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The Management of Household Food Waste

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Executive Summary

Approaches to waste management are being re-evaluated across the UK as a result of the introduction of landfill allowance schemes in England, Scotland, Wales and Northern Ireland. One of the primary challenges is the reduction of the quantity of landfilled biodegradable waste, which mainly comprises similar amounts of paper, garden and food waste. The most difficult fraction is food waste, given its highly putrescible nature and the associated environmental and public health concerns. The development of options and strategies to divert food waste from landfill has therefore been limited. However, demanding landfill allowance targets are forcing the responsible waste authorities and the industry to seek new solutions for food waste.

There are two basic approaches for dealing with food waste, namely household treatment using Food Waste Digesters (FWDs) and treatment at centralised facilities. FWDs are completely different from traditional garden composters, although often similar in appearance. Situated in the garden, FWDs treat all food waste while producing minimal residue. The main acceptable technologies available for centralised treatment are the biological processes of in-vessel composting and anaerobic digestion. There is little experience in the UK of anaerobic digestion facilities but the production of biogas as a renewable fuel source from the process is likely to make it an attractive alternative biological treatment to composting. The number of sites employing in-vessel composting technologies increased from twelve in 2001/02 to eighteen in 2003/04, with fourteen undergoing validation approvals for the processing of food waste.

Several hundred centralised treatment facilities will be required in the UK by 2020 to meet the landfill targets, the actual number being dependent upon the uncertain growth in waste and the extent to which the household treatment of food waste using FWDs is introduced. This projected major expansion in centralised treatment facilities is partly responsible for a review of the framework for developing waste management strategies and plans, with changes already introduced for England. However, there is also a growing intent on the part of the relevant national bodies to reduce the amount of household waste collected by local authorities through waste prevention measures.

One unintended consequence of the current formulation of the landfill allowance schemes has been to encourage authorities to work against government and national policies and not to promote household treatments to minimise waste collections, such as the use of home composters and FWDs. The Department for Environment, Food and Rural Affairs (Defra) is currently reviewing proposals from the Waste and Resources Action Programme (WRAP) to redress this anomaly but in the interim growing numbers of authorities are establishing schemes for the collection and centralised treatment of household food waste. Such an approach may be open to challenge if alternative options have not been given serious consideration and would be expensive to reverse due to the major capital investment required to establish these schemes.

To assess the potential contribution that the household treatment of food waste could make in diverting biodegradable waste from landfill, a "reference" FWD system has been compared with the centralised approach of segregated kerbside collection followed by in-vessel composting and disposal. This preliminary assessment, which was carried out in the context of the relevant EU Directives and the resultant national waste management strategy objectives and decision-making principles, indicates:

- The detailed health, safety, environmental, social, economic and operational risk assessments that should form part of the systematic approach to determining any waste management strategy are likely to favour the household treatment option for a majority of situations.
- The use of FWDs is a cost effective alternative to centralised collection and treatment, even when the reduced landfill credit afforded by the current landfill allowance schemes is taken into account. Costs are better than half the average for segregated collection and centralised treatment, which should improve by 30-40% once WRAP and Defra resolve the anomaly with the existing landfill allowance formula. The cost advantages of household treatment are greatest for authorities serving rural areas, which increase with rising oil prices.
- Several factors are common to both approaches, such as the need for education and ongoing support to maintain participation levels.
- The household treatment of food waste using a FWD meets the principles of the EU Framework Directive on Waste and national objectives.
- FWDs offer the additional potential benefits of:
    - Facilitating public acceptability of less frequent collections, thereby reducing vehicle operating costs, accidents and pollution.
    - Cleaner bins and waste for householders, thereby encouraging recycling of remaining domestic waste streams such as plastic and paper packaging, cans and bottles.
    - Engendering understanding and ownership of the waste problem.
    - Limiting the growth in food waste.

The household treatment of food waste is at the top of the waste hierarchy. Based upon 10% of UK households using FWDs, which is the current situation for home composters, half a million tonnes of food waste could be diverted from landfill and not have to be collected, between 10 and 25 centralised treatment facilities need not be constructed and there would be potential cost savings in excess of £20 million a year.

For the household treatment of food waste to become an accepted part of integrated waste management strategies, a number of real and perceived barriers would need to be overcome. The initial steps required to achieve this goal include:

- WRAP and Defra resolving the anomaly with the landfill allowance mass balance formula and completing their current trials of FWDs.
- The national advice and support programmes for the waste collection, disposal and planning authorities containing information on household treatments and not just the centralised approaches.
- The responsible authorities being required to include the option of household treatment when determining their waste management strategy.
- A range of specific targets and economic instruments being developed to drive waste prevention and the household treatment of food waste.

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1. Introduction

The decomposition of waste within landfill is a major source of the greenhouse gas methane. The methane is generated from biodegradable waste, such as paper, garden and food waste, decomposing in the absence of oxygen. In response to growing concerns over the impact of greenhouse gases, the EU Landfill Directive requires member states to reduce progressively the amount of biodegradable waste going to landfill by specified dates. The UK Government intends to use the four year derogation granted to members that landfilled over 80% of their municipal waste in 1995. The UK must therefore reduce the amount of biodegradable waste going to landfill in the target years of 2010, 2013 and 2020 to 75%, 50% and 35% respectively, of the amount landfilled in 1995.

Household waste makes up approximately 90% of the 30 million tonnes of the Municipal Solid Waste (MSW) generated each year in the UK. The food waste fraction of household waste represents about one quarter of the 20 million tonne Biodegradable Municipal Waste (BMW) component of MSW, which is equivalent to about 0.2 tonne/household/year.

In the UK, reductions in the amount of MSW going to landfill are largely being achieved through the recycling of glass, paper, metal and some plastics and the composting of paper and garden waste. The requirement for a significant reduction in biodegradable waste going to landfill has re-focussed attention on its three main constituents of paper, garden and food waste. There are two basic approaches for dealing with garden and food waste, namely collection and treatment at a centralised facility and household treatment using home composters and Food Waste Digesters (FWDs).

The framework for developing waste management strategies and plans is under review, with changes already introduced for England. The primary reason for these changes is to facilitate the delivery of the major expansion in centralised treatment facilities required to meet the landfill targets. However, there is also a growing intent on the part of the relevant national bodies to reduce the amount of household waste collected by local authorities through waste prevention measures. The government's Waste and Resources Action Programme (WRAP), which is jointly funded by the Department for Environment, Food and Rural Affairs (Defra), the Department of Trade and Industry (DTI), the Scottish Executive, the Welsh Assembly Government and the Northern Ireland Executive, is an important agent in many aspects of waste reduction and using waste as a resource. WRAP therefore has initiatives on both the centralised and household treatment of organic waste.

This paper examines the potential contribution that the household treatment of food waste could make towards achieving landfill targets and the barriers that would have to be overcome. The assessment has been carried out in the context of EU and national policies and legislation, the existing landfill allowance schemes, the decision making process and the treatment technologies currently available.

2. Options for Managing Household Food Waste

Appendix 1 summarises the key EU Directives and Regulation relevant to the management of household food waste, namely the Framework Directive on Waste (Reference 1), Landfill of Waste Directive (Reference 2), Strategic Environmental Assessment Directive (Reference 3), Integrated Pollution Prevention and Control Directive (Reference 4) and the Animal By-Products Regulation (Reference 5).

Biodegradable waste and municipal waste are defined separately in the EU Landfill Directive and these definitions are carried through into UK legislation. Municipal waste is defined as "waste from households, as well as other waste, which because of its nature or composition, is similar to waste from households" and biodegradable waste as "any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard". The proportions of waste types that are deemed biodegradable are also set out in legislation, ranging from 100% for paper and putrescible waste, through 50% for textiles, shoes and furniture, to 0% for glass, plastic and metal.

Until recently, little attention was given to the food waste fraction of household waste. The highly putrescible nature of food waste, coupled with a range of environmental and public health concerns, has limited the development of options and strategies for diverting household food waste from landfill. Firstly, the handling, transportation and treatment of food waste demand much tighter controls than those for dry waste or garden waste. Secondly, the health and environmental impact of the disposal of any residues or by-products resulting from the treatment of food waste must be carefully evaluated, particularly in the context of meat and other products of animal origin.

The main acceptable centralised treatments currently available for organic waste in the UK are the biological processes of in-vessel composting and anaerobic digestion. Descriptions of these and other treatment processes can be found in References 6 to 8, together with new technologies that are being developed and tested. Prior to biological treatment, segregation of the waste streams making up the MSW is required. Health, safety and environmental issues such as odours, flies and potential access by animals, vermin and birds preclude the use of "bring sites" for food waste. There are various options for kerbside collection schemes, ranging from the traditional "black sack" mixed MSW to single material, householder segregated, MSW. Safe, effective and affordable kerbside schemes are required for the collection of segregated food waste, as existing procedures for other waste streams using unsecured receptacles are inappropriate.

Mixed MSW can be mechanically sorted into recyclable material, organic material for biological processing, high calorific material for energy recovery and an unavoidable reject fraction that requires disposal. No matter what form of waste segregation process is employed, there is always a degree of cross-contamination. This limits the potential applications and markets for any residues or by-products, such as compost, mulch, soil conditioner and fertiliser. In general, householder segregated organic source material contains less contamination than mechanically separated MSW, which is often suitable only for landfill restoration. Growing awareness of the use of food waste in the production of compost has raised a number of other issues that may limit its market. These include concerns about the feedstock of compost that is subsequently used in food production containing GM derivatives, pesticide residues, food products from livestock reared under poor welfare conditions and illegal food imports.

The latest survey of the composting industry by the Composting Association (Reference 9) shows that two million tonnes of waste are composted in the UK, with 73% being household waste, 4% non-household and 23% commercial. The household component represents approximately one-fifth of the Composting Association's estimated seven million tonnes of garden waste included in MSW. This figure does not include the large fraction of garden waste that is home composted, shredded, burnt or simply left in situ to decompose naturally. Clearly, the indiscriminate introduction of garden waste collection schemes could increase MSW arisings by attracting this fraction (References 10 to 12).

The WRAP Waste Minimisation Programme was begun in 2003 "to stem the growth of household waste, as a vital part of the package of measures needed to enable the UK to meet the requirements of the Landfill Directive and move towards sustainable waste management" (Reference 13). The Home Composting Programme, which is a key element of the Waste Minimisation Programme, has focussed on the garden waste fraction of BMW to meet its target of diverting 400,000 tonnes of compostable waste by April 2006. More than two million home compost bins have been distributed by local authorities in England alone, 721,000 in the past three years (Reference 14). This represents about 10% of households with home compost bins.

A small, undefined quantity of green food waste, such as vegetable peelings, is also composted with garden waste, both in centralised facilities and home composters. Other food waste should not be put into the traditional home composter because of a number of health, safety and environmental issues. These include attracting vermin and potential access, through animal and human (particularly children) activity, to the surface soil around the composter and the compost material itself.

With regard to the centralised treatments currently available for organic waste, there is little experience in the UK of anaerobic digestion facilities. However, the production of biogas as a renewable fuel source from the process is likely to make this an attractive alternative biological treatment to composting. The majority of existing centralised composting facilities were designed for treating garden waste and not food waste, resulting in relatively low-technology open-air windrows. These are not compliant with EU Animal By-Products Regulation or National Regulations (listed in Reference 15), which require enclosed systems. The composting market is therefore being driven towards higher technology and higher cost solutions.

The number of sites employing enclosed, in-vessel technologies increased from 12 in 2001/02 to 18 in 2003/04, with 14 undergoing validation approvals for the processing of food waste (Reference 9). As part of the estimated 1500 to 2300 new facilities that will be required to treat, recycle and dispose of the UK's growing waste problem by 2020 (Reference 16), several hundred of these biological treatment facilities will be necessary to meet the landfill targets (Reference 6). The actual number of centralised facilities required to deal with biodegradable waste is dependent upon the growth in waste and the extent to which the household treatment of garden waste using home composters and food waste using FWDs is successfully introduced.

FWDs range in size, applicability, efficiency, ease of use and price (References 17 to 19). They are already successfully used in Guilford, Cornwall, West Sussex, Moray, Aberdeenshire, Orkney and the Isles of Scilly. Despite their widespread use, comprehensive and independent assessments of FWDs are limited and as a result Defra and WRAP are currently undertaking trials of different systems. The characteristics of a FWD system studied in some depth during a recent Defra funded trial (Reference 20)

has been used to examine the potential contribution that the household treatment of food waste can make towards achieving landfill targets (Section 5). A brief description of the "reference" FWD is provided in Appendix 2 of this paper, which also includes an outline of the digestion process, an overview of the relevant legislation and the health, safety and environmental impact of the system.

3. Landfill Allowance Mass Balance Formula

The UK landfill targets have been divided proportionately between England, Scotland, Wales and Northern Ireland at a level that will allow the UK to meet its landfill target in each of the three specified years. The individual authorities responsible for the disposal of waste in the UK have been allocated "landfill allowances". In the event that the UK fails to meet its overall targets, the Government has reserved the right to pass any EU penalties to the responsible authorities.

The BMW component of the MSW that goes to landfill is not routinely weighed in the UK. For the purposes of setting landfill allowances, BMW arisings have been defined as a percentage of MSW arisings, with values of 68% for England, 63% for Scotland, 61% for Wales and 71% for Northern Ireland.

In England, the Landfill Allowances and Trading Scheme (LATS) permits the 121 Waste Disposal Authorities (WDAs) to trade allowances as an aid to facilitating effective strategies for meeting their targets. Authorities exceeding the landfill allowances they hold after any trading year will be liable to a financial penalty of £150 per excess tonne.

In Scotland, the Landfill Allowance Scheme (LAS) does not allow the 32 Authorities to trade until 2008, with financial penalties of £10/tonne in 2005/06, £25/tonne in 2006/07, £50/tonne in 2007/08 and £150/tonne thereafter. For the 22 WDAs in Wales, the Landfill Allowances Scheme (LAS) does not permit the trading of allowances and failure to meet targets may result in financial penalties. The Northern Ireland Landfill Allowances Scheme (NILAS) also does not permit the 26 District Councils to trade their allowances. However, NILAS encourages District Councils to work together to achieve the Northern Ireland target and allows them to transfer unused allowances. The failure of a District Council to meet its target will result in a financial penalty of £200/tonne.

The Local Authority Recycling Advisory Committee has summarised the principal national differences in waste management (Reference 21) and the relevant national bodies provide comprehensive up-to-date information on their websites (e.g. Reference 22).

The amount of BMW landfilled in a given year is calculated using a so-called "mass balance" approach as follows:

$$BMW_l = P \times MSW - BMW_d + BMW_t$$

where BMW_l is the weight of BMW landfilled
MSW is the weight of Municipal Solid Waste
BMW_d is the weight of BMW diverted from landfill
BMW_t is the weight of BMW landfilled after treatment
P is the relevant nation's defined BMW fraction
(England 0.68, Scotland 0.63, Wales 0.61, Northern Ireland 0.71)

The following scenarios are provided to demonstrate the consequences of the current landfill allowance mass balance formula on the diversion of BMW calculated for household treatments, such as the use of home composters and FWDs.

If MSW is x tonne, BMW_d is y tonne and BMW_t is z tonne, then:

Base Case:

$$BMW_l^0 = Px - y + z$$

Scenario 1 – Centralised Treatment: Additional y' tonne of BMW segregated and centrally treated; additional z' tonne landfilled after treatment, which represents fraction f of y' tonne (i.e. $z'=fy'$)

$$BMW_l^1 = Px - (y + y') + (z + z')$$

Scenario 2 – Household Treatment: Household treatment of y' tonne of BMW of which fraction F was previously segregated and centrally treated; reduction of z' tonne landfilled after treatment, which represents fraction f of Fy' tonne (i.e. $z'=fFy'$)

$$BMW_l^2 = P(x - y') - (y - Fy') + (z - fFy')$$

Where all y' tonne of BMW treated at household previously went to landfill, $F=0$, $z'=0$ and

$$BMW_l^{2a} = P(x - y') - y + z$$

Where all y' tonne of BMW treated at household was previously segregated and centrally treated, $F=1$, $z'=fy'$ and

$$BMW_l^{2b} = P(x - y') - (y - y') + (z - fy')$$

Comparison of the resultant formulae for the centralised and household treatments of BMW demonstrates how the current mass balance approach disadvantages the latter. The consequence of the landfill allowance mass balance formula is best shown using some illustrative figures for the two scenarios, where the results are summarised in Table 1.

The base case uses a MSW value of 113,300 tonnes based upon the Parfitt annual household waste values for England (Reference 10) and 100,000 households. The BMW fraction of 0.68 for England has been used in the mass balance formula. The base case assumes a 25% diversion of BMW and that 15% of the diverted weight goes to landfill. It should be noted that the calculated quantity of BMW landfilled for the centralised treatment scenario is insensitive to these values, whereas the household treatment scenario is sensitive to the BMW fraction. The illustrative figures are provided to put in context the potential landfill credit available for treating a given amount of BMW. In each scenario 9,700 tonnes of BMW are treated, which happens to represent 50% of the total food waste generated by 100,000 households (Reference 10) but could equally well be garden waste.

Based on the scenarios summarised in Table 1, the BMW calculated to be landfilled using the mass balance formula is given in the first results column. The calculated amount of BMW diverted is the difference between the calculated BMW landfilled for each scenario and the base case. These values are provided in the second results column and effectively represent the landfill credit. The actual amount of additional BMW diverted is given in the third results column.

Table 1. Illustrative Consequences of Landfill Allowance Mass Balance Formula

Approach	Scenario			BMW landfilled (tonne)	BMW credit (tonne)[c]	True BMW diverted (tonne)[d]
	F[a]	f[b]	Description			
Base Case	-	-	113,300 tonnes MSW, BMW fraction 0.68, 25% of BMW diverted & 15% of diverted weight landfilled	60,672	-	-
Centralised Treatment (Scenario 1)	-	0	Additional 9,700 tonnes BMW composted & put onto land	50,972	9,700	9,700
	-	0.5	Additional 9,700 tonnes BMW composted & put into landfill (assumes composting gives 50% weight reduction)	55,822	4,850	4,850
	-	0.32	Additional 9,700 tonnes BMW composted & 68% put onto land, 32% into landfill	54,076	6,596	6,596
Household Treatment (Scenario 2)	0	-	All 9,700 tonnes of household treated BMW previously went to landfill	54,076	6,596	9,700
	1	0.15	All 9,700 tonnes of household treated BMW was previously diverted in base case	62,321	-1,649	0
	0.5	0.15	Half of 9,700 tonnes of household treated BMW was previously diverted in base case	58,199	2,473	4,850

Notes to Table 1:

a F is fraction of 9,700 tonnes BMW previously segregated and centrally treated.
b f is fraction of Fx9,700 tonnes BMW landfilled after treatment; 0.15 in household treatment scenario is equivalent to base case.
c Quantity of BMW diverted as calculated by mass balance formula.
d Actual quantity of additional BMW diverted.

It can be seen from Table 1 that the BMW landfilled figures from the mass balance formula are wrong in each of the household treatment scenarios, resulting in an underestimate of the landfill credit. In the worst-case scenario, where the mass balance formula gives a negative landfill credit, the household treatment of waste that was all previously collected actually makes it more difficult for an authority to achieve its targets. As a result of this anomaly, authorities are ceasing to promote the government's policy of increasing the number of households carrying out home composting (References 23 and 24). This is of particular concern to WRAP, which has been charged with delivering the home composting programme by working with local authorities.

The implication of the mass balance formula is not significant for FWDs at present as little food waste is collected for centralised treatment. However, because the mass balance formula only provides a landfill credit equivalent to the defined BMW fraction of between 61% and 71%, depending upon the relevant nation, growing numbers of authorities are establishing schemes to collect and centrally treat household food waste. If this is allowed to continue, FWDs will be in the same situation as home composters and effectively precluded from becoming an integral part of authorities' waste strategies.

4. Development of Waste Management Strategies and Plans

4.1. Framework and Process

The UK Government Sustainable Development Strategy (Reference 25) states "The overall objective of government policy on waste is to protect human health and the environment by producing less waste and by using it as a resource wherever possible. Through more sustainable waste management – reduction, re-use, recycling, composting and using waste as a source of energy – the Government aims to break the link between economic growth and the environmental impact of waste". Separate strategies for each administration are currently being prepared to support the framework set out in the government's sustainable development strategy.

The government's waste strategy for England and Wales was set out in Waste Strategy 2000 (Reference 26). The responsible authorities were expected to employ a systematic consultative decision making process to develop a waste strategy that was the Best Practicable Environmental Option (BPEO). The BPEO process aims to establish, for a given set of objectives, the option that provides the most benefits or least damage to the environment as a whole, at acceptable cost, in the long term as well as the short term (Reference 27). Sections of the waste management industry believe it should be removed from the UK's strategic and operational planning structures and procedures because it is "a serious impediment to the timely development of waste management infrastructure" (Reference 28).

In July 2005, changes to Waste Strategy 2000 were published (Reference 29) in conjunction with revised planning guidance given in Planning Policy Statement PPS10 (Reference 30). The changes were introduced to provide consistency within the legal framework for decision making on waste by removing the requirement for a local assessment of the BPEO and replacing it with a requirement for a Strategic Environmental Assessment (SEA) or Sustainability Appraisal. A key objective of the revised planning guidance and the replacement of BPEO is to meet "a need for thousands of new waste management facilities over the next 15 years" (Reference 31).

While SEA is a generic tool that can be used in a variety of situations, the EU SEA Directive introduced a particular form to ensure that potentially significant environmental effects arising from certain proposed plans and programmes are identified, assessed, subjected to public participation, taken into account by decision-makers and monitored. The SEA Directive also requires consideration of the likely effects of a plan or programme on human health and responsible authorities may consider it necessary to prepare a Health Impact Assessment. A practical guide to the SEA Directive has been prepared by the Office of the Deputy Prime Minister and the three devolved administrations (Reference 32), which includes a list of the regulations that transpose the Directive into law for England, Scotland, Wales and Northern Ireland.

Sustainability Appraisal is an iterative process that identifies and reports on the likely significant effects of a plan or programme and the extent to which implementation will achieve the social, environmental and economic objectives by which sustainable development can be defined (Reference 33). A Sustainability Appraisal will fully incorporate the requirements of the SEA Directive.

The Regulatory Impact Assessment on the changes to the decision-making process in Waste Strategy 2000 is provided in Reference 34, which includes Defra's analysis of the impact of each of the wording changes given in Reference 29. Defra conclude that the new approach is required to be more consultative and that this will enhance effective implementation of municipal waste management strategies. In addition, the waste hierarchy remains a key principle with increased prominence for determining the "best option". There is increased emphasis on individuals, community and organisations taking responsibility for their own waste but at the same time a shift towards more regional control and less local control over waste planning.

The equivalents to Waste Strategy 2000 for England are the National Waste Strategy for Scotland (Reference 35), Wise About Waste: The National Waste Strategy for Wales (Reference 36) and the Northern Ireland Waste Management Strategy (Reference 37). Similarly, the equivalents to PPS10 for England are the National Planning Policy Guideline NPPG10: Planning and Waste Management (Reference 38) and Planning Advice Note PAN63 on Waste Management Planning (Reference 39) for Scotland, Planning Policy Technical Advice Note TAN21 for Wales (Reference 40) and the Northern Ireland Planning Policy Statement PPS11 on Waste Management (Reference 41).

A BPEO approach was used to develop Area Waste Plans for 11 areas across Scotland, which were published in parallel with the National Waste Plan 2003 (Reference 42) as a major step towards implementing the National Waste Strategy for Scotland. The use of BPEO is currently under review in Scotland along with NPPG10, which will be replaced by Scottish Planning Policy SPP10. Both Wales and Northern Ireland have currently retained BPEO. The Northern Ireland Waste Management Strategy is currently being reviewed.

Detailed health, safety, environmental, social, economic and operational risk assessments should form part of a systematic approach to determining any significant waste management strategy or plan. If performed thoroughly, the approach of using a Sustainability Appraisal or a SEA and BPEO process should not affect the outputs. Proper consultation during the process is essential to ensure that undue weight is not given to political acceptability and achieving targets at the expense of wider considerations and policies that are not strongly enforced. A prime example of the latter is the current move away from promoting the government's policy on home composting by some authorities because of the existing landfill allowance schemes.

Based upon the EU Directives summarised in Appendix 1, together with other amending and associated Directives, national, regional and local objectives for waste management decisions are established. For example, the government's key waste management objectives for England are set out in Reference 43 as follows:

- Reducing the environmental impact of waste by driving waste management up the waste hierarchy of reduction, re-use, recycling and composting, energy recovery and, as a last resort, disposal.
- Managing waste in ways that protect human health and the environment and in particular:
    - Without risk to water, air, soil and plants and animals.
    - Without causing a nuisance through noise or odour.
    - Without adversely affecting the countryside or places of special interest.

- Disposing of waste at the nearest appropriate installation, by means of the most appropriate methods and technologies.

Following on from these objectives it is stated that decisions on waste management should be based on the following principles:

- Individuals, communities and organisations should take responsibility for their waste.
- In taking decisions there should be consideration of alternative options in a systematic way.
- Effective community engagement should be an important and integral part of the decision making process.
- The environmental impacts for possible options should be assessed looking at both the long and short term.
- Decisions should seek to deliver the environmental outcomes that do most to meet the objectives set out above, taking account of what is feasible and what is an acceptable cost.

The terms of waste reduction, waste minimisation, waste avoidance and waste prevention are often used interchangeably, which has led to some confusion. The National Resource & Waste Forum (NRWF) Waste Prevention Project has produced a UK framework for waste prevention (Reference 12). It defines household waste prevention as "Minimising the quantity (weight and volume) and hazardousness of household-derived waste generated in a defined community for collection by any party". The definition encompasses activities of waste avoidance, reduction and reuse, which includes home and community composting and those activities that allow items and materials to be reused, thereby reducing the amount of household waste entering the collected waste stream. A recent report prepared for Defra on international best practice in MSW prevention and reduction by the same consultants that NRWF used unsurprisingly employs the same basic definition of "Minimising the quantity and hazardousness of municipal waste generated for collection, by the local authority, through prevention/reduction at source and reuse in the local community" (Reference 44). The household treatment of food waste therefore sits right at the top of the waste hierarchy.

The NRWF, which is a DTI, Defra and Scottish Executive endorsed initiative (Reference 45), established a partnership with the Scottish Environment Protection Agency, the Environment Agency and the Northern Ireland Environment and Heritage Service to undertake a UK-wide development project to produce guidance on household waste prevention. This demonstrates a serious intent by the relevant national bodies to reduce the amount of household waste collected by local authorities as part of the overall strategy to limit growth and meet landfill targets. A "toolkit" for local authorities and community organisations to plan and implement a waste prevention programme was published in August 2004 (Reference 46). Most importantly, the toolkit includes a section on the problematic area of the measurement of waste prevention.

4.2. Issues Related to Food Waste

The issues that require consideration when developing a strategy to deal with household food waste include:

- Geo-demographic factors, particularly population densities.
- Waste targets.
- Financial costs and budgets.
- Potential growth in food waste.
- Health, safety and environmental legislation.
- Environmental impact, including long-term consequences.
- Health and safety risks to workers and public.
- Fit with rest of waste strategy.
- Technology developments and availability of solutions.
- Public education, incentives and penalties.
- Public and political acceptability.
- Risk management and contingency planning.

The composition and growth of future waste streams contribute significant uncertainties to the development of any strategy. Understanding trends in food waste requires analysis of the entire supply chain, from production through harvesting, packing, transporting and storing, to preparing and retailing. When all environmental impacts are taken into account across the life cycle of goods and services, food may be one of the most environmentally significant aspects of consumption. For example, consumption of food in the UK is estimated to be responsible for global greenhouse gas emissions equivalent to 22 per cent of the overall total for the country (Reference 25). While such a detailed understanding is outside the scope of most assessments, some appreciation of the issues would benefit strategies aimed at limiting the growth of food waste.

The generation of household food waste results from:

- Food preparation (e.g. fruit and vegetable peelings, removal of meat fat).
- Leftovers (e.g. excess quantities, fat and bones).
- Spoilt food (e.g. stale, mould growth, rancid).
- Poor preparation (e.g. under and over cooked, burnt).
- Refrigerator or freezer accidents (e.g. power cuts).
- Over-purchasing of food and adherence to sell-by and use-by dates.

A wide range of geo-demographic factors affect the quantity and composition of the food waste generated by a household, which include:

- Number in household, gender, age.
- Geographic location.
- Household affluence.
- Relative cost of food.
- Working from home and away from home.
- Leisure activities, eating out, extended holidays away from home.
- Take-away food eaten at home.
- Over-purchasing and influence of sell-by / use-by dates.
- Health and environmental concerns.
- Technology related to food preparation and keeping food fresh.
- Number of meals, meal sizes, snacking habits.
- Food types (ethnic variations, vegetarian and special diets).
- Degree of food preparation (unprepared or pre-prepared fresh foods; convenience food products and meals).

The complexity, inter-relationships and dynamics involved in modeling regional and national food waste arisings is illustrated by the following few examples. Clearly, population growth is a significant factor in itself and the predicted UK population of 64.7 million in 2021 (Reference 47) will result in well over two million tonnes of additional household waste by the third landfill target year.

For a variety of socio-economic reasons, there has been a large increase in the number of single person households. In England, between the census years of 1991 and 2001, the number of single person households increased by 21% to 6.2 million, which represented 30% of all households (Reference 48). This figure is projected to rise to 7.3 million in 2011 (33% of households) and 8.5 million in 2021 (35% of households). There is evidence that the waste generated per person increases as the number of occupants in a household unit decreases (Reference 49). Thus, any expansion in the number of single person households may increase the overall quantity of waste above that projected from population growth alone.

21% of the UK population is 60 years old or over (Reference 50), with food and food waste habits influenced to varying degrees by the Great Depression, World War 2 and rationing. As this sector of the population declines, the average food waste arisings per individual may show an increase without compensating behavioral influences. Global warming does not have the necessary immediacy to modify behavior in the same way as previous threats.

Trends in food retailing, such as pre-prepared meals, can generate less total waste than home preparation, despite the packaging. The trimmings from commercial food preparation are often a feedstock for other processes, whereas home preparation trimmings usually end up as waste. In addition, up to 20% of fresh "perishable" foods go to waste between producer and retailer compared with less than 1% of pre-prepared meals. However, to some extent, pre-prepared foods simply result in a move of food waste from the household stream to the commercial stream. It is also possible that this creates more waste overall through, for example, consumers removing further external portions of pre-prepared vegetables because of hygiene concerns. A recent study (Reference 49) found that 50% of households discarded the outer leaves of a supermarket cabbage even if they appeared in good condition.

Some indication of current trends in food waste is provided in References 51 and 52. Serious research is required into the potential growth of household and commercial food waste and into the development of effective strategies to limit this growth.

5. Potential Contribution of Household Treatment of Food Waste

The majority of the Articles, Rules and Regulations in the EU Directives are applicable only to the large-scale collection, handling, transportation, treatment and disposal of waste. To assess the potential contribution that the household treatment of food waste could make to diverting BMW from landfill, the reference FWD system has been compared with the centralised approach of segregated kerbside collection followed by in-vessel composting and disposal. To put the comparison on a common basis, it has been carried out in the context of the relevant EU Directives and the resultant waste management strategy objectives and decision-making principles outlined previously.

Table 2. Comparison of Processes for Dealing with Household Food Waste

Consideration	Centralised Composting	Household Food Waste Digesters
Costs[a]	Segregated collection £25 - £60/tonne plus treatment £25 - £50/tonne; total average £80/tonne[b]	£25/tonne[c]
Landfill Allowance Value	100% credit for composted food waste in MSW going onto land, which is proportionately reduced to about 50% for amount going to landfill	61% (Wales), 63% (Scotland), 68% (England) & 71% (NI) credit for food waste removed from MSW. Approach to allow greater credit under review
Growth in Waste	Household collection does not discourage growth Economies of scale may offset some increased cost	Household treatment tends to limit growth Projected 10 year growth absorbed by 95% of households
Applicability	All households that can accommodate additional segregation bin with suitable access & householders that can manage process	Approximately 85% of UK households with suitable gardens (Reference 53) & householders that can manage process
Waste Collection	Kerbside collections of segregated waste required, with suitable recording, inspection and auditing processes Contamination of segregated food waste with other waste Frequent collections necessary for food waste	Collection of food waste not necessary Encourages rigorous food waste separation Facilitates less frequent collections of other waste
Process By-Product	Medium quality compost (high nutrient but some contamination from other waste streams) suitable for agriculture, restoration & landfill Currently limited commercial value; generally given away. Transport & disposal costs when no market value	None No transport & disposal costs
EU & National Waste Management Objectives & Legislation	Partially meets waste management objectives Meets legal requirements	Meets waste management objectives (e.g. top of waste hierarchy, Principles of Proximity & Self-Sufficiency) Meets legal requirements
Environmental	Collection, treatment & disposal uses non-renewable energy resources Collection & disposal contributes to transport pollution, congestion & accidents Visual impact & obstruction from additional segregation bins ("street clutter"). Noise, odour & visual impact of treatment plants reducing with new technologies Risk & consequences of treatment plant operational problems or accidents very low Potential access to food waste by animals & birds prior to treatment and hence by-pass of process barriers	Process uses sun. No collection necessary for food waste & less frequent collections for other waste No noise or odour issues, minimal visual impact Natural benign process; no accident scenarios Food waste direct from household to sealed food waste digester
Public Acceptability	High - although education programmes essential, with possible incentives and/or penalties Acceptability decreases if coupled with less frequent waste collections Initial NIMBY planning concerns over treatment plant; possible localised traffic & environmental complaints	High - although education programmes essential, with possible incentives and/or penalties Facilitates acceptability of less frequent collections of other waste Initial concerns over installation & use; possible problems due to incorrect installation & use
Contribution to Public Involvement in Waste Issues	Segregation of food waste increases other recycling rates Waste collections without limits tends to encourage growth of waste	Increases other recycling rates (Reference 49) Engenders understanding & ownership of household waste problem
Other Potential Benefits & Risks	Participation levels in segregating waste reducing without suitable support, incentives and/or penalties Industrial action impacting collection, treatment or disposal Increasing public awareness and concerns regarding compost made from food waste restricts market Rising fuel prices increasing cost of collection & disposal	Participation levels reducing without suitable support, incentives and/or penalties Participating households expect some financial benefit over non-participating households Assistance with installation necessary for some households Major savings in collection costs for rural areas, particularly as fuel prices rise

Notes to Table 2:

a Public information, education and support costs not included in either case.

b Plant costs based upon References 6 & 7 and supplier's literature, where range covers different systems, plant scale, income from by-products and accounting treatment of capital and operational costs. Waste collection costs based upon Reference 54 and sample authorities, where range reflects investment in transport equipment, segregation receptacles, efficiency (particularly resulting from cross benefits with collection of other waste streams) and population density (e.g. rural vs. urban authorities). The NRWF use an average avoidable collection & disposal cost of £80 (Reference 46)

c Cost of FWDs is usually volume sensitive. Delivery cost dependent upon whether delivered direct to households or collected by residents from centralised locations. It may be necessary for responsible authorities to install FWDs for "incapacitated" residents without family or friends. The above cost is based upon the ten year guaranteed life of the reference FWD and includes purchase & delivery (Reference 17) and installation for 25% of households at £30/unit.

This preliminary assessment indicates the following:

- The detailed health, safety, environmental, social, economic and operational risk assessments that should form part of a systematic approach to determining any significant waste management strategy are likely to favour the household treatment option for a majority of situations.
- The use of FWDs is a cost effective alternative to centralised collection and treatment, even when the reduced landfill credit afforded by the current landfill allowance schemes is taken into account. Costs are better than half the average for segregated collection and centralised treatment, which should improve by 30-40% once WRAP and Defra resolve the anomaly with the existing landfill allowance formula. The cost advantages of household treatment are greatest for authorities serving rural areas, which increase with rising oil prices.
- Several factors are common to both approaches, such as the need for education and ongoing support to maintain participation levels.
- The household treatment of food waste using a FWD meets the principles of the EU Framework Directive on Waste and national objectives, namely:
    - Moves the management of food waste to the top of the waste hierarchy.
    - Manages waste in ways that protect human health and the environment.
    - The principle of best available technology not involving excessive costs.
    - The principle of proximity of treatment and disposal to the source of waste.
    - The principle of self-sufficiency in waste disposal.
- FWDs offer the additional potential benefits of:
    - Facilitating public acceptability of less frequent collections, thereby reducing vehicle operating costs, accidents and pollution.
    - Cleaner bins and waste for householders, thereby encouraging recycling of remaining domestic waste streams such as plastic and paper packaging, cans and bottles.
    - Engendering understanding and ownership of the waste problem.
    - Limiting the growth in food waste.

The household treatment of food waste is likely to have high public acceptability if offered as an alternative to centralised solutions. Despite this, and the potential advantages outlined above, FWDs barely feature in waste management strategies and plans across the UK and certainly not in any large-scale strategic role. Possible reasons for this situation include:

- Limited awareness and/or promotion on the part of the Government and the devolved administrations, together with their departments and agencies.
- Limited awareness and/or promotion by the responsible authorities, advisory consultancy companies, designated consultation bodies, other interested parties and the public.
- Little interest by the waste management industry, which is rewarded for collection, treatment and disposal and not for waste prevention.

- The landfill mass balance formula discriminating against household treatment.
- A lack of specific targets and economic instruments to drive waste prevention and the household treatment of food waste.
- A focus on other targets, some of which conflict with waste prevention activities.
- Household treatment is not yet considered a proven solution.
- Authorities have historically been responsible for the centralised collection and treatment of household waste and are comfortable with the status quo (i.e. waste collection and waste disposal authorities continue to do what their job titles describe).
- Authorities consider the communication, implementation and monitoring of large-scale household treatment programmes too difficult and/or they do not have the necessary skills.
- There are shortcomings in the processes and/or level of analyses used to determine waste management strategies and plans.

With regards the last point, a 2002 review of waste strategy planning in the UK (Reference 11) indicated a number of inadequacies in the level of analysis. These shortcomings included the inability to follow national guidance, the quality of the data employed, the detail of the assessment, the use of comparative costs and comparative environmental impacts, consideration of social effects (e.g. public participation) and the lack of justification of predictions and decisions. Clearly, an inadequate assessment can lead to poor decisions and will be open to challenge.

The availability of improved data and processes, greater support from central government and the devolved administrations (e.g. References 55 & 56) and growing experience in developing waste management strategies and plans, should have improved the situation. Reviewing the quality of the decision making process and the robustness of the decisions themselves is a major task. Final waste strategies and plans tend to reiterate EU, government and national principles and policies, describe the magnitude of the problem and current practices, outline the main options and present the conclusions. Justification of predictions and decisions, if available, is generally within supporting documentation that is most readily accessible during any consultation period. There is no dedicated body in the UK that reviews and controls the quality of waste management strategies and plans, just as there is no intention at present to create one to oversee SEAs (Reference 32).

6. Conclusions

The management of biodegradable waste is the focus of detailed planning for many authorities as a result of the introduction of landfill allowance schemes in England, Scotland, Wales and Northern Ireland. An anomaly in the mass balance formula used to calculate the quantity of biodegradable waste diverted from landfill is encouraging a growing number of authorities to establish schemes for segregated kerbside collection and centralised treatment and not to follow government and national policies on minimising the amount collected by promoting household treatments, such as the use of home composters and FWDs. Such an approach may be open to challenge if alternative options have not been given serious consideration and would be expensive to reverse due to the major capital investment required to establish these schemes.

This preliminary assessment of the potential contribution that the widespread introduction of FWDs could make in treating household food waste concludes that their use could be a cost effective alternative to the centralised treatment approach. The detailed health, safety, environmental, social, economic and operational risk assessments that should form part of the systematic approach to determining any significant waste management strategy are likely to favour the household treatment option for a majority of situations. Indicative costs are better than half the average for segregated collection and centralised treatment, which should improve by a further 30-40% once WRAP and Defra resolve the anomaly with the existing mass balance formula. The cost advantage of household treatment is greatest for authorities serving rural areas, which increase with rising oil prices.

The principles of sustainability, self-sufficiency, dealing with waste at its source (principle of proximity) and the cost of disposal being borne by the waste owner (principle of polluter pays) apply to individuals and not just counties, regions and nations. Waste prevention and the household treatment of waste are at the top of the waste hierarchy. There is a strong case for encouraging householders with gardens to be self-sufficient in the management of their own biodegradable garden and food waste.

Based upon 10% of UK households using FWDs, which is the current situation for home composters, half a million tonnes of food waste could be diverted from landfill and not have to be collected, between 10 and 25 centralised treatment facilities would not have to be constructed and there would be potential cost savings in excess of £20 million a year.

A realistic optimal household food waste management strategy for an authority, in terms of delivering targets, minimising costs and achieving acceptable health, safety, environmental and operational risk management, will be a combination of both centralised treatment and household treatment. The relative proportions of the two approaches will depend upon factors such as the location of centralised treatment facilities relative to population densities and planning consent issues, the rural-urban composition, existing strategies for dealing with other waste streams and the frequency of collections.

For the household treatment of food waste to become an accepted part of integrated waste management strategies, a number of real and perceived barriers would need to be overcome. The initial steps required to achieve this goal include:

- WRAP and Defra resolving the anomaly with the landfill allowance mass balance formula and completing their current trials of FWDs.

- The national advice and support programmes for the waste collection, disposal and planning authorities containing information on household treatments and not just the centralised approaches.

- The responsible authorities being required to include the option of household treatment when determining their waste management strategy.

- A range of specific targets and economic instruments being developed to drive waste prevention and the household treatment of food waste.

Appendix 1

Key EU Directives and Regulation Relevant to the Management of Household Food Waste

Framework Directive on Waste
Directive 75/442/EEC as amended by 91/156/EEC (Reference 1)

This Directive establishes a framework for the management of waste across the European Union. The Directive sets out a waste management hierarchy, which stipulates waste management options based on their desirability. The most desirable option is the prevention and reduction of waste production, followed by recycling, re-use, reclamation or energy recovery.

The Directive also requires the application of the following principles in waste management:

- The principle of best available technology not involving excessive costs.
- The principle of proximity of treatment and disposal to the source of waste.
- The principle of self-sufficiency in waste disposal.
- The principle of polluter pays for the disposal of waste to ensure that the cost of disposal is borne by the producer or holder of waste.

Landfill of Waste Directive
Directive 1999/31/EC (Reference 2)

The main objective of this Directive is "to provide for measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from landfilling of waste, during the whole life-cycle of the landfill".

The main goals of the Directive are to:

- Reduce both the amount and toxicity of landfilled waste.
- Set standards for the design and operation of existing and new landfills.
- Encourage pre-treatment of waste before it is landfilled.
- Prevent mixing of hazardous waste with municipal waste.
- Ban the landfill disposal of used tyres, healthcare waste and explosive, corrosive, oxidising, flammable and liquid waste.

Most importantly, the Landfill of Waste Directive sets targets for the total quantity of biodegradable municipal waste sent to landfill. Member States are obliged to achieve a reduction of 1995 levels of landfilled biodegradable waste to 75% of weight by 2006, to 50% by 2009 and to 35% by 2016. Member States that relied on landfill to dispose of 80% or more of their municipal waste in 1995 may postpone the attainment of these targets by up to four years.

Strategic Environmental Assessment (SEA)
Directive 2001/42/EC (Reference 3)

The objective of this Directive is "to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment".

SEA is a process designed to ensure that potentially significant environmental effects arising from proposed plans and programmes are identified, assessed, subjected to public participation, taken into account by decision-makers and monitored. Article 5 of the SEA Directive requires the preparation of an Environmental Report, which must include information specified in Annex I of the Directive.

Integrated Pollution Prevention and Control
Directive 96/61/EC (Reference 4)

The purpose of this Directive as it applies to waste management is to achieve integrated prevention and control of pollution arising from defined waste treatment facilities. The Directive requires consideration of the Best Available Techniques (BAT) to avoid or reduce emissions from certain installations and to reduce the impact on the environment as a whole.

Animal By-Products Regulation
Regulation (EC) No. 1774/2002 (Reference 5)

The Animal By-Products Regulation "lays down animal and public health rules for:

- **(a)** the collection, transport, storage, handling, processing and use or disposal of animal by-products, to prevent these products from presenting a risk to animal or public health;
- **(b)** the placing on the market and, in certain specific cases, the export and transit of animal by-products and those products derived therefrom referred to in Annexes VII and VIII".

In relation to household food waste, the Regulation introduces controls for the processing and end use of composted material derived from food waste that contains, or has been in contact with, meat or other products of animal origin.

Appendix 2

Description of Reference Food Waste Digester

Function

The function of the reference Food Waste Digester (FWD) is to:

- Accelerate the natural decomposition process by
    - raising temperatures;
    - maintaining aerobic conditions; and
    - encouraging the growth of micro-organisms.
- Contain and enclose the food waste to prevent dispersion and eliminate odours.
- Create barriers to human, farm animal, wild animal, pet and bird activity.
- Prevent surface and top soil contamination.
- Meet all relevant health, safety and environmental legislation.

The system takes all household food waste, including vegetable scraps, raw and cooked meat or fish, bones, dairy products and other organic food waste such as bread and pasta.

Design

The reference FWD is a four-part plastic injection moulded system comprising a digestion basket that is installed below ground and which forms the base for an above ground double-walled solar chamber with an access lid. The design of the reference FWD utilises solar heating in the double-walled chamber to facilitate and accelerate the aerobic decomposition process within the digestion basket. The system should therefore be installed to obtain the maximum sunlight in a household's garden. A 4.5 litre receptacle, which can be sealed, is provided for collecting and carrying the food waste to the FWD.

The diameter of the 440 mm deep digestion basket is 550 mm at the top and 400 mm at the bottom. A series of slots designed into the basket commence 190 mm below ground level and effectively remove about half of the side wall and base material. The inner and outer walls of the conical solar chamber are 20 mm part, providing an internal gap that is open at the top and bottom of the unit. The diameter of the outer chamber reduces from 550 mm at its base to 285 mm at the lid end. The chamber is 680 mm high but when assembled and installed, the FWD stands 650 mm above ground level and extends 460 mm below ground level. Access to the system is through a 200 mm diameter hole in the top of the solar chamber, which is sealed by a hinged lid with a twistlock security catch.

The reference FWD will dispose of 5 kg of food waste a week, which is more than 25% greater than that produced by the average household. The food waste is converted into water, carbon dioxide and a small amount of residue, without the need for user intervention such as the mixing or turning of the waste. In a well operating system the residue will occupy the bottom 250 mm of the digestion basket after the decomposition of about a tonne of food waste. Thus, after about five years this small quantity of residue must be removed and dug into the garden sub-soil.

Process

The decomposition of organic material is a natural process. Much of the dry weight of plant and animals is attributable to proteins and their remains are eventually converted into soil through a continuous cycle of activity by a wide range of interdependent organisms and micro-organisms. The distribution of these organisms follows that of organic matter and is therefore not uniform, with more than 90% concentrated in the top 100 mm of the soil. By locating the digestion basket below ground, the reference FWD takes advantage of this distribution of soil organisms. The system works best in fertile, well-drained soil, which means that areas of solid rock or with a high water table are unsuitable. In heavy clay soils, drainage should be improved by using a mixture of gravel and compost around the digestion basket. Soil fertility can be enhanced by the addition of suitable natural bacteria, as described later.

The smallest and most numerous micro-organisms are bacteria, with one gram of fertile soil containing around a billion bacteria. Bacteria are unicellular micro-organisms and amongst the smallest living creatures known. There are three bacterial cell shapes, spherical (coccus), rodlike (bacillus) and spiral (spirillum). Under favourable conditions bacteria numbers grow rapidly. Some survive in a dormant or spore state when conditions are not suitable, reviving when they become favourable again.

On the basis of temperature requirements for growth, bacteria are grouped into psychrophiles (0 - 30^{o}C), mesophiles (15 - 45^{o}C) and thermophiles (45 - 60^{o}C). Bacteria within each group exhibit specific minimum, maximum and optimum temperatures for growth, where, for example, mesophiles grow best in the temperature range 25 - 40^{o}C. To ensure a healthy population of bacteria, the reference FWD is provided with a mixture of these natural, non-pathogenic bacteria for use when the system is first installed and if the decomposition process slows because of an imbalance of organic material and bacteria.

Most bacteria grow in a near neutral environment (neither acidic or alkaline) and without light. Atmospheric oxygen is required by some but not all bacteria, others are inhibited by its presence. Bacteria are classified as aerobes when they require oxygen to grow and anaerobes when they cannot grow in the presence of oxygen. Facultative anaerobes do not require oxygen but can grow in its presence; obligate anaerobes are poisoned by free oxygen. Under poor oxygen conditions some micro-organisms can produce toxins that inhibit the growth of higher plants and other micro-organisms. These toxins include methane, hydrogen sulphide, phosphine, skatole, indol and various organic acids. It is for this reason that the reference FWD is designed to maintain aerobic conditions through generating air movement, which results from the temperature gradients created by the double walled solar chamber.

In addition to bacteria, other soil micro-organisms are intimately involved in the natural decomposition process. Actinomycetes resemble both bacteria and fungi. Their spores, although similar to those of bacteria, germinate into very fine colourless threads (mycelia) that resemble those of fungi. Fungi such as moulds, mildews or mushrooms are usually more variable in form than either bacteria or actinomycetes. There are also algae, which are found as motile single cells or non-motile filaments.

Soil fauna ranges from microfauna, usually defined as animals less than 100 microns long, through macrofauna to megafauna, which are the largest soil organisms. Microfauna includes single-celled protozoans, some smaller nematodes, small flatworms, rotifers and tardigrades. Many microfauna only exist in the water films on the organic matter. The most common macrofauna are the small white segmented enchytraeidae that feed on fungi, bacteria and decaying matter. Soil macrofauna play a valuable role in fragmenting organic waste and increasing its surface area. In addition, with the help of symbiotic organisms in their guts, some also break down complex substances such as cellulose, keratin and chitin. Megafauna includes the larger earthworms, which also pass both soil and organic matter through their guts. The fragmented organic waste and soil fauna excretions create an environment suitable for the growth of micro-organisms. The continuous cycle of consumption, digestion and excretion by soil fauna alternates with increases in the population of micro-organisms.

Heterotrophic soil micro-organisms, which derive their carbon and energy from organic materials, are concerned mainly with the breakdown of organic matter, the carbon cycle and nitrogen fixation. Autotrophic micro-organisms, which obtain carbon from carbon dioxide and energy from the oxidation of simple organic compounds, form nitrites and nitrates and oxidise sulphur and iron compounds. Most micro-organisms produce carbon dioxide, which dissolves in water to form carbonic acid. Mineral elements such as sodium, potassium and magnesium are released to the soil during the decomposition process. The weak carbonic acid dissolves relatively insoluble soil minerals.

The different bacteria outlined above produce different enzymes, which are the protein catalysts responsible for the metabolism of organic waste. The principal enzyme types important in the decomposition of food waste are:

- Lipases to digest the fats in foods such as dairy produce, oil and meat.
- Amylases to digest the carbohydrates in foods such potato peelings, bread, biscuits, rice and pasta.
- Proteases to digest the proteins in foods such meat, milk and eggs.
- Cellulases, or cytases, to digest the cellulose in fruit and vegetable matter.

Where conditions are such that the decomposition process is very efficient, such as within the reference FWD, only a small residue of humic substances comprising lignin and protein remains.

Relevant Legislation

The UK has amongst the most comprehensive legislation and controls related to food waste and animal by-products in the world. The recent EU Animal By-Products Regulations (Reference 5) and the UK's National Regulations (listed in Reference 15) introduced controls for the processing and end use of composted material derived from food waste. Under the legislation, all food waste that contains, or has been in contact with, meat or other products of animal origin must be disposed of so that animals and birds cannot gain access. This does not just apply to the collection, transportation and centralised treatment of food waste but also to household treatment. Detailed guidance on the treatment of animal by-products and catering waste, which covers household food waste, has been provided by Defra (Reference 15).

Meat or other products of animal origin fit for human consumption are classified under legislation as low risk Category 3 animal by-products. Regulation 16 of the National Animal By-Products Regulations states that the composting requirements for centralised treatments "do not apply to the composting of Category 3 catering waste on the premises on which it originates provided that (a) the decomposed material is only applied to land at those premises; (b) no ruminant animals or pigs are kept on the premises; and (c) if birds are kept at the premises the material is composted in a secure container which prevents the birds having access to it during decomposition". As a consequence, the household treatment of food can take place only in an enclosed container that prevents access by poultry, wild and domestic animals and birds. In addition, a household FWD must be physically separated from pigs or ruminants (e.g. sheep, cows, goats, deer) by a suitable barrier, such as a fence. This applies to both farmed and pet animals.

The design and operation of the reference FWD meets all the relevant legislation.

Health, Safety and Environmental Impact

The reference FWD is a benign technology and as such causes minimal health, safety and environmental impact. The below ground digestion basket and the sealed solar chamber provide sound physical barriers to odours, insects, birds and animals. With 40% of the unit below ground, the green conical solar chamber of the reference FWD creates negligible visual impact. The reference FWD is constructed from as much recycled material as possible, which in practice means that 100% of the digestion basket and inner solar chamber are made from recycled plastic.

Common to all handling of food and food waste, good housekeeping practices are the cornerstone of health and safety. Such practices include not spilling or leaving food uncovered in the home or elsewhere and the washing of hands before and after handling food. One advantage of the FWD approach is that no third party is involved in the collection and treatment of the waste, with householders handling their own food waste of which they know the provenance. In addition, the individual choices made in the home production or purchasing of food regarding organic growing and farming methods, GM derivatives, animal welfare and pesticide residues can be carried through to the household food waste disposed of in the garden FWD.

In use, food waste is transferred as soon as practical from the kitchen to the FWD, which allows food waste to be removed daily as opposed to weekly or fortnightly with a centralised collection approach. Once deposited in the below ground digestion basket, there is no possibility for unintentional access to the food waste by human activity. As with any gardening activity, particularly those involving soil or compost, gloves should be worn when removing the small amount of residue that accumulates in the digestion basket after several years of operation.

As noted in the previous section, much of the legislation relevant to the treatment of food waste is concerned with the risk to pigs, ruminants and poultry of infection from pathogens potentially present in meat and the subsequent risk to humans. A detailed risk assessment of the centralised treatment of food waste and land disposal of the compost produced has been carried out for Defra by Gale (Reference 57), which concluded that the approach is acceptable provided that a number of key conditions are met.

The derivation of reliable absolute risk values covering human intervention in environmental systems is extremely complex. The reference FWD has been assessed relative to the benchmark established by Gale using both qualitative and quantitative information. As pointed out by Gale, environmental risk assessment is not concerned with the complete elimination of a pathogen by any one barrier but relies on a multiple barrier approach. Many of the barriers involved in the centralised treatment of food waste are common to household treatment using the reference FWD. These include the reduction and elimination of by-pass to the treatment process using physical barriers, the effectiveness of the process itself, decay in the soil, dilution in the soil and the fact that only household food fit for human consumption is being treated, of which a few per cent is uncooked meat.

Temperatures are generally lower with the natural decomposition process in the reference FWD than in centralised biological treatment facilities. As a result, the indigenous micro-organisms can be preserved to grow at the expense of any pathogens present through competition for nutrients and predation. In addition, the process is performed over extremely long periods, which allows for effective pathogen destruction. This has been demonstrated through the microbiological analyses of samples taken from around both dormant and operating reference FWDs. While there is no statutory requirement for household FWDs to undergo any form of sampling and testing, analyses have been performed equivalent to those required by the EU and National Animal By-Product Regulations for the centralised treatment of Category 3 catering waste in biogas and composting plants. The measurement results for the reference FWD were in full compliance with the required microbiological standards.

Due to the effectiveness of the reference FWD in controlling process by-pass and the efficacy of the natural decomposition process itself, the overall health, safety and environmental risk is considered to be extremely small and comparable to that for centralised treatment facilities.

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