11 GENERAL DISCUSSION AND CONCLUSIONS

11.1 SIGNIFICANCE OF THE RESEARCH

Treatment of organic waste by composting is expanding in response to UK and European controls on landfilling biodegradable waste. This research project represents one of the first quantitative assessments of HC for waste diversion from landfill in the UK. Previous studies on HC have generally focussed on surveys of the general public and local authority activities and have not provided evidence of the actual amounts of waste composted by homeowners. Therefore, the data reported here contribute to improving understanding of the effects of HC on the diversion of domestic biodegradable waste from landfill under UK conditions.

11.2 WASTE INPUTS AND DIVERSION FROM LANDFILL

Biodegradable waste inputs to home compost bins measured in the RBC Study Trial indicated the total annual diversion rate was potentially 360 kg per household. This value is considerably larger than the default value for HC of 100 kg y^{-1} per household suggested by DETR (DETR/WO, 1999c), which is suggested as minimal diversion figure in uncontrolled environments. The results reported here suggest that actual diversion rates may be significantly larger than this.

The relative contribution of kitchen, paper and garden waste to the total waste input to home compost bins was 29, 3 and 68 %, respectively. A general trend of declining kitchen waste inputs with increasing household occupancy was observed and was particularly apparent in the second year of the investigation. This could reflect dietary habits and a possible shift from the consumption of fresh fruit and vegetables in low occupancy households to more convenience processed foods with increasing occupancy. Inputs of waste paper were variable and householders were generally reluctant to add paper to the compost bin. Interestingly, the total amount of garden waste deposited in the bins was independent of garden size. Homeowner behaviour and management of the bin may be a more important factor controlling the input of garden waste than a simple physical relationship with garden size. Also, the capacity of the bins to receive garden waste was probably exceeded for the majority of garden sizes in the HC Study.

Home composting is not suited to the treatment of woody garden material and homeowners indicated (Chapter 10) that they transported this type of waste to the CA site for disposal. Therefore, HC cannot provide a single solution to the disposal of biodegradable waste and should be considered as an integral part of an overall strategy for the collection, treatment and disposal of biodegradable waste.

The research concluded that HC could potentially divert approximately 10 % of the household waste stream from landfill disposal if 21 % of the community were actively engaged in HC. This level of activity would achieve up to 40 % of the waste diversion required to fulfil the 2005 target set by the Government of composting or recycling 25 % of household waste (DETR/WO, 2000).

Cost savings to be gained by the waste disposal authority due to HC are also potentially considerable. The total annual waste disposal cost saving is £11.50 assuming that 360 kg/household of waste is diverted by HC and this would be equivalent to a saving of £80,500 in RBC. In addition, cost savings in relation to waste collection would be expected. These cost savings, however, do not account for purchase of compost bin containers or possible composting educational/training programmes.

11.3 WASTE STABILIZATION IN HOME COMPOSTERS

Biodegradation in small home composter units is a biodynamic process and involving microbial transformations and the activities of micro- and macro-fauna including invertebrate animals. Unlike large scale composting, which treats large batches of material that pass through an ecological succession as biodegradation proceeds, small-scale composting involves the frequent addition of waste to the compost bin. This supports a much more diverse community of organisms that occur simultaneously in the degrading waste, sometimes in stratified layers of material of different age, composition and stages of decomposition.

The research demonstrates that small-scale composters are effective in stabilising organic waste materials (chapter 5), achieving total losses equivalent to 53 % of the input material, and an dry matter loss of 56 %. Thus, losses of volatile matter in small-scale composters tend to be larger, in comparison to large-scale centralised systems. This is because the timescale of the composting process is longer in the small-scale bin, a potentially more diverse ecosystem develops with a significant contribution to degradation from invertebrate animals, and generally the majority of the deposited organic matter is the most putrescible material, compared to centralised systems, which also treat woody materials.

11.4 COMPOST TEMPERATURE AND GAS PROFILES

Evaluation of compost bins temperature profiles (Section 5.2) demonstrated that active biodegradation of waste occurred at cooler temperatures in comparison to the conventional thermophilic conditions of large-scale centralised composting systems. Gas composition profiles (Section 5.3) reflected aerobic decomposition at all depths of the compost bins. Mixing was consistently associated with a slight reduction temperature, increase in O_2 and CO_2 concentration and decreases in CH_4 concentration. Overall, these variables in unmixed systems remained close to ambient and the O_2 status was well above the minimum threshold recommended for optimum composting activity. Mixing material in home compost bins encouraged oxygenation and uniformity of material decomposition. Concentrations of CO_2 were in the range of 0-6 % and in only a few cases was CH_4 detected (Section 5.3.3 and section 5.3.4).

In comparison with landfilling untreated waste, composting of putrescible wastes significantly reduces the net flux of greenhouse gases. The largest contribution to this effect is the avoidance of emissions from landfills as a result of recycling these materials (EC, 2001c). The net greenhouse gas flux associated with HC has been estimated as -18 kg CO_2 eq/t MSW (CEC, 2001b) and is regarded as one of the smallest net fluxes of greenhouse gases.

11.5 HOME COMPOST QUALITY

The major plant nutrients contained in home composted material (Section 6; Table 6.1) were larger than those typically reported for centralised composting (TCA, 2001). This could be explained because woody plant remains of low nutrient status are generally excluded from small-scale home composters, which are mainly supplied only with soft plant tissues of higher potential nutrient content as a feedstock for composting. No statistically significant effects of garden size or compost bin management treatment on the chemical properties of the residual compost were detected by ANOVA (Table 6.4). Large variations observed in the nutrient status of home produced compost could be related to the extent of fertiliser use by individual homeowners in the garden and the nutrient content of plant debris, which was the main waste input to the bins.

11.6 AIRBORNE RELEASE OF *ASPERGILLUS FUMIGATUS* FROM HOME COMPOST BINS

Airborne *Aspergillus* spp. is known to be associated with large-scale composting processes (Epstein *et al*., 1994; Millner *et al*., 1994; Milner, 1995; Gilbert and Ward, 1998) and was detected during the physical disturbance of composting residues in all home compost bins monitored in the study. The average airborne concentration of *Aspergillus* was 79 cfu m^{-3} and a maximum value of 123 cfu m^{-3} was recorded, which are well within the recommended tolerable concentration of 1000 cfu m^{-3} and levels of $>10^6$ cfu m^{-3} that may cause sensitisation (Millner *et al*., 1994). Therefore, HC activities do not convey a potential health hazard associated with airborne fungal micro-organisms.

11.7 FRUIT FLY POPULATION DENSITIES IN THE VICINITY OF HOME COMPOST BINS

Fly nuisance was the main complaint of homeowners regarding problems experienced with composting waste in the first year of the Study Trial and motivated investigation of their association with home composters (Section 8). Fruit flies are advantageous to waste degradation in the bins, however, and increase organic matter decomposition by feeding on fermenting fruit and vegetation. The heat generated during the composting process increases the metabolism and rate of growth of fruit flies, thus increasing the fly population. Fruit flies were particularly attracted to compost bins at properties with small garden size compared to large gardens (Figure 8.2 c and d). This could be attributed to the predominance of kitchen waste in these home composters, which provides a food source and a favourable environment for life cycle sustainability. Most homeowners became more tolerant to fly nuisance during the second year of the Study Trial monitoring period because the flies were only present in the immediate vicinity of the compost bin (Section 10).

11.8 HOME COMPOST END-USE

The end-use of composted products from the Study Trial as soil conditioners for the growth of *Petunia grandiflora* F_1H was assessed in a field experiment (Chapter 9). Flower production increased significantly in linear relation to the rate of nutrient (N, P, K and Mg) addition to soil in compost. Composting management practices were generally not important factors controlling flower production, except where this influenced the nutrient status of the compost. Thus, composted material in the large garden treatment group generally contained more nutrients than for the other composting groups and this probably explained the greater overall flower production with this material compared with other sources of compost applied in the field experiment. The relationships between the nutrient inputs and concentrations in leaf samples showed that the composts supplied useful amounts of bioavailable nutrients for plant growth. However, comparison of leaf tissue concentrations with optimal values for the growth of petunias suggested N supply from the composts was limiting, although the release of P and K was adequate to supply the demand for these nutrients (Table 9.6). Therefore, home produced composts are effective soil improvers and are superior to peat at increasing plant growth performance.

11.9 SOCIO-ECONOMIC AND DEMOGRAPHIC ANALYSIS

Analysis of the socio-economic and demographic factors influencing participation in HC within RBC showed the main requirement was access to a garden for material end-use (Section 10.3). Therefore, certain types of dwelling such as flats and apartments are unsuitable for HC activities. Home composting is dependent on voluntary participation and is not under the direct control or management of the local authority. Therefore, participation depends on the willingness and attitude of homeowners and is strongly influenced by socio-economic and demographic factors.

The total number of requests received for compost bins in the RBC Study was 838, equivalent to 21 % of the households in the Study Area. This provided an indicative participation rate in HC within the Study Area in response to the promotional campaign for subsidised compost bins. Home composting activity prior to the Study Trial was not recorded and therefore residents within the Study Area who purchased compost bins or who were already engaged in HC activities prior to the Study were not included. This value could therefore be regarded as the minimum activity rate occurring within the Study Area, in comparison to the national rate of 34 % (Burnley and Parfitt, 2000). The total number of questionnaires distributed to the Study Area and the number of responses received from homeowners represented the largest survey of HC currently undertaken in the UK (Table 2.8).

11.10 HOME COMPOSTING GUIDANCE FOR LOCAL AUTHORITIES

Although this research has demonstrated the potential of HC as an effective method of diverting biodegradable waste, the extent to which this voluntary activity can be successfully implemented in the community is uncertain.

Local authorities have found considerable difficulties in quantitatively assessing actual waste diversion rates achieved by HC due to variability and practical constraints in monitoring and thus HC is currently excluded from the recycling rate performance indicators that monitor progress towards achieving national objectives for municipal waste (DETR, 1999c). Home composting activity is therefore considered as a method of waste minimisation (DETR/WO, 2000), which further discourages local authorities to monitor waste diversion by HC and hence de-prioritises the importance of this practice in waste management.

Home composting participation is very much dependent on the willingness and attitude of homeowners and is influenced by socio-economic and demographic factors within the community. Sustainability of HC is linked to the individual householder's behaviour. The survey of homeowner attitudes and behaviour indicated that 65 % of participating individuals in the RBC HC Study Trial had not previously composted (Section 10) and suggested that composting waste at home had altered the waste disposal patterns of the majority of participants. In particular, most kitchen waste (uncooked fruit and vegetable peelings predominately) was disposed of by HC and was therefore removed from the wheeled bins. In addition, the frequency of visits to the CA site was reduced. The analyses of socio-economic and demographic behaviour indicated participation in HC can be increased and sustained through promotion and educational support by the local authority.

In the RBC Study, there was no overall reduction measured in the amount of waste collected in the Study Area following the distribution of home compost bins (Figure 4.12), despite a significant amount of waste, including kitchen waste, being removed by HC. This may be explained due to the substitution of the removed waste with other types of waste in the residual waste bin, such as woody garden waste that may have otherwise been transported to the CA site. Therefore, the benefits of HC at removing biodegradable waste may only be realised if measures are also in place to limit the disposal of other substituted waste materials eg by having a smaller bin size, less frequent collections and collections for garden waste that is unsuitable for HC.

The HC survey in RBC showed that homeowners with high value, detached properties with large gardens were the group showing the greatest willingness to participate in HC activities. Therefore, targeting this sector of the community with HC promotional activities is likely to lead to the most positive response.

11.11 FURTHER RESEARCH

Home composting is a voluntary activity and assessing participation rates is critical to predicting its impact on waste diversion. This will require ongoing monitoring and involvement with the public. For example, continued monitoring of HC activity in RBC by distributing questionnaires and home visits would determine the sustainability of this practice. The effectiveness of different forms of support (eg leaflets and home visits) for HC should also be assessed to determine the level of resources necessary to maintain HC programmes.

Measuring the impact of HC on overall waste reduction based on gross measurements of the amounts of waste collected for whole collection rounds is difficult because of demographic changes and increasing background waste arisings. In addition, there are often operational pressures to change the organisation of collection round structures, which disrupt the continuity of data collection. The data presented in this project was obtained by measuring waste inputs to HC bins. For paper and kitchen waste, this provides a direct measure of the amount diverted from the residual waste stream. However, garden waste diversion is more difficult to quantify by this approach because the amounts produced are likely to exceed the capacity of a home composter at different times and surplus material can be disposed of by a variety of ways including: transportation to CA site, burning, residual waste bin, do-it-yourself composting. Therefore, a more accurate assessment of waste diversion attributable to HC would be obtained by weighing the refuse collected from individual participating households, for example, by equipping a refuse collection vehicle with electronic weighing and data collection devices. A statistically designed assessment programme could compare the quantities of waste collected from households engaged in HC activities with a control group who are not composting biodegradable waste at home. This should also be coupled with detailed waste analysis to assess the impact of HC on the composition of the residual waste stream to demonstrate the effective removal of the biodegradable fraction.

Approximately, 50 % of fresh matter deposited into home compost bins is removed through moisture and volatile solid losses during the composting process (Section 4.3.1). The nature of the gaseous and aqueous emissions should be determined to assess the potential leaching of N from the base of the bins in leachates and extent of gaseous emissions, particularly of CH_4.

Fundamental research on the dynamic ecology of composting waste in small scale composters would provide better understanding of the biological mechanisms of waste degradation in these systems to improve management and waste treatment. This would also consider the broadening of the differentiation of composting to include other aerobic decomposition mechanisms which do not necessarily follow the conventional ecological sequence associated with large-scale, batch operated industrial composting processes. In addition, this area of research would enable the identification and assessment of the role and attraction of fruit flies in HC waste.

The microbiological quality, in particular pathogen inactivation should be quantified in relation to HC.

Waste inputs to the bins were not specifically controlled and were at the discretion of the homeowner. Further work is necessary to examine the effects of different relative inputs of garden, kitchen and paper waste on end product quantity parameters. These would include moisture content, conductivity and particle size as well as nutrient and heavy metal content. These are critical issues for producing an end-product which is perceived to be of high quality, an incentive to homeowners to continue HC activity.

11.12 CONCLUDING COMMENTS

This research project has quantified the potential contribution and effectiveness of HC at diverting biodegradable waste from landfill disposal, waste biodegradation processes in small-scale composters and the end-use of the compost in a two year Study Trial. The main relevance of this work is to increase recognition of the role and significance of HC in recycling and reducing disposal of waste in landfill. In urban areas where homeowners have access to garden space, HC could potentially divert 20% of the biodegradable household waste stream from landfill disposal if 21 % of the community are actively engaged in HC with potential cost savings of £80,500.

Home composting cannot provide a single solution to the disposal of biodegradable waste. It is a voluntary activity and maintaining significant levels of homeowner participation is likely to require an ongoing commitment by local authorities to promotional activities. However, the principal conclusion of the work reported here is that HC contributes significantly to diversion from landfill disposal and should be considered as an integral part of an overall strategy for the collection, treatment and disposal of biodegradable waste.