Bioreactor Landfills: Transport Processes and Chemical Engineering Perspectives

Don Augenstein, I E M, Palo Alto, CA 94306[1]

ABSTRACT

Bioreactor landfills are receiving increased attention as their possible benefits are recognized. Among benefits potentially available are waste volume reduction and landfill life extension, greater energy recovery, and lowered long-term care. A number of other benefits have been covered in SWANA's recent White Paper (Pacey et. al., 1999).

Landfill bioreactors are actually fermentation processes, of a unique sort. They have no close parallel among "classical" fermentation operations for antibiotic, ethyl alcohol and other product manufacture, or even in wastewater treatment or manure digestion to methane. Some important issues arising in the realm of biochemical engineering (chemical/biological reactions and transport processes) with fullscale bioreactors include:

1. Thermal and heat transfer effects.

   Anaerobic bioreactors generate sufficient heat from biological and other reactions to elevate temperature by several tens of degrees. It can be shown that the generated heat tends to be retained; with conduction out of deep landfills extremely slow (time constant, order of decades) Practical consequences are that enough heat can be generated anaerobically to either speed reactions, or, if there is too much heat, (> 135-140F) to cause anaerobic processes to "cook to a stop". There has been evidence for both of these in field demonstrations (several thousand ton scale) to date.

   For aerobic bioreactors, generated heat be 10-20 times that of anaerobic for each pound of waste destroyed (i. e. completely oxidized biologically to CO_2/H_2O). Analyses suggest generated heat could easily require centuries to dissipate from landfills if heat loss by conduction alone. In practice it appears heat must be lost via latent heat of evaporation of water into the air stream passing through the aerobic landfill.

2. Mass transfer effects and limitations.

   Early analyses (1970's) of methane generation from solid waste examined possible rate-limiting steps including diffusional transfer of intermediates One surprising result of such calculations was that, given adequate moisture, diffusional transport limitations do not appear serious in anaerobic processes, i. e. diffusional mass transfer will generally not limit rates. One implication is that little or no further mixing or recirculation would be required providing all components can be sufficiently mixed initially. However, it is possible to envision many cases ("gedanken" situations) where substantial effort, such as recirculation, must continue for some time to obtain the necessary initial contacting. Such situations are likely, and will be discussed

---

[1] Abstract to be considered for International Landfill Conference, Lulea, Sweden, December, 2000

For aerobic bioreactors, transport of oxygen necessary for waste destruction may limit rates and/or conversion. This is in part due to sparing solubility of oxygen so that oxygen transport rates into water or biofilms surrounding waste elements may be slow. It is also in part due to the fact that oxygen may bypass waste within the landfill, i. e., there could be "channeling". Example calculations show that oxygen diffusion could easily be a limiting factor as waste consumption progresses. Another possible adverse effect, if insufficient water reaches a given zone within waste, is development of a zone of dry waste where reactions cease within the aerobic landfill.

Another transport-related phenomenon of interest is convective and conductive heat transfer to and from, and consequent temperature elevation of, bioreactors' base layers. For certain combinations of parameters, transfer of heat by warm liquid percolating to base layers over longer terms may be such as to substantially elevate base layer temperature. Limited experimental data bear this out, and base layer performance under such conditions must be assured.

Certain interrelations among parameters can be predicted. These include relationships among water consumption, air throughput, and waste destruction for aerobic bioreactors, and between degree of waste decomposition and temperature elevation for anaerobic bioreactors. Solutions are available, in principle, for some of the apparent hurdles such as heat generation in bioreactor operation. The interrelations that seem clear-cut, and also some possible solutions to problems, will be described. For many other performance parameters of interest, (for example degrees of gas channeling) the situation is complex. There is not enough information for modeling; the answers are only likely to be obtained through careful performance monitoring at large scale. Such measurement and testing has been very limited to date. This presentation will cover some large-scale testing needs as well.