and (ii) volume of liquid for effective operation of a bioreactor landfill is significant and may limit the size of the facility.

- Gas Generation: (i) gas flow rate depends on the size of the influence zone and the number of gas extraction pipes; (ii) gas flow rate is determined by the time rate of waste degradation; (iii) vacuum head loss is dominated by the diameter and length of the extraction pipes and the gas flow rate; and (iv) vacuum head requirements significantly vary with time at any given facility.

Research Questions

The results from this study provide several important lessons and conclusions. In addition, these results indicate several research needs. In general, there is a strong need for information regarding the operating performance of bioreactor landfills. It is desired to obtain confirming information regarding the wetting profiles of the waste mass and the influence of these profiles on injection pressure. The leachate quantity and quality should be monitored, as well as the resulting gas quality and quantity. This information should be correlated to the waste composition, waste degradation, and settlement. Information is needed regarding the anisotropic hydraulic conductivity and strength of waste and the changes in these properties over time.

References

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