Institution: The Open University

Unit of Assessment: B7 Earth Systems and Environment Sciences

Title of case study: Research and development of UK standard tests for determining the biodegradability of treated and untreated municipal wastes.

1. Summary of the impact

The research of Prof Jim Frederickson and the Integrated Waste Systems Research group at The Open University (OU) has impacted industrial partners and government agencies in developing a sustainable approach to waste processes and treated products. In particular they have developed the biodegradability tests (DR4 and BM100/BMc) used extensively for the evaluation of Mechanical and Biological Treatment (MBT) waste plants, and also the Residual Biogas Potential (RBP) test for determining the stability of anaerobic digestates, which forms part of the BSI PAS110: 2010 specification. This work is a significant contribution to the development of sustainable waste management practices in the UK.

2. Underpinning research

The Open University has a long heritage of research into composting systems and novel methods of measuring waste biodegradability with particular reference to reducing the environmental impact (e.g. greenhouse gas emissions, odour and leachate pollution). The combination of vermiculture (tertiary treatment of waste using selected earthworm species) with suitable composting systems to enhance waste decomposition and compost stability (e.g. Frederickson et al., 1997, one of the more highly cited academic papers in this area, 50 on Scopus Oct. 2013) led to research and quantification of biodegradability in relation to composting municipal waste. Jim Frederickson led the first UK investigation into the effectiveness of large-scale composting to treat municipal waste, which was commissioned by the Environment Agency (Frederickson, 1999). This research included empirical studies on the effect of key composting parameters (moisture content, aeration) on waste decomposition rates.

Arising from this early research into biological treatment of waste was the recognition that more sophisticated methods for determining the biodegradability of municipal waste were required. These were investigated at The Open University during a NERC (CASE) studentship project sponsored by Shanks Waste Solutions Ltd starting in 2002 (PhD awarded 2006). One conclusion from the research was that the level of greenhouse gas emissions emitted during processing was positively correlated with the stability or biodegradability of waste undergoing treatment. This relationship was particularly notable for methane emissions arising from anaerobic conditions during composting. It led to future work on the effects of anaerobic conditions on waste biodegradability and the development of biodegradability tests for evaluating the decomposition potential and environmental impact of waste subjected to anaerobic conditions during treatment (biogas generation) and disposal (landfill).

The Open University pioneered and promoted the concept of biodegradability testing for waste-based projects and was commissioned in 2005 by the Environment Agency to work with WRc plc on the development of the aerobic DR4 test and the anaerobic BM100 test methods for determining biodegradability losses during mechanical and biological treatment (MBT) of household waste. Both of the test methods were subsequently adopted by the Environment Agency for use in the statutory evaluation of MBT plants commencing in 2005, with the BM100 test method undergoing minor modification in 2009 to become the BMc test.

Also in 2005, Defra commissioned the OU, WRc plc and Cranfield University to investigate the characteristics, biodegradability and environmental impact of novel wastes, pre and post biological treatment. The DR4 and BM100 tests were employed to help characterise a number of untreated and treated waste types, such as anaerobic digestates, to help predict the relationship between biodegradability and environmental impact from disposal and/or application to land.

Following the Defra research project, in 2009 the OU was commissioned by the Waste & Resources Action Programme (WRAP), established by the government as an independent not-for-profit company limited by guarantee in 2000, to jointly develop the anaerobic 'Residual Biogas Potential (RBP)' test with Southampton University. This test forms a key part of the PAS110: 2010 evaluation criteria for determining anaerobic digestate stability prior to application to land.

3. References to the research

Frederickson, J., Butt, K.R., Morris, R.M. and Daniel, C. (1997) 'Combining vermiculture with traditional green waste composting systems', *Soil Biology and Biochemistry*, vol. 29, pp. 725–30.

Hobson, A.M., Frederickson, J. and Dise, N.B. (2005) 'CH4 and N2O from mechanically turned windrow and vermicomposting systems following in-vessel pre-treatment', *Waste Management*, vol. 25, pp. 345–52.

Frederickson, J., Howell, G. and Hobson, A. (2007) 'Effect of pre-composting and vermicomposting on compost characteristics', *European Journal of Soil Biology*, vol. 43, pp. S320–6.

Godley, A., Lewin, K., Frederickson, J., Smith, R. and Blakey, N. (2007) 'Application of DR4 and BM100 biodegradability tests to treated and untreated organic wastes', Sardinia 2007, *Proceedings of the Eleventh International Waste Management and Landfill Symposium*, S. Margherita di Pula, Cagliari, Italy. 1–5 October 2007, Paper 225.

Wagland, S.T., Godley, A.R., Frederickson, J., Tyrrel, S. and Smith, R. (2008) 'A novel enzymatic biodegradability test method: comparison with microbial degradation methods', *Journal of Communications in Waste and Resource Management*, vol. 9, no. 3, pp. 80–6.

Lewin, K., Frederickson, J., Smith, R. and Hall, D. (2009) *Characterisation of Residues from Industrial Processes and Waste Treatment (WR0110)*, Defra Final Report.

Funding

2004-5: £22,500 awarded by Environment Agency/WRc plc to Frederickson for a project entitled 'Development of a national respirometry (aerobic) test for evaluating the stability of biodegradable waste pre and post Mechanical and Biological Treatment (MBT)'.

2009-10: £25,000 awarded by WRAP (with Southampton University/WRc plc) to Frederickson for a project entitled 'Development of the BSI PAS110 anaerobic stability test'.

2007-9: £99,500 awarded by Defra (WRT220) to Frederickson for a project entitled 'Biodegradable waste characterisation' jointly with WRc plc and Cranfield University, total grant £361,000.

2009-14: £700,000 awarded by AmeyCespa Ltd to Frederickson for a project entitled 'Performance and environmental impact of Cambridgeshire MBT plant'.

4. Details of the impact

The following are a series of examples of the way in which the research of Frederickson and the Open University group has helped the UK Government and waste management industry reduce the quantity of organic waste going to landfill sites. The EU Landfill Directive (31/1999/EC) sets tough targets for reducing the amount of biodegradable municipal waste (BMW) sent to landfill: for the UK these are to reduce to 75% of 1995 BMW level by 2010, 50% by 2013 and 35% by 2020. In 2004 these targets were embodied within the Landfill Allowance and Trading Schemes (LATS and LAS) administered by the Environment Agency. Waste Disposal Authorities investigated sustainable waste management technologies such as composting of source-segregated BMW and the use of mechanical biological treatment (MBT) to pre-treat residual BMW to reduce landfilling of BMW.

In 1995 Jim Frederickson co-founded the Composting Association which is now the Organics Recycling Group (ORG) at the Renewable Energy Association. In 2005 and 2009 he was invited to

join the BSI committees which developed and then updated the first UK specification for waste-derived compost (BSI PAS100) and in 2005 The Open University developed a new PAS100 compost bioassay test and updated this in 2010. Frederickson was appointed to the Technical Advisory Committee overseeing the UK Compost Quality Protocol (2007 to present); this is the Quality Assurance scheme for waste-derived compost products. Jeremy Jacobs, Technical Director of the ORG, comments: 'Jim's extensive contribution to promoting and developing standards in the waste industry has made a significant impact on waste policy, resulted in improved environmental protection and has undoubtedly benefited the natural environment enormously.' According to the WRAP survey of the UK organics recycling industry (WRAP, 2013), the UK composted almost 6 million tonnes of BMW in 2012 compared with just 150,000 tonnes in 1995.

The use of mechanical and biological treatment (MBT) to pre-treat residual BMW prior to landfill is a new technology to the UK. The Environment Agency working with industry developed an evaluation scheme for quantifying decreases in BMW landfilled due to MBT. The Open University was part of the Environment Agency team (with WRc PLC) that developed the core test methods (DR4 and BM100) and protocols for this; these were embodied in the Agency's 2005 and 2009 guidance for the statutory evaluation of MBT plants ('Guidance on monitoring of MBT and other treatment processes for the landfill allowances schemes (LATS and LAS) for England and Wales'). Kathryn Nicholls (Senior Technical Advisor waste recovery (Biowaste) at the Environment Agency comments: 'By developing the DR4 and BM100 biodegradability tests and by contributing to the overall MBT evaluation methodology, The Open University has made a significant impact on reducing environmental risk (e.g. through leachate pollution and greenhouse gas emissions) of landfilling residual household waste.'

Approximately 2.5 million tonnes of residual waste was treated by MBT at 30 sites in the UK in 2012 (WRAP, 2013). In 2009, The Open University entered into an ongoing research partnership agreement with AmeyCespa Ltd to assist them in the evaluation and optimisation of the Cambridge MBT facility. Open University research findings included exceptional reductions in potential landfill methane emissions (>90%) from treating BMW. Jonathan Jones (Principal Operations Manager) comments: 'This Open University research has been immensely valuable to AmeyCespa Ltd and has contributed much to our understanding of the biological treatment process and how best to optimise plant operations and minimise environmental impacts.'

Further evidence of the key role played by The Open University group in supporting government initiatives is in the development of test methods and specifications for anaerobic digestion (AD). Jim Frederickson was appointed to the British Standards Institute PAS110 committee in 2008 (PAS110 is the UK specification for application of digestates to land).

The Open University was commissioned by WRAP to develop the Residual Biogas Potential (RBP) digestate stability test for inclusion in PAS110: 2010. The OU undertakes this key RBP test on behalf of the AD sector with approximately 250 RBP tests having been completed. PAS110: 2010 underpins the Biofertiliser Certification Scheme (BCS). According to http://www.biogas-info.co.uk/, the AD sector currently comprises 106 AD plants processing approximately 5 million tonnes of waste per year. There are currently 12 AD plants which have achieved certification under the BCS (http://www.biofertiliser.org.uk/).

Dr Nina Sweet OBE (WRAP Anaerobic Digestion Special Adviser) comments: 'In providing a key stability test method (RBP) for digestate in PAS110: 2010 and by contributing to the wider development of the PAS110: 2010 specification, Jim Frederickson and the Open University team have directly aided the development of the anaerobic digestion sector, which is a Government priority.'

5. Sources to corroborate the impact

External sources corroborating impact:

1. Guidance on monitoring of MBT and other treatment processes for the landfill allowances schemes (LATS and LAS) for England and Wales, issued by the Environment Agency outlining the biodegradability tests https://publications.environment-agency.gov.uk/skeleton/publications/ViewPublication.aspx?id=26a86ff8-8043-4f53-966f-2c64c22f9841

2. Article in the AWE International illustrating the general adoption of biodegradability testing in the UK http://www.aweimagazine.com/article.php?article_id=238

Beneficiaries who have provided testimonials to corroborate impact (available on request):

3. Senior Technical Advisor, Waste Recovery (Biowaste), Environment Agency

4. Principal Operations Manager, AmeyCespa (East) Ltd

5. Specialist Adviser, Waste & Resources Action Programme

6. Technical Director, Organics Recycling Group, Renewable Energy Association