1st Intercontinental Landfill Research Symposium

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Session Chair report of Bioreactor Technology specialist session

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Session background and aims

Bioreactor landfills are seen as a future technology for managing wastes deposited to ground. They differ from conventional 'dry tomb' landfills in that they are operated as active biological waste processing facilities, where the following benefits can be obtained:

- on-site management of leachate
- increased biogas production and utilisation
- rapid landfill settlement
- reduction in organic content of waste, leading to
- biological stabilization
- removal of polluting potential (both organic and inorganic) when combined with leachate flushing

The aim of the session was to identify measurable parameters that can be used to demonstrate

1) the operational performance of a bioreactor and;

2) the extent to which a landfilled waste has been both biologically stabilised and flushed of soluble degradation products to achieve completion criteria.

Session outline

It was recognized that very often operators and researchers have different ideas about what constitutes a bioreactor landfill. Therefore the following definition was proposed and adopted at the start of the session.

A bioreactor landfill is a landfill where waste stabilization processes are actively managed and accelerated. Waste stabilization includes both the biological stabilization of the waste and also the achievement of waste completion criteria by the removal of organic and inorganic polluting potential (by flushing). Bioreactor landfills may either be aerobic or anaerobic. The emphasis on this definition is very much on the requirement to actively manage the stabilization processes, rather than to allow a landfill to degrade and stabilise at its own pace. Consequently, operators running bioreactor landfills require monitoring information to provide feedback on how the processes that are being managed are performing.

Five papers were presented at the session. These were:

Bioreactor Landfills: Transport Processes and Chemical Engineering Perspectives, by Don Augenstein, USA;

Enhancement of waste degradation with leachate recirculation at an old landfill, by Markku Pelkonnen & V. Nykänen, Finland;

Treatement of MSOR (Mechanical separation organic residues) in a landfill biorector, by Hans Oonk & H Woelders, The Netherlands;

Leaching behaviour of VAM Bioreactor Rest Product at different stages of degradation at laboratory and pilot scale to assess potential utilization options, by Hans van der Sloot, and J Woelders, The Netherlands; and

Measurement of Carbon and Nitrogen Cycles in Landfill Bioreactors, by Gary Hater, R Green & C Goldsmith, USA.

The papers fell into four categories. There was 1 paper on process engineering perspectives of landfill bioreactor (Augenstein); 2 papers on operational practice and field results (Pelkonnen & Oonk); 1 paper on organic and inorganic waste stabilization in a full scale bioreactor (van der Sloot); and 1 paper on an extensive monitoring programme being implemented at over 15 test bioreactor landfills in the US (Hater).

Discussion

The paper presented by Don Augenstein provided an overview of the biochemical processes that operate in aerobic and anaerobic landfills in terms of their energy demands, effect on landfill temperatures and water balance. As such it provided pointers to important parameters that should be monitored. Temperature and water content were highlighted. Firstly, in anaerobic reactors, rates of degradation are proportional to temperature (up to ~ 55 °C), but fall off rapidly if temperatures exceed ~ 60 °C. Secondly, anaerobic degradation reactions release energy which can heat up the landfill. Therefore, moderately elevated temperatures are indicative that degradation has been occurring and will be proceeding at a rate proportional to the temperature (taking into account other limiting conditions). This was supported by field data from the Yolo County landfill site. Aerobic degradation generates 10 to 20 times more energy than anaerobic degradation and is much more likely to lead to overheating of the landfill. The role of recirculating water or leachate was considered mainly as a means to either heat up or cool the waste.

Discussion of the paper concentrated on the problems of waste heterogeneity, particularly with regard to moisture content distribution. Many studies that have looked at water content with depth have demonstrated considerable variations in vertical profiles. Chris Zeiss considered the quantitative measurement of water contents in waste materials was exceedingly difficult. Existing techniques based on gypsum blocks and neutron probes had considerable problems associated with them. Reference was made to another paper within the conference on the application of TDR probes to water content determination.

A comment was made that there may be some ambiguity about the temperature data from Yolo County landfill and its use to support the theory about variation in degradation rates with temperature. Observed temperature variations may have related to inadequacies in the surface seal to the landfill, especially as there was little fluctuation in temperature below a depth of 3 m (10 ft).

The paper presented by Markku Pelkonnen investigated the feasibility of increasing degradation in a 20 year old landfill by leachate recirculation. Recirculation at 1 and 0.6 m/a was undertaken within injection wells in two research cells over a limited period of time and compared with results from a control cell. Discussion of the paper was based on the observation that recirculation had only resulted in a slight increase in degradation rates compared with the control cell, and that the differences observed might be explained by natural variations in the monitoring data anyway.

Hans Oonk presented a paper on the ESSENT (previously VAM) bioreactor in The Netherlands. This was an 8 m deep 50,000 tonne trial bioreactor which was operated with the aim of achieving biological stabilisation of the waste. Leachate recirculation was undertaken to promote degradation. However, lower than anticipated waste hydraulic conductivities prevented as much leachate being injected as was intended. A subsequent investigation of the *in situ* waste mass indicated that the wetting of the waste by leachate injection was very inhomogeneous. A comparison of the degree of wetting with biological stabilization indicated that whereas rapid stabilization had occurred in all wastes, the most rapid stabilization had occurred in areas of waste that were predominantly dry. Temperature monitoring in the cell had revealed an apparent drop in temperature from between 50 °C to 35 - 40 °C that was largely unexplained.

A large part of the discussion of this paper concerned the uneven nature of water distribution and its apparent inverse relationship with degree of degradation. The measured *in situ* water content could not be related to areas of leachate injection and it was not possible to determine flow paths or flow characteristics of the waste. The need for better *in situ* water content instrumentation was again highlighted.

Hans van der Sloot presented another paper on the ESSENT bioreactor, considering the leaching potential of the landfilled material at various stages of decomposition. Tests on samples from laboratory tests and on samples recovered from the full scale bioreactor indicate that Dissolved organic carbon (DOC) is a useful indicator of the potential leachability of a wide range of elements. The leaching characteristics of fully degraded MSW may be little different from that of a mildly contaminated soil. The validity of the leaching tests and how they would be implemented with regard to the Landfill Directive was raised in the discussion. The leaching tests that will eventually be defined by a National standardisation body have been under development over the last 5 years but may take some time to finalise. This was considered highly unsatisfactory by some landfill operators as the waste characterisation tests are a key element of the landfill directive. It was noted that the samples recovered from the ESSENT bioreactor showed a high scatter in the degree of stabilisation, with little correlation with depth or water content. The engineering challenge to overcome waste heterogeneity was again emphasised.

The final paper was presented by Gary Hater on a monitoring programme implemented at over 15 test landfill bioreactor sites operated by Waste Management inc. in the United States. The bioreactors covered 4 different biological conditions varying from aerobic to anaerobic. The programme of gas, leachate and solid waste monitoring was extensive and was aimed at demonstrating that bioreactors can accelerate the degradation of waste and hence reduce the aftercare period of a landfill. Topics raised in discussion were varied, and included aspects relating to controlling bioreactor processes. It was considered that increasing the water content of most U.S. wastes was critical, although subsequent movement of the water by recirculation was not critical to accelerate (anaerobic) degradation. The cost of aeration in aerobic bioreactors was justified in increased degradation rates, although there were concerns about the effect of temperature increases.

Conclusions and recommendations for future research

Landfill bioreactor technology is still in its infancy. There is a reasonable understanding of the biological processes that are required to make them work, and a wide range of monitoring is being undertaken. Typical monitoring is as follows:

Gas
Landfill flow rates/ total production
CH_4 CO_2 O_2

Leachate
Head on liner
Leachate production
COD/ BOD
pH
VOCs

Solid Waste
Temperature
Settlement
Volatile Solids
Moisture content
BMP

Monitoring of bioreactors tend to concentrate on obtaining information to demonstrate compliance with regulatory controls and to establish what is being achieved. The need to obtaining sufficient data to allow an accurate mass balance to be undertaken is considered critical. In general, the session did not identify any major new parameters that should be monitored that are not already being monitored at landfill sites (to varying degrees of success). This is again indicative that the biochemical processes are reasonably well understood. The greatest challenges appear to be as follows

- monitoring of emissions tends to give an overall picture of the 'health' of the bioreactor. As there is significant evidence for heterogeneity in both the waste and waste degradation how necessary is it to obtain more monitor information from within the body of the landfill? Measurement of *in situ* water content and temperature are considered especially important.

- monitoring is largely aimed at demonstrating what is being achieved in a bioreactor. Although some monitoring is undertaken to guide operational control of bioreactors (e.g. controlling the rate of air injection with temperature in aerobic landfills) there is a need to improve this link so that the processes occurring in a bioreactor can be optimized. This is potentially difficult as further research is required into both the type of monitoring required for this purpose and the landfill engineering necessary to provide the necessary controls over the processes.