The WasteConsortium

Appropriate scales and technologies for bioprocessing of organic urban wastes

Dr Paul Eades, Dr Ian Williams, Marty Climenhaga

University of Southampton

Strategies and Technologies for Sustainable Urban Waste Management Symposium April 21, 2008 London

EPSRC Sustainable Urban Environment Programme

University of Southampton School of Civil Engineering and the Environment

Aims of Project 3

- Identify the best environmental option(s) for biowastes
- Establish the environmental impact(s) of home composting
- Investigate AD of source separated catering wastes

The **WasteConsortium**

Best Environmental Options for Biowastes

Dr Paul Eades

University of Southampton

Strategies and Technologies for Sustainable Urban Waste Management Symposium April 21, 2008 London

EPSRC **Sustainable Urban Environment Programme**

UNIVERSITY OF Southampton
School of Civil Engineering and the Environment

Introduction

- What is bioprocessing?
  - The use of micro-organisms to decompose biodegradable wastes
    - Can be either aerobic (composting) or anaerobic (digestion)
- Why has bioprocessing become a ‘political hotcake’ ?
  - European Landfill Directive 93/31/EC - *(LATS targets in UK)*
- What are the options for managing biodegradable waste
  - Bioprocessing – Composting, AD, Mechanical-biological treatment (MBT)
  - Thermal – EfW incineration, Advanced thermal treatment (ATT)
  - Landfill
- Numerous options but limited guidance on ‘best practice’

Management of green municipal waste

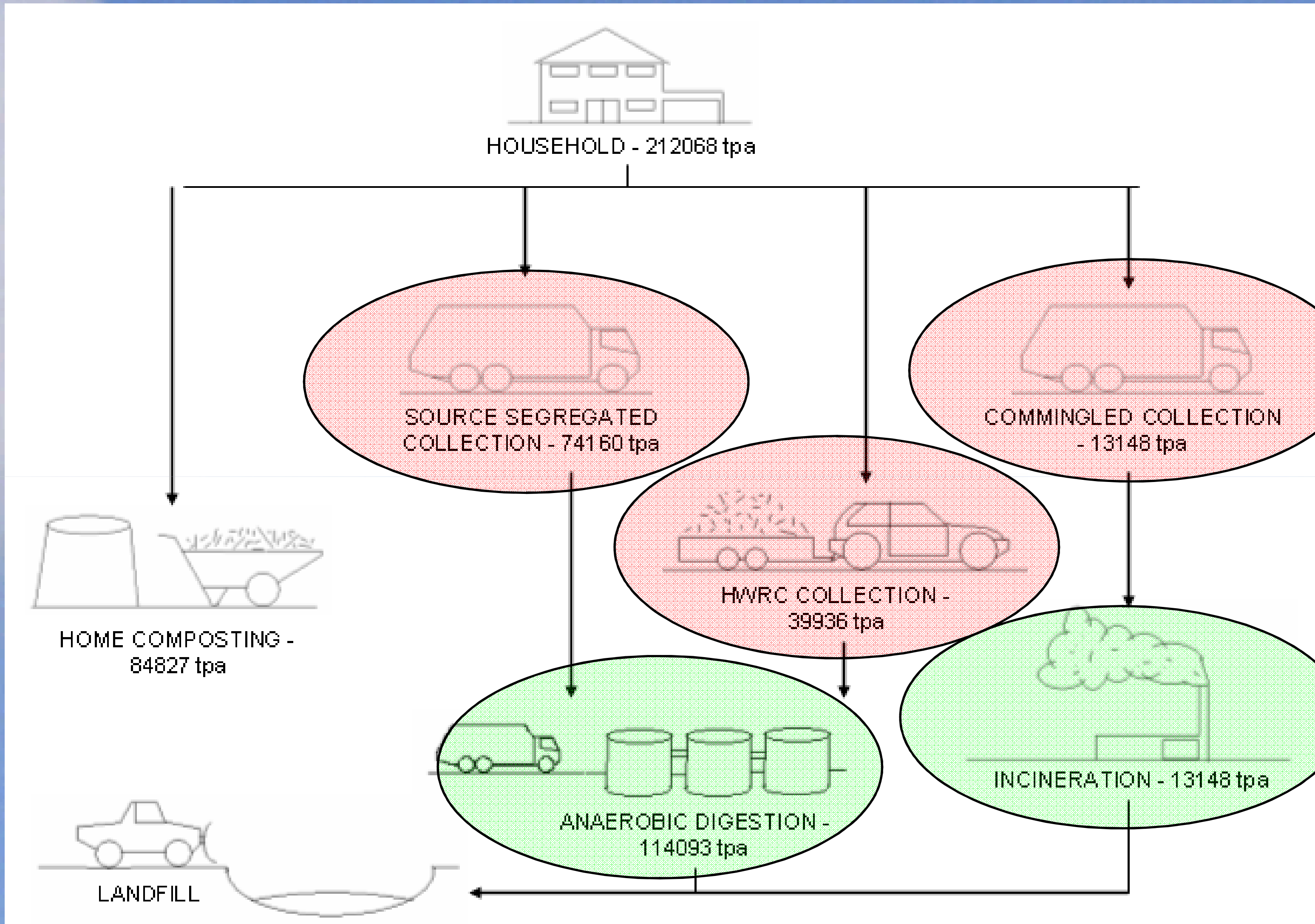
- Why green waste?
  - Constitutes ~30% of biodegradable waste stream (or 20% of MSW)
  - diversion from landfill would therefore greatly assist meeting targets
- Cradle to grave approach in modelling green waste options
  - household > collection > processing > disposal
- 12 potential scenarios modelled for the management of green waste
  - Based on Hampshire demographics (~800,000 population - 90% urban)
  - Scenarios informed by current practices and ‘pipeline’ policies
  - All scenarios used a combination of management methods
- Modelling outputs give environmental impacts including:
  - Energy consumption and impact on LATS
  - Global warming, acidification and eutrophication potential

What do the results indicate?

- Four of the six most preferential options predominantly used AD
  - Energy recovery through the combustion of biogas
  - Digestate production for use as fertiliser substitute
  - Offset emissions from energy production and fertiliser substitute
- Three of the four most preferential options used home composting
  - Reduced requirement for transportation and mechanised processing
- Only one option that used in-vessel composting was located in top four
  - This was only made favourable due extensive use of home composting
  - IVC was energy intensive when compared to other options
- Windrow composting demonstrated an intermediate option

The most preferential option

The **WasteConsortium**



How can the results be used?

- Indicates where the focus of green waste policy should be - a combination of…
  - Minimisation – reduces transport and processing costs
  - Energy recovery technologies (*notably AD*)
- Indicates that local authorities should not focus on:
  - Energy intensive technologies such as in-vessel composting

Assessing the environmental impacts of home composting

Dr Ian Williams, Stephen McKinley

University of Southampton

Strategies and Technologies for Sustainable Urban Waste Management Symposium April 21, 2008 London

Project Aims

- Enable estimation of potential environmental impact(s) of home composting
  - Focus on gaseous emissions
    - Compost quality and leachate emission
- Previous work
  - Visitation of volunteer households
  - Limits analysis frequency and methods
  - Emission estimates require airflow assumptions
- Controlled experiments
  - Investigate specific home composting variables
  - Certainty over input materials and composting conditions
  - Frequent analysis and data logging

Experimental Methods

- Analyse gases emitted from home composting
  - 220 L open bottomed compost bins
  - Feed mixture of fresh grass and mixed garden waste
  - Feed rates 5-10 Kg waste/week
  - Mature compost layer in all bins
  - Fresh additions added to mesh bags
  - Monitoring of temperature, headspace gas composition and compost properties
- Quantify gas emission, estimate open bin air flow
- Simultaneously run open bottomed compost bins and sealed reactors:
  - Forced aeration 0.5 – 2.0 Litres per min
  - Raised plastic grid in base
  - Leachate removal through drain in base

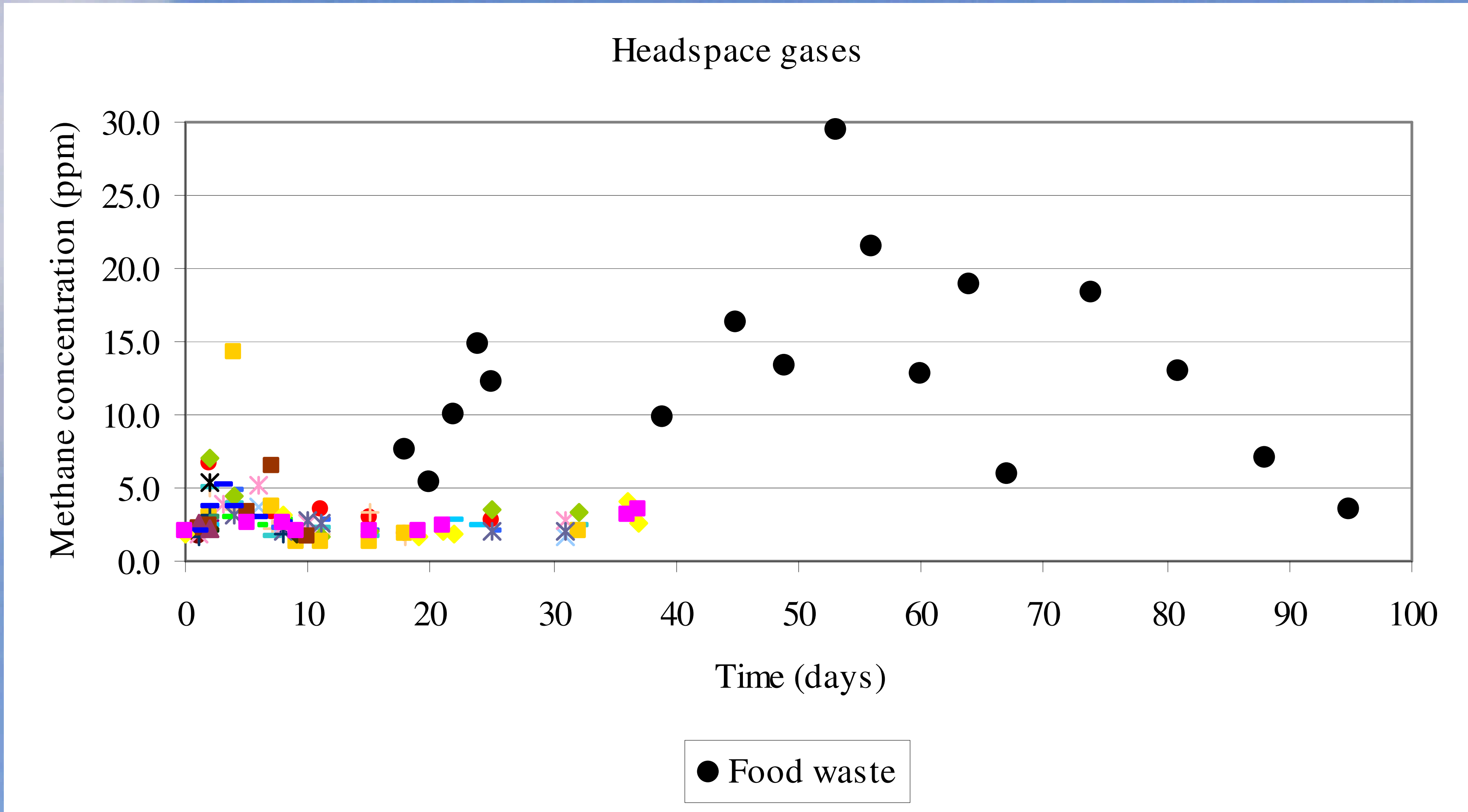
Results

Trace gas analysis:

- Average ammonia concentrations up to 22 ppm
- Concentrations of N_2O at or below atmospheric
- VOCs detected at concentrations of 20-95 ppb
  - Limonene, Phellandrene, Pinene, DMS, Carene

Feed material/ 14 days	Concentration of NH_3 (ppm)*	Emissions of NH_3 g/T feed
9.9 Kg grass	22	16
9.9 Kg grass	17	12
5.5 Kg food waste	0.8	1.0
5.5 Kg food waste	0.5	0.7

Results and Discussion



Results

Emissions Investigation - potentially toxic elements:

Parameter	Element mass in dry matter (mg/kg)			
	High load	Low C:N ratio	With kitchen waste	PAS 100 upper limit
Cadmium as Cd	0.7	0.6	0.6	1.5
Chromium as Cr	12	8.8	11	100
Copper as Cu	47	36	37	200
Lead as Pb	93	69	82	200
Mercury as Hg - less than	0.5	0.5	0.5	1
Molybdenum as Mo	2.5	2.1	3.3	N/A
Nickel as Ni	8.4	5.8	7.8	50
Zinc as Zn	164	170	152	400

Results

Emissions Investigation - potentially toxic elements:

Parameter	Element mass in dry matter (mg/kg)			
	High load	Low C:N ratio	With kitchen waste	PAS 100 upper limit
Cadmium as Cd	0.7	0.6	0.6	1.5
Chromium as Cr	12	8.8	11	100
Copper as Cu	47	36	37	200
Lead as Pb	93	69	82	200
Mercury as Hg - less than	0.5	0.5	0.5	1
Molybdenum as Mo	2.5	2.1	3.3	N/A
Nickel as Ni	8.4	5.8	7.8	50
Zinc as Zn	164	170	152	400

Results

Emissions Investigation - potentially toxic elements:

Parameter	High load	Low C:N ratio	With kitchen waste	PAS 100 upper limit
	Element mass in dry matter (mg/kg)			
Cadmium as Cd	0.7	0.6	0.6	1.5
Chromium as Cr	12	8.8	11	100
Copper as Cu	47	36	37	200
Lead as Pb	93	69	82	200
Mercury as Hg - less than	0.5	0.5	0.5	1
Molybdenum as Mo	2.5	2.1	3.3	N/A
Nickel as Ni	8.4	5.8	7.8	50
Zinc as Zn	164	170	152	400

Conclusions

- Home produced composts can be used as a safe and beneficial soil improver
- Highest composting activity in the first 2-3 days
- Air exchange mechanism in home compost bins shown to be primarily diffusion not bulk convective flow as previously assumed
  - Important implications for interpretation of previous studies and the design of any future investigations
- Trace gas emissions from home composting low
- Combined with low gas flow rates from diffusion this leads to extremely low environmental impacts

Conclusions

- Home composting should continue to be encouraged as a waste management tool
  - Fully adheres to proximity principle
  - Diverts waste from costly and energy consuming collection, handling and processing steps
- Very little effort and only basic knowledge is required by the public to produce safe composts with negligible environmental impacts compared to the alternative treatment methods

The **Waste**Consortium

Anaerobic Digestion of Catering Wastes

Marty Climenhaga

University of Southampton

Strategies and Technologies for Sustainable Urban Waste Management Symposium April 21, 2008 London

EPSRC Sustainable Urban Environment Programme

UNIVERSITY OF Southampton
School of Civil Engineering and the Environment

Project Background

Anaerobic Digestion at Institutional Scale

– Part 1: Determine amount and type of organic wastes generated by campus catering facilities
– Part 2: Test amenability for digestion in bench-scale trials (5-L anaerobic bioreactors)
– Provide recommendations for next steps

Food Waste Digestion

- Source-separated food waste collection
  - Defra and WRAP funding kitchen waste collection trials at local authorities across UK
    - Separate collection and processing of food waste recommended as best environmental option
  - Funding to support development of AD facilities

- Operating experience on pure food waste
  - Many plants in Europe digesting organic fraction of MSW but few on pure food waste feedstock
  - In UK one facility digesting pure food waste – Biocycle

Part 1: Collection and Characterisation of Catering Wastes

- Collection of waste from campus canteen kitchen and dining areas
- Analysis of waste for digestibility parameters, preparation of composite for substrate in bench-scale digestion trials

Catering Waste Digestion Considerations

- Energy-rich feedstock
- Contains mix of readily-degradable and slowly degradable material, i.e.:
  - Fruit & vegetables: rapidly degradable sugars
  - Fried & fatty foods: more slowly degradable lipids
  - Meats & proteins: potentially inhibitory breakdown products
    - N: ammonia inhibition
    - S: competition from sulphate reducing bacteria, reduced bioavailability of micronutrients

Catering Waste Substrate Characteristics

Parameter	Unit	Average ± Standard Deviation
Total Solids	%	28.1 ± 0.25
Volatile Solids	% of TS	95.5 ± 0.06
Total Lipid Content	% of TS	22 ± 1
Total Kjeldahl Nitrogen	% of TS	3.8 ± 0.24
Chemical Oxygen Demand	g/kg	422 ± 16

The **WasteConsortium**

Part 2: Digestion Trials

EPSRC **Sustainable Urban Environment Programme**

UNIVERSITY OF Southampton
School of Civil Engineering and the Environment

Digestion Trials

- Single-stage Completely Stirred Tank Reactor (CSTR) mesophilic digesters, 5 L working vol.
  - Single – stage system: most common in commercial facilities
  - Simplest system for daily feeding
  - ‘Wet’ system due to feedstock’s high moisture content and lack of structural material
- Pure food waste substrate, no co-substrate

Results of Digestion Trials

- Good gas production but poor stability
  - Average methane production 0.4 L CH_4/gVS_{added}
  - Average VS destruction 75%
  - Process susceptible to upset
    - Rapid increase in acidic intermediates and cessation of methane production
- Strategies effective in maintaining stability:
  - Trace element supplementation
  - Uncoupling of solid RT from liquid RT
    - Retaining solids, flushing liquids resulted in stable digestion

Conclusions

- Catering waste good potential feedstock for AD but requires further research
  - Good gas production and VS destruction
  - Process susceptible to upset
- Process stability an important consideration
  - Two strategies tested:
    - Trace element supplementation
    - Maintaining solids in the system
- Recommendations for catering waste digestion:
  - Use of digestion modes that maintain biomass in system and allow for degradation of more slowly-degradable components
  - Possible co-digestion with other wastes