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CHARACTERISATION OF TREATED WASTES TO SUPPORT AN EVIDENCE BASE FOR SUSTAINABLE WASTE MANAGEMENT

K. LEWIN[1], A. GODLEY[1], J. TURRELL[1], R. SMITH[2], J. FREDERICKSON[3], A. GRAHAM[1], J. GRONOW[2] AND N. BLAKEY[4]

[1]WRc plc, Frankland Road, Blagrove, Swindon, UK, SN5 8YF
[2]Integrated Waste Management Centre, Cranfield University, Cranfield, Bedfordshire, MK43 0AL
[3]Integrated Waste Systems, Open University, Walton Hall, Milton Keynes, MK7 6AA
[4]Waste Research Team, Waste Strategy Division, Defra 7/D11, Ashdown House, 123 Victoria Street, London, SW1E 6DE.

SUMMARY: Defra must consider policies and strategies to manage environmental challenges such as climate change and sustainability. At a basic level the strategies need good quality data on waste characteristics. The dataset for UK wastes, in particular the new generation of treated wastes, is not fit for this purpose. This paper outlines the gaps in knowledge needed to underpin policy development and initial findings from a new project funded under Defra's Waste and Resource Management Research Programme. The project team from WRc, Open University and Cranfield University aims to improve understanding of the characteristics of treated organic and inorganic wastes, methods of testing and knowledge of treatment process performance. Potential opportunities from the research are also described. New data will be collated into the presentation.

1. POLICY BACKGROUND

The waste hierarchy, landfill pre-treatment requirements and landfill diversion targets are among the drivers for reducing the amount of waste that is landfilled. The EU Thematic Strategy on the Prevention and Recycling of Waste states that the waste hierarchy should not be seen as a hard and fast rule, since different waste treatment methods have different environmental impacts. The hierarchy is therefore a framework within which to design waste management strategies and recycling and recovery will not always be the most environmentally sound solution.

Defra is committed to evidence-based policy making, as set out in the consultation document on its Evidence & Innovation Strategy, published in October 2005. Sustainable Consumption and Production (SCP) also features in this document as one of six strategic priorities for the department. Under the SCP heading, the priority outcome for waste and resources management is given as "the protection of human health and the environment by minimising amounts of waste produced and getting as much value as possible out of what is left by re-use, recycling or composting and the recovery of energy".

There will always be residual materials for landfilling, but this needs to be carried out in a sustainable way, by inter alia, limiting the input of materials that prolong the aftercare of landfills and minimising the generation of environmentally challenging emissions.

2. GAPS IN THE EVIDENCE BASE

The paucity of appropriate data is a serious barrier to successfully implementing these policies. There is a lack of technical information about the new generation of treated residue streams, for example their gross composition, leaching behaviour and biodegradability. It is therefore difficult to predict their behaviour when landfilled or recycled to land with respect to release of metals, nutrients and greenhouse gases. As the proportion of these new treated wastes in landfill increases, modelling the changing source term will become critical. There are also gaps in technical and operational knowledge – how efficient are organic waste treatment methods at removing biodegradability and how should biodegradability be defined?

The mechanism of setting waste acceptance criteria that Europe has adopted may provide us with a means of contributing to the aim of sustainable landfill, even if the values we are using at present do not cover the right components (e.g. organic compounds) and may be insufficiently strict (i.e. not sufficiently close to final storage quality). Once we can comply with a system of acceptance criteria, pre-treatment of waste to meet criteria that contribute to a more sustainable landfill may be relatively easy to introduce.

3. APPROACH OF DEFRA-FUNDED WASTE CHARACTERISATION PROJECTS

3.1 Objectives and methodology

Two projects commissioned under Defra's Waste and Resource Management Research programme are using waste characterisation to plug the gaps in the evidence base. Waste characteristics dictate waste management options, and the use of the data underpins science on, for example, control of contaminants/emissions to the environment and resource flow through the economy as highlighted in Figure 1.

The objectives of the projects are to:

- characterise organic and inorganic residues from industrial processes and waste treatment processes, and
- provide a national waste characterisation database focusing on composition and leachability (UK support to "leachXS").

In outline the main steps of the sampling and testing programme include:

1. Design of sampling plans to generate appropriate samples of UK waste streams as required by EN 14899 and the Landfill Regulations (as amended).

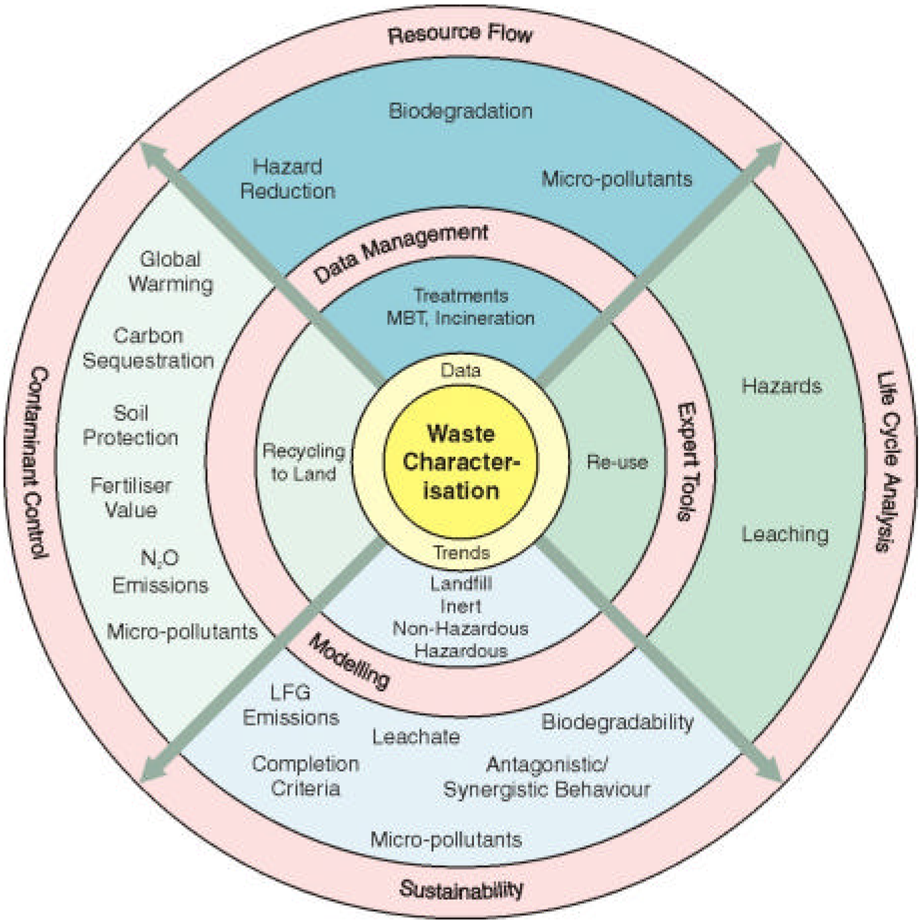

Figure 1. Using characterisation data to understand the potential for emissions and resource recovery during the treatment and disposal of wastes

2. Collection of samples of pre- and/or post-treatment wastes from mechanical-biological treatment (MBT), partial and full windrow-composting and anaerobic digestion, effluent treatment plant residues and filter cakes, cement stabilised APC residues and gasification or pyrolysis residues.

3. Comprehensive characterisation including the traditional 'inorganic waste characterisation' approach for all wastes: composition (general composition, nutrients and potentially toxic elements e.g. metals) and the use of a toolbox of leaching behaviour tests (e.g. upflow percolation, pH dependence, maximum availability for leaching and batch leaching tests) to enable assessments to be made of potential hazard properties, landfill waste acceptance criteria (WAC) compliance etc.

4. Biodegradability assessments (e.g. biodegradability by the aerobic 4-day dynamic respiration (DR4) and anaerobic 100-day biochemical methane (BM100) tests, biochemical composition (hemicellulose, cellulose and lignin contents), and BS EN 13652 (Soil improvers and growth media – extraction of water soluble nutrients). Additionally the project is developing further and evaluating an enzyme hydrolysis test.

5. Export of data to the national UK satellite database of the leachXS system, the leaching expert system developed by ECN (Energy Research centre, Netherlands), DHI (Denmark) and vanderbilt University (US) (van der Sloot et al., 2003).

3.2 Initial findings/work in progress

3.2.1 Sampling

The design of the sampling plans follows the guidance provided by the Framework Standard EN 14899 (CEN 2005) and five supporting Technical Reports produced by CEN Technical Committee 292, Working Group 1. Preparation of a sampling plan ensures that the key objectives of a test programme are considered at an early stage, as well as how those objectives can be practically achieved for the situation and material under investigation, and ultimately provides an audit trail of the sampling exercise.

The following two basic approaches have been used in sampling plan design for the Defra ‘waste characterisation project’.

- The organic waste programme required collection of a wide range of organic residues to provide a calibration line for the new BM100 and DR4 biodegrability tests. For the initial test programme, single snap shots were needed from a comprehensive set of processes, as opposed to repeat sampling for a small number of residues. To ensure compatibility between sample types and sampling events, a generic sampling plan was produced that could be used anywhere, for any process, at any time, and by anyone for this project or for future sampling events. The sampling plan was supported by site-specific sampling records.

- In contrast the inorganic waste testing was focused on collecting more comprehensive data for a smaller number of waste streams. This objective could be achieved by selection of a discrete number of processes or plants, each of which handled a complex cocktail of input wastes and operated a suite of basic treatment recipes. A second objective of this testing programme was to obtain samples that represented the extremes and middle ground of waste inputs and outputs and encompassed the range of processes being undertaken at the selected plants. Process complexity and variability dictates in this instance that sampling would need to take place over a much longer period of time than the single point in time snap-shot approach used in the organic waste programme. A discrete number of site-specific sampling plans were produced that targeted each individual operating regime. Paired input/output samples were collected from a suitable fixed operating period, determined after analysis of background testing data and discussions with plant personnel.

3.2.2 Organic wastes and test methods

Organic waste samples have been selected that cover a diverse range of sources, biochemical composition and degree of biological or physical/chemical treatment in order to challenge the selected waste characterisation methods. For example, this range includes materials with high carbon/nitrogen (C/N) ratios (such as wood and cardboard packaging wastes), low C/N ratios (such as feathers and fish wastes), partially and fully composted municipal solid waste, partially anaerobically digested wastes, and selected wastes treated by autoclaving. The organic wastes include samples of MBT derived compost-like outputs and fully composted greenwastes being used in plant growth trials as part of a Grantscape funded project at Reading University.

The management of organic wastes entails measuring the biodegradability of waste for process monitoring, landfill diversion of biodegradable municipal waste (BMW) for the Landfill

Allowance Trading Scheme and product quality. Such measurements are currently carried out using biological test methods (either the anaerobic BM100 or aerobic DR4 test) that involve the use of microbial cultures to decompose the waste during the test. It is envisaged that comparison of the methods in relation to each other and the type of organic waste will help to derive an understanding of how useful each test is with regard to waste characterisation and prediction of how the waste might behave if composted, anaerobically digested, autoclaved, landfilled or recycled to land.

The organic waste characterisation data may, for example, be used to understand more fully mechanical biological treatment (MBT) plant performance in terms of estimated BMW diversion from landfill, evaluating the impact of processing times on BMW treatment, and process performance monitoring and optimisation (Malhotra and Godley 2006). We are also evaluating how the data might be used to predict the impact on emissions from landfilling MBT residues (by application of leaching tests to organic wastes) and organic waste treatment processes.

For example one of the composting plants included in the study treats a mixture of garden and kitchen wastes by composting initially for 4 days in covered aerated piles and then subsequently in open turned windrows. We have analysed samples before and after these stages and have then estimated the CO_2 production, based on calculating the reduction in loss on ignition at 550°C (LOI). Then, assuming the LOI is 45% C we have calculated the loss in total N, and the potential nitrification and denitrification that occurred as possible sources of NO_2 emissions. The preliminary results (Table 1) indicate that there was significant formation of NH_4^+ during the initial 4 days but that there was no nitrification, as the NH_4^+ did not subsequently decline. Therefore the risk of NO_2 emissions was very low. The results, however, indicated an overall loss of about 33.3% of the N with half the N being lost in the first 4 days, giving a high potential CO_2-C/NH_3-N ratio during this initial period. Therefore potential NH_3 emissions can be quantified by the waste characterisation methodology and, in this case, were maximal during the first few days during the decomposition of the most readily biodegradable fraction of the waste.

Organic waste biodegradability tests are complex, costly and time-consuming (up to 100 days in the case of the BMP test), and can be unreliable due to the need for biological living microbes in the test. There is a requirement for a simple, low cost, reliable chemical or physical based

Table 1. Application of organic waste characterisation data to estimate fate of N in composting process

Parameter	Start aerated pile 0 day	End aerated pile 4 day	End windrow 56 day
DM %wet weight	33.3	38	50.8
LOI % DM	75.1	73.1	59.6
Total N % DM	1.65	1.5	1.78
NH_4^+-N (mg N kg DM)*	194	626	672
NO_3-N (mg N/kg DM)*	1.4	<0.1	<0.1
LOI reduction (t LOI/t input waste)	0	0.024	0.124
CO_2 produced (kg CO_2-C/t input waste)		10.8	55.8
Total N (kg N/t input waste)	5.4	4.5	3.6
N lost (kg N/t input waste)	0	0.9	1.8
CO_2-C/NH_3-N		12	31

* From BS EN 13652 – Soil improvers and growth media – extraction of water soluble nutrients.

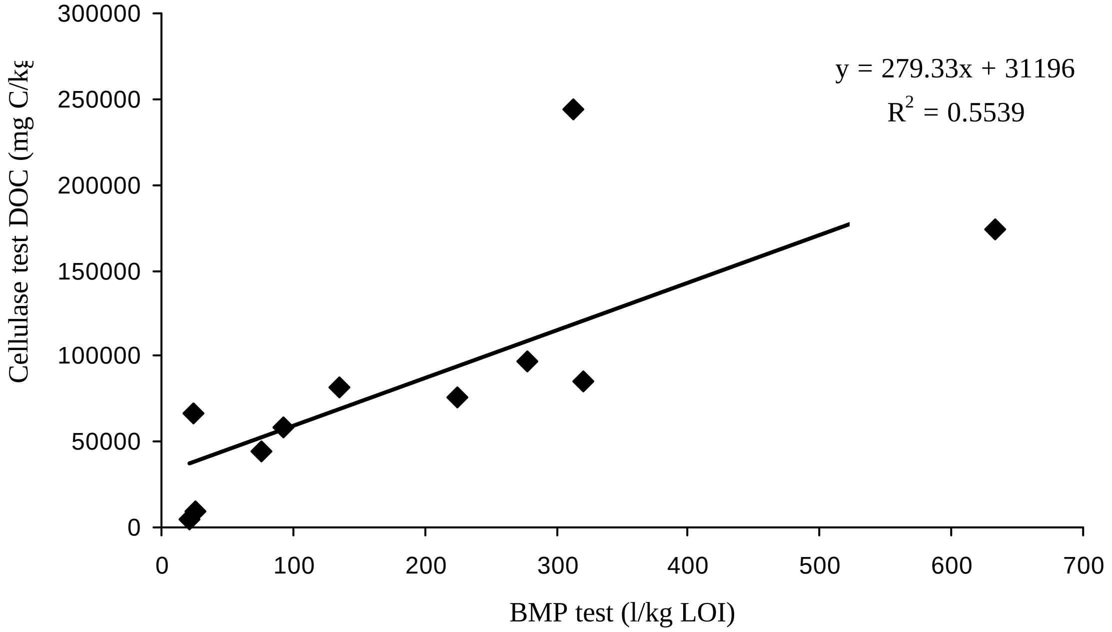

Figure 2. Potential correlation between release of dissolved organic carbon (DOC) by the cellulase hydrolysis test and biogas production by the anaerobic BMP (now called BM100) biodegradability method (from Godley *et al.* 2004)

method that provides a surrogate measurement of organic waste biodegradability without the limitations of using a live biological test.

A potential solution is a test based on the enzymatic hydrolysis of organic wastes that has been shown to have the potential to provide a surrogate method of determining organic waste biodegradability and can be used to monitor reduction in biodegradability during composting (Godley *et al.* 2004, Figure 2). Such a test has certain advantages over biological test methods, it would be:

1. cost-effective - it is considered that the cost of the test would be less than a fifth of biological tests;
2. rapid - the test may be completed and reported within three days; and
3. microbe free - the test does not involve the use of live microbes but is applicable as it is based on the hydrolysis of the waste by enzymes, which are naturally involved in waste decomposition.

3.2.2 Inorganic wastes

At the time of writing, testing has not yet begun. However, the data will be interpreted in the context of potential acceptance to landfill, fitness for purpose against end-use specifications, or potential for recovery of resources (e.g. energy, nutrients, secondary materials). Where other relevant good quality datasets have been identified, this background information may be included to provide context.

4. OPPORTUNITIES

4.1 Cross-programme collaboration

There is considerable synergy with other ongoing and proposed research programmes such as 'Sustainable Landfill', the Environment Agency's programme on MBT outputs including estimation of BMW diversion (EA 2005), MBT modelling and other work of the New Technology Data Centre (www.environment-agency.gov.uk/wtd). There are also linkages with several themes within Defra's Waste and Resource Research programme related to biowastes, compost-like outputs and biodegradable municipal waste. Every opportunity is being made, as with R3/Reading University's GRANTSCAPE compost-like output project, to share samples in order to increase the value of specific monitoring data by placing it in context with other characterisation data. In some cases, other projects could offer opportunities for further testing of outputs from the same plants, increasing the confidence in individual data points for outputs from specific plants from this project.

4.2. Other opportunities

As the research develops over the next 2 years, other opportunities will be identified and developed. These are likely to include:

- the ability for Local Authorities to use data from the comparative assessment of treatment processes to inform their purchasing decisions;
- the ability to predict and model MBT process performance from the biochemical composition of the feed waste;
- prediction of the impact landfilling of MBT treated residues has on landfill emissions and sustainability of landfills;
- prediction of impact of residual materials on soil quality, soil fertility and environmental emissions if recycled to soils;
- 'better regulation' with the potential to move away from limit values on outputs to monitoring the efficiency of a treatment process.

5. WHERE NEXT?

The data will be exported to the national satellite database of the leachXS system (van der Sloot, *et al*, 2003 and http://www.leachxs.org/LeachXSFlyer.pdf). The database can be interrogated on several levels by a range of users, allowing the leaching behaviour and composition of specific plant outputs to be compared and the characteristics of generic waste streams to be evaluated on a national and, ultimately, European basis. Operationally, such powerful contextual information may reduce future requirements for plant-specific testing. LeachXS is backed up by a powerful geochemical modelling framework, ORCHESTRA, which offers potential for predicting long-term emissions as undertaken for the Sustainable Landfill project (van Zomeren *et al.*, 2005).

The boundaries for this research project are clearly defined, with testing limited to gross characteristics, biodegradability and predominantly inorganic components, with no analysis of organic pollutants. As understanding of the characteristics of the treatment residues and expertise with leaching behaviour tests develops, opportunities will arise to determine total and leachable micropollutants such as pesticides, pharmaceuticals or endocrine disrupting chemicals. As the focus for landfill acceptance moves to limit organic components, the issue of leachable organic parameters will become increasingly significant.

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