COULD REACTION FRONTS FORM IN LANDFILLS?

Duncan J Martin, Dept of Chemical & Environmental Sciences. University of Limerick, Ireland. Tel/fax: +353 61 213123/202602; email: duncan.martin@ul.ie

Introduction

Heterogeneous mechanisms have featured in several recent models of the anaerobic decomposition of a bed of solids (Kalyuzhnyi et al., 1999; Martin, 2000, 2001). This paper explores Martin's hypothesis of an advancing reaction front.

In slurry digestion, all reaction occurs in the liquid phase or at interfaces, often under some degree of acid inhibition. However, methanogenesis could occur *within* the solid phase in a bed of solids. Reaction rates here might be higher, because:

a) the methanogenic zone is protected from inhibitors by mass-transfer resistances in a buffer zone between the acetogenic and methanogenic zones;
b) metabolic intermediates and extracellular enzymes are localized;
c) syntrophic microbial communities can develop (Stroot et al, 2001).

The proposed reaction front forms only at the surface of a body of seed material (Martin, 1999) but it then advances into the waste, through points of particle-particle contact (Martin & Potts, 2001). Vavilin et al (2002) predicted the spread of comparable concentration waves in slurry digestion, if initiated by localized seeding.

Summary of model

The minimum viable size of seed body is determined by the thickness of the reaction front, which largely forms within it. A mass-transfer model suggests that the buffer zone occupies most of the thickness of the front. Thus, the thickness of either can be estimated, in terms of the diffusivity of acetate in a moist organic solid and the volumetric rate of acetate utilization in the methanogenic zone. Results for a plausible range of input values give a minimum viable seed size of the order of 1-100 cm.

Experimental verification is now under way. Four 500 mL batch lysimeters seeded with 10 cm seed bodies were all progressing well when last sampled. After 60 days, methane levels were measured as 9-36%, with 1-4% hydrogen, indicative of normal development towards high-rate methanogenesis. Neither methane nor hydrogen has yet been observed in controls seeded with 0.5 cm seed bodies.

Discussion

In a bed of solids, seeding techniques might determine the dominant mechanism. It is noteworthy that semi-dry digesters seeded with previously digested waste (likely to be

rich in viable seed bodies) achieve stabilization about a thousand times faster than unseeded landfills. The proposed heterogeneous mechanism might dominate in such digesters, whereas the conventional homogeneous mechanism might dominate in slurry digesters and 'flushing bioreactor' landfills. The two mechanisms could readily co-exist in different regions of one landfill.

It might be as easy to stimulate the formation of reaction fronts in landfills as it appears to be in digesters. High seeding rates are not needed where short retention times are not required: the key criterion is the presence of seed bodies of viable size. Optimum seeding might employ coherent layers of suitable seed material, placed at regular intervals. This is predicted to give a constant-rate biogas output.

Research questions

Proof of concept: how could a reaction front be detected?
How can its thickness be measured – and how much does it vary?
Are bench-scale tests on simulated wastes the best starting point?
What is the minimum viable size of seed body – and how much does it vary?
How fast does the front advance – and how much does it vary?
Have any historic or unpublished data been overlooked?
Could optimized seeding really be more stimulatory than leachate recycle?
What are the other implications for operational practice?

Conclusions

The predicted thickness of the reaction front falls into a wide but credible range. A very thin front could form in small seed bodies, which would be common, so the reaction front mechanism would often be dominant. A very thick front could form only in very large seed bodies, which might never occur naturally. However, operational data suggests that a reaction front mechanism can occur locally in landfills and might be the norm in semi-dry digesters. This suggests that the reaction front hypothesis is indeed feasible.

References

Kalyuzhnyi, S., Veeken, A., and Hamelers, B., (1999) *2nd International Symposium on Anaerobic Digestion of Solid Waste, Barcelona, 15-17th June,* 1, 332-339.
Martin, D. J. (1999) *Biotechnology Letters*, 21, 09-814.
Martin, D.J. (2000) *Biotechnology Letters*, 22, 91-94.
Martin, D. J. (2001) *Trans. I. Chem. E.* ,79 (B1), 29-37.
Martin, D. J. & Potts, L. G. A., (2001). *Sardinia 2001, Oct 1-5th,* 1, 139-148.
Stroot P.G, McMahon K.D, Mackie R.I. & Raskin L. (2001) *Water Res.*, 35, 1804-16.
Vavilin V.A., Schelkanov M. Yu. & Rytov, S.V. (2002) *Water Res.*, 36, 2405-2409.