CURRENT ISSUES IN SOURCE SEPARATION, TREATMENT AND UTILISATION OF FOOD RESIDUALS.

Ian G. Mason & Mark W. Milke.
Department of Civil Engineering, University of Canterbury, Christchurch, New Zealand.

Abstract
Current issues in the management of urban food residuals relating to source separation, waste stabilisation options, product utilisation, risk management and decision making are reviewed. Source separation is increasingly seen internationally as a key component in sustainable food residuals management strategies, with a number of behavioural studies reported. However, there is a pressing need for local research, as little information relating directly to New Zealand society has been published. Composting is a mature technology for organic residuals stabilisation and is being actively considered for food residuals treatment in several parts of New Zealand. Anaerobic digestion is now an increasingly favoured food residuals stabilisation technology worldwide, with the prospect of significant nett energy production and a quality solid product. Important current issues in treating organic residuals include odour management and the disinfection of pathogens. In this respect, the relative roles of and required degrees of process control needed for, anaerobic digestion and composting require further study. Stabilised product utilisation is discussed, with particular reference to the emerging interest in producing a range of environmentally beneficial products. Aspects of risk analysis and decision-making in selecting appropriate sustainable systems for food residuals management in New Zealand are outlined.

Introduction

Separate treatment of food residuals has been an emerging trend in solid residuals management internationally for several years (Goldstein et al., 2003), and because these materials represent a significant proportion of the total organics stream in New Zealand, it is likely to assume increasing importance here in the future. Already several local authorities are signaling their intention to include domestic kitchen residuals within their overall waste minimization and beneficial re-use programmes. Food residuals from industrial sources, although not specifically targeted in the NZ Waste Strategy (MfE, 2002), will be captured within the general industrial organics stream. Source separation, composting systems and anaerobic digestion technologies promise to play a key role in these strategies.

In this paper we highlight some of the current technical and conceptual issues involved in each of these areas and outline aspects of the decision-making and risk assessment process.

Source separation

Good source separation will provide cleaner feedstocks for subsequent stabilization processes, such as composting and anaerobic digestion, and improve the final product quality from these technologies. Additionally, by eliminating or minimizing downstream sorting processes, it will reduce associated health hazards, minimise energy and labour inputs, avoid wastewater, and on a social level, may help to create an increased awareness of the composition and potential value of these residuals. In a recent article, the editors of Biocycle magazine identified 15 trends in composting and organics recycling, and their associated equipment implications (Goldstein et al., 2003). Two items of particular relevance to source separation of food residuals are a) the increasing requirement for improved feedstock quality, for both process control and product quality reasons, and b) the decreasing tolerance for plastics contamination and the associated high costs of either mechanical pre-process, or post-process, plastics separation. Both trends highlight the desirability of good separation at source.

Because source separation is dependent on the actions of individuals, understanding ways in which they can be encouraged to "pick up the 'rubbish' and put it in the right bin" (with apologies to the Wombles!) is crucial. Many studies of psychological, social and demographic factors in recycling programs (which of course involve source separation) have been reported in the literature, often with conflicting findings. However, three well-established observations from the literature are:

- that a discrepancy between pro-environmental beliefs (i.e. "recycling is good for the environment") and concrete pro-environmental behaviours (ie a high level of participation in recycling) is often found,
- that personal inconvenience is often associated with low levels of participation in recycling,
- that the belief that one's actions in this area are, or may be, futile, is also associated with low levels of participation in recycling.

The latter two findings may help to explain the, perhaps initially puzzling, divergence between beliefs and behaviours, and point to potential solutions. For example, in cases when the benefits of expanded separation programmes are not clear, attempts at improving participation can erode support for existing, limited, separation programmes. In terms of positive measures to encourage improved participation, the following are pertinent and encouraging:

- the literature contains reports of several studies indicating that publicity and education schemes seem to be very successful in overcoming the above attitudes. Maintaining the credibility of recycling programs is extremely important in this context however, ie. ensuring that source separated residuals are indeed recycled and not sent by a roundabout route to final disposal in a landfill.
- positive correlations with improved recycling behaviour have been found with one's level of education, age, level of income and owning one's own home.
- technical factors (such as the impact of design, size and functionality of the collection systems) are assuming increasing importance as the move to food residuals separation gains momentum. These will be important in minimising the inconvenience factor cited above, as well as providing new opportunities in system design, from individual bins to transportation options.

One readily identifiable gap in the knowledge base in these areas concerns the social aspects of source separation and recycling within New Zealand. Several non-refereed surveys, including a NRB report (NRB, 1990) are available. However, apart from one study carried out at the University of Otago (Bryce et al., 1997) there seems to be no further information in the peer-reviewed literature about the attitudes and behaviours of the New Zealand population in this important area. There is also a particular need to conduct longitudinal studies in which participants are studied at selected intervals over a number of years. We suggest that these are priorities for future research.

Composting

Composting is well established as a stabilization technology for a range of organic materials and is widely used in New Zealand for the "green waste" stream. Food residuals composting is presently practiced at several New Zealand and South Pacific locations and is being actively explored in other parts of New Zealand. An expression of interest document regarding a proposal to compost food residuals from the Auckland region was released in July, 2003.

Odour control has been an issue in composting systems over the years and promises to be a major concern when food residuals are a feedstock. Odours can arise during collection, storage and mixing of food residuals, so materials handling at these stages will require special attention. Opportunities for innovative solutions may be anticipated in a) hardware design and b) the addition of odour adsorbents (e.g. sawdust) at the collection stage. In one European study, odour and vector nuisance during collection was minimized by allowing incorporation of other biodegradable residuals such as soiled paper at the collection stage, prior to either composting or anaerobic digestion (Gellens et al., 1995). Containment and treatment of in-process composting odours suggests that only in-vessel systems, or aerated static piles operated in the suction mode, will be acceptable for food residuals composting. This will enable off-gases to be collected and treated, and biofilters, which may well incorporate finished compost, are a well-established option for use in this type of situation. Research has indicated that the most serious in-process odours are produced during the very early stages of composting. Thus potential process management solutions, including ensuring the appropriate initial ingredient mix, sequential addition of materials and the addition of adsorbents, merit consideration. In view of the considerable literature on the topic of composting odours, and the likelihood that odour control will be a significant issue in the future, we suggest that development of a set of composting odour control guidelines would be beneficial at this time in order to bring this information together and tailor it for New Zealand conditions.

Disinfection is currently a major European issue in food residuals stabilization where materials of animal origin are present, with particular concern over BSE and foot and mouth disease transmission (Defra, 2003; Papadimitriou et al., 2003). This has led to proposals for composting process temperatures to be maintained at greater than 60-70 ^{o}C, and the specification of maximum particle sizes. For certain raw materials, a separate sterilization or disinfection process may be required. Whilst we may initially anticipate less stringent requirements in New Zealand, it is nonetheless a significant issue with a number of important process implications. For example, in order to attain specified temperature-time requirements, sufficient bio-available energy must be present in the initial composting mix, moisture must not be limiting, and aeration systems need to supply sufficient oxygen, but without over-cooling the system. Food residuals may also need to be ground prior to mixing with amendments in order to meet appropriate particle size requirements. This has other process benefits however, for example homogenization, and has already been adopted by food residuals composters elsewhere. Further study on disinfection performance of composting systems treating food residuals is required.

Composting is relatively robust biologically and is suited to small, medium and large-scale operation. It can be operated with relatively modest technical knowledge and equipment. However, it is a nett consumer of energy and the potential for loss of nitrogen during the process means that some nutrient value can be lost during the stabilisation process.

Anaerobic digestion

Anaerobic digestion (AD) is emerging as a viable technology for food residuals stabilization and increasing interest in AD in general is being shown in many parts of the world (Mata-Alvarez, 2002; Riggle, 1998). One of the attractions is the production of biogas, of which the methane component is potentially a source of energy, and some significant benefits in terms of sustainability have been identified with this technology (Edelmann, 2003). The ability to manipulate the process to produce hydrogen gas (Anon, 2003), which may be used in fuel cells, is also of considerable interest.

Issues relating to odour control apply to AD as they do to composting, but with some important differences. Firstly, in-process odours from AD systems are a normal consequence of the process and their impact should they escape is potentially serious. However odorous gases are normally contained within reactor vessels and can be satisfactorily treated and/or further contained by bio-gas handling and scrubbing systems. Secondly, the digested sludge and liquid stream, which exit the process, are also potential odour sources and appropriate arrangements to minimize nuisance are therefore needed. Thus modern AD systems must include odour management systems as an integral part of their design and operation.

In relation to hygiene concerns, AD may give either lesser, or equivalent, disinfection performance when compared to aerobic composting systems, depending upon the temperature of operation. When operating in the mesophilic temperature range (e.g. around 35 ^{o}C), AD sludges will require additional treatment in order to meet the proposed European standards. However, for AD systems operating at thermophilic temperatures (e.g. around 55 ^{o}C) there is evidence that their disinfection performance can match, or even exceed, that of aerobic composting systems (Papadimitriou et al., 2003). Non-thermal mechanisms appear to play an important role in disinfection in AD systems, however, as with composting, further investigation into AD disinfection performance will be needed. Aerobic composting may be used in the post-treatment of the digested solids fraction in order to further stabilize the material, reduce odour and give further disinfection treatment. Where this is considered, careful consideration of appropriate co-composting materials is needed because the digested solids are relatively energy poor.

An important strategic issue will be how best to combine AD and aerobic composting activities in one system. For example, where green waste composting is present or proposed, this may provide a suitable post-treatment for digested AD sludges from food residuals processing. However, if green waste composting is unavailable, then an alternative strategy will be required. Another concern associated with AD is the need for the liquid fraction to be either treated further, or marketed as a product.

Anaerobic digestion is a biologically sensitive process, when compared to aerobic composting, and typically involves a higher degree of technical input in order to optimize gas production, maintain process temperatures and minimize the risk of process failure. In New Zealand, anaerobic digestion of food residuals may be more suited to large and medium scale operation, both for technical reasons, and because scientific and engineering know-how is likely to be more readily available.

Product use

One of the emerging trends identified by Goldstein et al. (2003) was the evolving perception of the industry as one involved in the manufacture of environmental products, rather than in the treatment of wastes in order to meet regulations. This will require a careful consideration of all the properties of the final products from various stabilization processes, and a high degree of quality control at all stages of collection, treatment and post-treatment, in order to ensure final product quality.

Beneficial properties of composts include the potential for slow-release nutrient supply to plants, structural conditioning of soils and the suppression of plant diseases. In Western Australia and Italy, incentives have been made available for the use of composts in the improvement of poor quality soils, and elsewhere compost has been used in the remediation of contaminated sites. Compost has also been used in applications such as stormwater runoff control and bank stabilization. With increasing interest in organic food production methods, the disease suppression properties of composts and the use of compost "teas" are receiving growing recognition.

Anaerobically digested sludges are typically valuable soil conditioners and can contain considerably higher nitrogen levels when compared to aerobic composts. However since this nitrogen is largely in the ammonium form, a fraction can be lost during post-processing operations such as drying (Svensson et al., 2003) and composting. Composting is frequently used to further treat and disinfect AD sludges, and in Switzerland this is required if the product is to be marketed as compost (Edelmann, 2003). Products from an AD/composting operation include energy, in the form of biogas, electricity and/or heat, plus compost and a nutrient rich liquid. Where aquaculture is used to treat the AD wastewater stream, plant biomass and fish may also result.

Thus the potential markets for the final products will influence the decision-making process. For example, if soil textural improvement and plant disease suppression are major goals, aerobic composting may provide the best product. Alternatively, if nutrient concentration and energy production predominate, then AD may have the advantage.

Decision-Making

Food residuals management issues such as source separation, process selection, and product use all are part of a larger issue of the construction of the best system for managing food residuals. Decisions on specific aspects of food residuals management need to be made strategically, meaning that they are made with a view to the overall system and its long-term goals. Because large quantities of economic and social capital are tied into decisions on management of food residuals, developing a robust process for strategic decision-making is currently a significant issue. It is a difficult issue because of the many decision variables and the many criteria on which a decision need to be based.

Key factors influencing decision-making in the New Zealand situation will include the scale of the food residuals management operation, the availability of technical knowledge/skill, and the degree to which flexibility in the system is desired. Sustainability issues including ecosystem impact, economic viability and social effects also need to be factored into the decision-making process.

As with many complex situations, it helps to focus on the decisions rather than the issues. For food residuals, the decision is not what technology to use, but what overall system should be selected, and what are the key variables that affect that choice. For example, our choices might be:

- a system using large quantities of well-segregated food residuals in an anaerobic digestion process and linked to an aerobic composting system for garden residuals,
- a system using windrow composting for combined treatment of relatively small quantities of well-segregated food and garden residuals,
- a system using in-vessel composting for intermediate quantities of well-segregated food residuals,
- a system using a landfill bio-reactor to treat poorly-segregated food residuals along with other biodegradable residuals, or
- a system of poorly-segregated food residuals being placed in a CAE-grade landfill (a do-nothing option).

When faced with multiple choices and many variables that affect the decision, it is valuable to look for key variables that affect the decision (Guikema and Milke, 2003). In this highly hypothetical case, we could pick two key variables: the total amount of food residuals, and the effectiveness of source separation. Figure 1 provides an assessment of the preferred system under the conditions a decision-maker might encounter in this hypothetical case. Even accepting that grey zones could blur the lines dividing the zones of the preferred systems, strategic decision-making could benefit from approaches that look to clarify and simplify strategic choices in this way.

The above analysis assumes that decision-makers can decide on the appropriate measure on which to compare options. In fact, a major issue affecting decision-making on food residuals is the appropriate manner to merge economic, environmental, and social measures of desirability into one decision. Although people will quickly agree that a triple-bottom-line approach is appropriate for society as a whole, people will use different methods to include all three aspects, leading to some good decisions and some bad ones. The major factors contributing to bad decisions are the lack of clarity or transparency in the approach taken. At one extreme, non-quantitative approaches can be misinterpreted and difficult to justify. At the other extreme, highly quantitative approaches, such as WISARD, tend to have too much detail to allow the results to be easily understood or interpreted. The lack of trust in decisions made at the two extremes indicates a need for intermediate approaches, and their development. We also need to carefully examine new, and possibly surprising, findings. For example, a recent assessment of composting and AD systems found composting to have a negative ecological impact (in some cases greater than incineration), whilst AD was assessed as ecologically neutral (Edelmann, 2002).

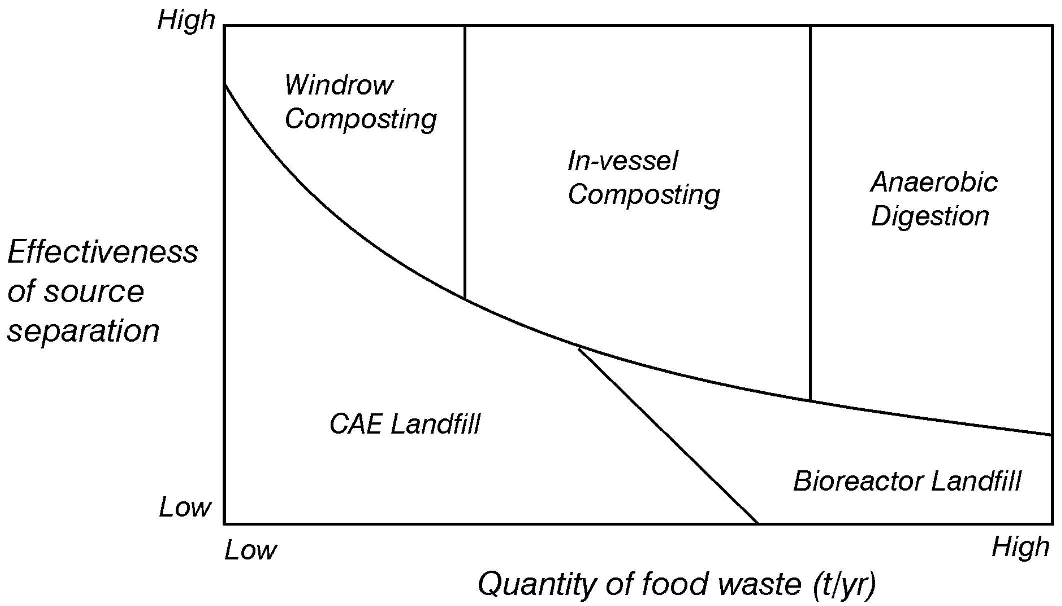

Figure 1: Decision diagram for an assessment of hypothetical food residuals management options.

The relevance of the assessment technique employed to New Zealand conditions, and how we might use the findings, requires close examination. A great deal of research is underway to improve "life-cycle" analyses and social impact assessments (Chung and Poon, 1997; Doberl et al., 2002; Nolan-ITU, 2001; Rosenblum, 2000; Thorneloe et al., 2002), and a significant issue for food residuals management will be the application of new knowledge and tools.

Furthermore, because communities are increasingly interested in participating in resource management decisions, public consultation is vitally important. It is now normal practice in many parts of New Zealand, and contrasts markedly with the more traditional top-down "decide-announce-defend" (DAD) policy (Annandale et al., 2003). In order to successfully involve the community in food residuals management decisions, the systems or "big-picture" analysis, delivered in appropriate language and through readily accessible media, will be even more necessary.

A third key issue related to decision-making for food residuals is the appropriate method to manage risk. Managers in the public and private sector acknowledge risk, and risk affects decisions now; however, the many causes of risky decisions will need to be addressed soon. Some key uncertainty issues related to management of food residuals are:

- uncertainty in the variation in quantity and composition of food residuals,
- uncertainty in how analysts should include variability in decision-making processes
- uncertainty in the ability of social policy to lead to individual change,
- uncertainty in the interaction with sustainability decisions in the transport, housing, and production sectors,
- uncertainty in the public/private relations in the future

Risk management is a rapidly developing discipline, and the interaction of risk management of food residuals will likely be a key arena for further developments.

Conclusions

1. Source separation is a key component of food residuals management strategies, with important product quality implications. Further research on recycling attitudes and behaviours in New Zealand is required.

2. Odour control and disinfection performance are important current issues for food residuals stabilization systems, with significant process implications for both composting and anaerobic digestion technologies.

3. A focus on the production of environmentally beneficial products, rather than the treatment of waste, is an important paradigm shift in organic residuals management.

4. Decision-making for food residuals management should focus on the total system, with stabilisation technology choices made in relation to overall system needs. Issues of scale, technical resources, sustainability and flexibility will be significant, and the incorporation of risk assessment methods of key importance.

Acknowledgements

The authors wish to thank Markus Leiss for research assistance.

References

Annandale, D., Lantzke, R., and Skinn, M. (2003). Making good waste management decisions. *Proceedings of the Fourth International Conference of ORBIT Association on Biological Processing of Organics: Advances for a Sustainable Society,* 30th April-2 May, 2003, Perth, Australia, 205-211.

Anon. (2003). Energy from wastewater. *Environment*, **45**(3), 5-6.

Bryce, W. J., Day, R., and Olney, T. J. (1997). Commitment Approach to Motivating Community Recycling: New Zealand Curbside Trial. *The Journal of Consumer Affairs*, **31**(1), 27-52.

Chung, S-S, and Poon, C-S. (1997). Quantifying externalities in solid waste management in Hong Kong. *J. of Environmental Engineering*, **123**, 282-289.

Defra. (2003, June 13 - last updated). Consultation on the proposed use of catering waste containing meat in composting and biogas treatment. Web address: http://www.defra.gov.uk/corporate/consult/animalbyprod (Accessed 2003, September 2).

Doberl, G., Huber, R, Brunner, P.H., Eder, M., Pierrard, R., Schonback, W, Fruhwirth, W. and Hutterer, H. (2002). Long-term assessment of waste management options—a new, integrated and goal-oriented approach. *Waste Management and Research*, **20**, 311-327.

Edelmann, W. (2003). Products, impacts and economy of anaerobic digestion of OFMSW. In: J. Mata-Alvarez, (Ed) Biomethanization of the organic fraction of municipal solid wastes, IWA, London, UK., 265-301.

Gellens, V., Boelens, J., and Verstraete, W. (1995). Source Separation, Selective Collection and in-Reactor Digestion of Biowaste. *Antonie Van Leeuwenhoek International Journal of General and Molecular Microbiology*, **67**(1), 79-89.

Goldstein, J., Rynk, R., and Goldstein, N. (2003). 15 trends in composting and organics recycling. *Biocycle*, **44**(4), 64-66.

Guikema, S. and Milke, M.W. (2003). Sensitivity analysis for multi-attribute project selection problems. Accepted for publication by *Civil and Environmental Engineering Systems*.

Mata-Alvarez, J. (2002). The biomethanisation of the organic fraction of municipal solid waste. *Water 21*(October 2002), 59-61.

MfE. (2002). New Zealand Waste Strategy. NZ Ministry for the Environment, Wellington, New Zealand.

Nolan-ITU Pty. Ltd. and Sinclair Knight Merz (2001). Independent assessment of kerbside recycling in Australia. Ref: 4046-01. Environment Australia.

NRB. (1990). Recycling attitudes and behaviour. National Research Bureau, Auckland, New Zealand.

Papadimitriou, E. K., Stentiford, E. I., Diaz, L. F., and Alexiou, I. E. (2003). EU and UK sanitisation requirements for the bioprocessing of municipal biodegradable waste with respect to materials of animal origin. *Proceedings of the Fourth International Conference of ORBIT Association on Biological Processing of Organics: Advances for a Sustainable Society,* 30th April-2 May, 2003, Perth, Australia, 442-452.

Riggle, D. (1998). Acceptance improves for large-scale anaerobic digestion. *Biocycle*, **39**(6), 51-55.

Rosenblum, J., Horvath, A., and Hendrickson, C. (2000). Environmental implications of the service industries. *Environmental Science and Technology*, **34**, 4669-4676.

Svensson, K., Odlare, M., and Pel, M. (2003). The fertilising effect of compost and anaerobic digestion residues from source separated houshold waste. *Proceedings of the Fourth International Conference of ORBIT Association on Biological Processing of Organics: Advances for a Sustainable Society,* 30th April-2 May, 2003, Perth, Australia, 490-499.

Thorneloe, S.A., Weitz, K.A., and Nishtala, S.R. (2002). Informing choice: the MSW decision support tool. *Waste Management World*, May-June, 19-23.