EXECUTIVE SUMMARY

DEFINING SUSTAINABLE LANDFILL

1. To achieve sustainable landfill it must first be defined.

2. The definition requires two components, firstly a statement of broad environmental principles, defining what end point is to be achieved ('Final Storage Quality') and the timescale for achieving it. These qualitative objectives must then be expressed in the form of quantitative technical criteria that can be used for regulation. The former provide the driving force and represent the value judgements made by society. The technical criteria are then necessary as a practical tool for implementing the concept.

3. The following principles, from Switzerland, provide one of the earliest (1986) and clearest statements of the broad objectives and have formed the basis for much of the discussion in the UK in recent years:

   - Each generation should manage its wastes to a status of Final Storage Quality;

   - Final Storage Quality: any emissions to the environment to be acceptable without further treatment;

   - One generation = 30 years.

   Definitions in current UK official guidance are similar to these, but are stated rather more equivocally, particularly regarding the timescale.

4. Technical criteria for final storage quality (FSQ) may encompass one or all of:

   - solid waste characteristics;

   - gas quality and gas emission rates;

   - leachate quality.

5. In the UK, WMP26A sets out FSQ levels for solid waste characteristics, based on its potential to degrade. The criteria are restricted to non-hazardous wastes and do not address other characteristics such as leachable metals. WMP26A also sets levels for gas quality and emission rates. It does not set FSQ levels for leachate quality but instead advises a site-specific approach based on the characteristics of the local environment.

6. The solid waste and gas criteria in WMP26A require degradation of more than 99.9% of the gas potential in typical MSW, from ~200m^3LFG/t down to less than 0,1$m^3$$CH_4$/dry tonne. No information is given on the derivation of this target or any associated risk assessment.

7. Other countries have not set FSQ criteria and appear not to have addressed the problem. Rather they have concentrated on developing landfill acceptance criteria for pre-treated wastes. These are not the same, conceptually, as FSQ criteria. In Germany for example, a gas potential of 20m^3/t has been proposed as an acceptance criterion for composted wastes. This represents only 90% degradation of MSW and when landfilled in bulk, gas and leachate management may still be needed.

8. For leachate, it has been assumed in this report that FSQ levels will be similar to the limits set in discharge consents for leachate treatment plants discharging to surface waters. Comparison of these limits with typical concentrations and raw leachate indicates the likely dilution needed to reach FSQ. The dilution factors thus derived are:

chloride	6-12
NH_3-N	20-400
BOD	2 - 50
COD	10-50
Fe	1-20

This shows ammonia to be the controlling parameter, with typically two orders of magnitude dilution of the landfill required (i.e. 99% removal).

9. For other types of landfill the dilution factors and the controlling parameter may differ. For example, chloride may be the controlling parameter at landfills for incinerator ash. For treated hazardous wastes there is very little published information from which to infer probable controlling parameters and dilution (flushing) requirements.

ACHIEVING SUSTAINABLE LANDFILL

10. Achieving sustainable landfill (i.e. reaching FSQ in less than 30 years) requires:
either, waste pre-treatment to FSQ before landfilling;
or, degrading and flushing the wastes within the landfill, at a sufficiently high rate.

11. Pre-treatment technologies currently in common use do not produce FSQ residues:

- Incineration of MSW produces ash leachates with 10,000 - 20,000mg/l of chloride and air pollution control residues that leach high concentrations of toxic metals.
- Composting of MSW organics produces residues that leach similar concentrations of non-degradable COD to those found in methanogenic leachate, and that may have a gas potential up to $20m^3$/t.
- Conventional liquid waste treatment plants produce sludges that are physically unstable and that can leach high concentrations of TOC, including phenols.

12. There is no documented case, to date, of untreated wastes in landfills (other than inert wastes) being taken to FSQ, regardless of timescale.

13. The current status of knowledge on the promotion of decomposition of degradable wastes and the flushing of soluble pollutants is summarised in the table below. There seems every likelihood that a high proportion of waste degradation can be achieved in very much less than 30 years. An aerobic phase following active methane extraction appears to offer a promising route to accelerate the final stages of degradation.

The current state of knowledge on the flushing of soluble pollutants from landfills is summarised in the table below. It remains unclear whether it will be practicable to flush MSW landfills to the necessary dilution, once degradation and settlement have occurred. Heterogeneity and the low permeability of the wastes are the main concerns. It is, however, clear that depth will be an important factor and that the chances of success appear best for landfills less than ~20m deep.

14. A significant volume of research has been directed at promoting faster degradation and flushing, and is reviewed in the report. This research effort is continuing, with funding coming mainly from the Environment Agency, EPSRC and from Landfill Tax.

A summary listing of current and recent research projects in the UK is shown in Table 1 of the report (pages 2/3).

15. Additional research needs identified in the report are shown in Table 10 of the report (page 22), with the most urgent shown in bold type. The majority are not being addressed by any of the projects known to be underway or planned.

Promotion of decomposition [Target 99%]

What we know

- Key factors are: moisture content, temperature, inoculation and recirculation
- Brogborough and LF2000 showed acceleration to 20-60m3/t.a easily achievable
- Yolo (USA) and VAM (Holland) test cells show we can reach ~140m3/t in ~2 years, even with crude MSW
- Point at which gas rate slows to uneconomic level = f (temperature)
- At T>30°C we may get 90% of gas at > 1Om3/t.a
- Every likelihood that we can reach BMP <20m³/t in 5 years (i.e. >90% degradation)
- No evidence of salts or NH3-N reaching inhibitory levels as a result of recirculation
- In situ aeration can lead to huge reduction in NH3-N
- In situ aeration has negligible effect on soluble hard COD

What we don't know

- Last third of gas curve is very poorly characterised at large scale
- Characteristics of solid residues when gas, leachate and BMP targets are met
- Nature and concentration of non-degradable COD from a flushing bioreactor landfill
- Aerobic post-treatment:
  - optimum point to begin aeration
  - efficiency at full scale
  - quality/odour of off-gas
  - how low we can get TKN
  - what effects on other leachate parameters (COD, BOD, S04, pH, metals)
  - - any temperature problems

Flushing of pollutants

What we know

- MSW lysimeters and landfills appear to behave like completely mixed reactors
- Explained by 2-domain or 3-domain models: rapid flow in channels and rapid equilibration between mobile and non-mobile water
- Positive implications for flushing
- 7 BV (3-5m3/tonne) needed for NH3-N; 2-4 BV (1-2m3/tonne) needed for COD
- Re-injection systems susceptible to chemical and biological clogging
- Waste K may be too low for required flushing rates, at depths >20m

What we don't know

- Hydraulic behaviour of highly degraded wastes under high compaction
- Hydraulic behaviour of treated hazardous wastes
- Effects of other hydraulic barriers (e.g. cover layers)
- Optimum design of liquid re-injection systems
- Effects of settlement on leachate re-injection systems
- Actual flushing efficiency achievable at large scale
- Extent of flushing required for hazardous waste landfills