

Biodegradability of municipal solid waste

WR1003

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Prepared for Lynn Raw, DEFRA

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## Glossary

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**ANOVA.** Analysis of Variance (ANOVA) is a test of the significance of the difference in the **means** between more than two **samples**. A **significant** ANOVA result does not imply that all the means are significantly different, merely that there is a significant difference somewhere. As such, ANOVA results need careful interpretation, and can often be clarified with the application of further tests such as **Tukey's Honestly Significant Difference**.

**Case.** The term “case” has been used to describe each individual load of material extracted from a vehicle to be sorted. All of the cases together make up the **sample**. In this context, it should be understood that the loads themselves represent samples of the total material in each vehicle, but a different terminology has been used to avoid confusion between samples (i.e. the sample of 20.03.01 material) and cases (where each case represents a single load).

**Correlation.** Correlation is a measure of whether – and how – two independent variables vary in relation to one another. For example, if variable x tends to increase as variable y increases, they are said to be positively correlated. If one variable tends to decrease as the other increases, they are negatively correlated. If there is no pattern of variation in this way (or if the variation is not **significant**) then the two variables are not correlated.

**EWC Code.** The European Waste Catalogue is a hierarchical list of types of wastes. It is used on waste transfer notes to catalogue the type of waste, and provides a means of describing waste materials consistently. The catalogue is divided into 20 Chapters, which are in turn subdivided into narrower categories. For example, Chapter 15 covers waste packaging, wiping cloths, fillers and clothing; within this 15.01 covers all packaging wastes, and this is further divided into specific types of waste (for example, 15.01.01 refers to paper and cardboard packaging). This study concentrates on two specific waste codes, 19.12.12 (mixed wastes from mechanical treatment) and 20.03.01 (mixed municipal waste).

**Mean.** The most commonly used type of average, the mean is a measure of the central tendency of a **sample** or population, the “typical” result. It is calculated by adding together the value of each case and dividing the total by the number of cases.

**Sample.** In this report, sample is used to refer to the total number of waste loads studied of a given type (e.g. a sample of 150 loads of waste). To avoid confusion, the individual loads analysed have been referred to as “**cases**”.

**Significance.** When two or more samples have different **means**, this could be the result either of a real underlying difference in the sample populations, or of random variation in the sampling (i.e. the underlying populations are not, in fact, different). Significance tests (such as **T-tests** and **ANOVA**) determine the probability of a given difference in sample means occurring purely by chance, *assuming that the underlying populations are the same*. If this chance is determined to be very low (in this report we use a figure of 5%), we may reasonably assume that the difference in sample means reflects a real underlying difference – we call this a significant result (in this case, significant at the 95% level, because we can be 95% sure that the difference in means is not purely the result of random variation).

**Standard deviation.** Where **mean** is a measure of central tendency, standard deviation is a measure of spread. It gives the “typical” difference between the **sample** mean and the score for an individual **case**. Sample standard deviation is calculated by adding together the squared difference between each case and the sample mean, dividing the total by the number of cases *minus one* and calculating the square root of this figure.

**T-test.** A t-test compares the **means** of two **samples**, along with their **standard deviation** and the number of **cases** in each sample, to determine whether the difference in sample means is **significant**.

**Tukey's Honestly Significant Difference (HSD).** Tukey's HSD is a follow-up test to **ANOVA**, and is used to calculate the difference between a pair of **sample means** that can be regarded as **significant**. Any pair of sample means that are further apart than the critical value for Tukey's HSD can be regarded as significantly different from one another.

# 1. Introduction

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Resource Futures was contracted by DEFRA to carry out an analysis of the composition of municipal solid waste (MSW) landfilled in the UK. The primary aim of this analysis was to provide accurate and reliable information on the amount of biodegradable material landfilled under a range of European Waste Catalogue codes, with particular emphasis on codes 19.12.12 (Waste from mechanical waste treatment) and 20.03.01 (Mixed municipal waste).

The compositional analysis was conducted over three phases, with Phase 1 conducted in Autumn 2010, Phase 2 in Winter/Spring 2011 and Phase 3 in Summer/Autumn 2011.

The third phase included follow-up laboratory analysis of sorted waste fractions in order to assess the biodegradability of the material.

This report presents the findings of the project, including the compositional and laboratory analysis, and attempts to model the amount of biodegradable municipal solid waste (MSW) arising in the UK.

## 1.1 Background

This work was commissioned in the context of the revision of the UK definition of Municipal Waste, and the consequent revision of the approach to reporting against Landfill Directive targets.

Previously defined in the UK as waste collected by local authorities – mostly household and local authority waste, plus a small proportion of local authority-collected trade waste – the revised definition is based on a more literal interpretation of the Landfill Directive definition of Municipal Waste as:

“...waste from households, as well as other waste which,  
because of its nature or composition, is similar to waste  
from households.”

Council Directive 1999/31/EC of 26 April 1999 on the  
landfill of waste, Article 2(b)

This definition includes a large amount of material that previously would have been classified as commercial and industrial waste – the amount of material now classified as MSW is approximately double compared with the old definition.

A consequence of this is that Waste Data Flow is no longer sufficient when calculating the quantity of municipal waste arising. The revised approach to reporting on the Landfill Directive will instead be based upon quarterly returns from landfill operators to the Environment Agency, with particular European Waste Catalogue (EWC) codes classified as municipal waste – this approach found support in the June 2010 consultation on changing the UK’s approach to meeting the landfill diversion targets.

Municipal waste includes all of Chapter 20 of the EWC, plus parts of Chapter 19 (waste from treatment facilities) and Chapter 15 (packaging waste).

To report against targets for landfill of biodegradable municipal waste (BMW), it is necessary to identify from these returns the amount of biodegradable waste landfilled against the EWC codes included within municipal waste. The majority of EWC codes are material specific, and in these cases it is straightforward to determine whether the material should be classed as biodegradable or not. However, there are a small number of mixed codes, and two of these (19.12.12 and 20.03.01) account for the vast majority of MSW.

Therefore, assessment of the biodegradable content of the waste landfilled under these codes is crucial to understanding the amount of BMW landfilled. In order to give some idea of the preponderance of the 19.12.12 and 20.03.01 codes in the mixed waste sent to landfill, Table 1

shows the quantities disposed in 2011 of some of the major codes covering mixed materials that could be regarded as municipal waste.

**Table 1: EWC codes covering mixed municipal waste**

| EWC    | Type                            | Definition   | Tonnes (2011) |
|--------|---------------------------------|--|---------------|
| 190501 | Waste from aerobic treatment    | non-composted fraction of municipal & similar wastes | 5,004         |
| 190503 | Waste from aerobic treatment    | off-specification compost                            | 84,532        |
| 191212 | Waste from mechanical treatment | other wastes from mechanical treatment of wastes     | 8,431,131     |
| 200301 | Other municipal wastes          | mixed municipal waste                                | 9,088,763     |
| 200302 | Other municipal wastes          | waste from markets                                   | 1,898         |
| 200303 | Other municipal wastes          | street-cleaning residues                             | 196,651       |
| 200307 | Other municipal wastes          | bulky waste  | 210,012       |
| 200399 | Other municipal wastes          | municipal wastes not otherwise specified             | 90            |

Source: Environment Agency, RATS database.

In addition to assessing the amount of BMW sent to landfill, a secondary aim of the project was to collect data to assist in assessing the carbon impact of this waste. Current modelling for the UK Greenhouse Gas Inventory assumes that biodegradable materials are composted. The research aimed to improve the accuracy of this modelling by providing an assessment of the amounts of biodegradable waste sent to landfill without being fully stabilised through composting or other pre-treatment.

## 1.2 Project design

While there is a large body of work on waste analysis, this has been overwhelmingly concerned with waste collected by local authorities, at the kerbside, through HWRCs or through municipal trade waste collections. These studies are commissioned with a range of goals, and the use of a range of different classifications of material can make direct comparison of results problematic. However, DEFRA's *Municipal waste composition* study (Bridgwater and Parfitt, 2009) carried out a major review of the existing waste analysis work and provides an important source of data, particularly on the kerbside collected fraction.

Many other inputs to landfill (such as commercially collected waste or inputs of mixed material from transfer stations) are underrepresented in the analysis. A major element of the project was to characterise these other inputs, and to identify differences in composition and target potential gaps in the available data.

In addition to compositional analysis of material arriving at the landfill sites, Phase 3 included sampling of material for laboratory analysis, in order to provide a more detailed understanding of the biodegradability of the waste fractions.

## 2. Methodology

### 2.1 Sampling strategy

As a result of the relatively unknown composition and variability of much of the material, it was decided that the analysis would not select sample cases in the proportions in which they occur in the national waste stream, but would begin by treating each category of waste equally, in order to gain a comparable measure of composition and variability that could inform the sampling strategy in future phases. It was agreed that the first phase of the analysis would target an equal number of cases from each EWC code, and attempt to split each EWC code equally depending on whether the waste was trade waste or of domestic origin.

The second phase of the analysis identified that the waste over which there was most uncertainty was from EWC code 19.12.12, and so concentrated on this code in order to improve the reliability of the data. The third phase concentrated primarily on EWC code 20.03.01 in order to attempt to

further characterise the commercial waste stream collected under this code. The study did not target specifically commercial waste, since the proportion of the 20.03.01 code made up of commercial waste is not known – hence, concentrating purely on commercial 20.03.01 would have distorted the understanding of the code more generally by overemphasising commercial waste.

In addition to classifying each sample by EWC code, the research team also attempted to classify each sample case as either commercial or household waste, through asking the driver of the vehicle about the origin of the material. Cases containing mixed waste or waste of uncertain origin were classified as mixed.

In order to identify sites at which analysis could be conducted, Resource Futures entered into partnership with Viridor and Biffa, who agreed to supply the sites. This greatly speeded the recruitment process, which was important given the short turnaround time for each phase of the project, while ensuring that more than one landfill operator was represented in the study.

Once a shortlist of potential sites had been identified, each site was visited and the landfill manager liaised with in order to assess its operational suitability for carrying out the planned work. Key factors to consider were the availability of suitable working space, the range of materials accepted at the site, the accessibility of these materials to the analysis team and the health and safety implications of working on the site.

When selecting landfills, it was also important to gain as wide a geographical coverage as possible. A number of sites were identified that provided a good coverage of most regions of the UK, although there was a shortage of viable sites in the Midlands area.

The sites selected for sampling in each phase, and their locations, are shown below in Table 2 and Figure 1.

When devising a sampling strategy, a key consideration was to achieve the correct balance between the size of each individual case and the number of samples sorted.

While increasing the weight of each individual case reduces the number that can be sorted, it also increases the likelihood that the case is a reasonable representation of the load from which it is extracted. Larger individual cases also reduce the variation between cases, with the result that fewer cases are needed, and also reduce the amount of time spent recording results as opposed to sorting and categorising material. On the other hand, too large a case weight runs the risk of reducing the number vehicle loads sampled to such an extent that statistical tests become unreliable.

The sampling plan was based around sorting 25 150kg cases each week. This was felt to be a good compromise between maximising caseweights and maximising the number of samples sorted.

## 2.2 Selecting the samples

Vehicles to be sampled were selected by the Resource Futures site manager, working with weighbridge staff in order to identify loads by EWC code. The site manager would then accompany the vehicle to the tipping face (or tipping hall, where one was available).

Material was extracted from the tipped pile by the site operator, using a shovel loader or other mechanical handling equipment, and dumped on a tarpaulin – when sampling waste on a landfill, this is necessary in order to enable a distinction to be made between the material to be sampled and the rest of the operating environment.

In most cases, the shovel load of material would be in excess of 150kg of material. In order to extract a 150kg sample, Resource Futures staff worked from one side of the pile, shovelling or manually loading all of the material into wheeled bins until a 150kg sample was achieved.

In cases where two samples were taken from a single vehicle, the Resource Futures site manager generally instructed the loader to take two separate scoops where this was possible. In cases where this was not practical (e.g. if the tipping face was extremely busy or if the waste was bound together and not easily separable) a single load was taken and two samples extracted from different sides of the tipped pile.



While every attempt was made in the first phase to select an equal number of samples from each EWC code on each site, it was often necessary to adapt this approach to target the material that was available. Added to this, it should be considered that EWC 19.12.12 tends to arrive at landfill in bulk carriers, which results in fewer vehicles to target. In order to ensure a reasonable number of samples, the sampling approach was revised such that multiple samples were taken from bulk carriers.

**Table 2: Sites included in the study, with analysis dates**

| Site            | Location           | Operator | Analysis dates        |
|-----------------|--------------------|----------|-----------------------|
| <b>Phase 1</b>  |                    |          |                       |
| Beddington      | London             | Viridor  | 16-27 August 2010     |
| Walpole         | Somerset           | Viridor  | 23-27 August 2010     |
| Masons          | Suffolk            | Viridor  | 31 Aug – 4 Sep 2010   |
| Erin            | Derbyshire         | Viridor  | 6-10 September 2010   |
| Lean Quarry     | Cornwall           | Viridor  | 6-10 September 2010   |
| Parkwood        | Yorkshire          | Viridor  | 13-17 September 2010  |
| Rochester TS    | Kent               | Viridor  | 20-24 September 2010  |
| <b>Phase 2</b>  |                    |          |                       |
| Trecatti        | Wales              | Biffa    | 21 – 25 February 2011 |
| Redhill         | Surrey             | Biffa    | 28 Feb – 4 March 2011 |
| Skelton Grange  | Yorkshire          | Biffa    | 7 – 11 March 2011     |
| Roxby           | Yorkshire          | Biffa    | 14 – 18 March 2011    |
| Tipton TS       | West Midlands      | Biffa    | 21 – 23 March 2011    |
| Lean Quarry     | Cornwall           | Viridor  | 28 Mar – 1 Apr 2011   |
| <b>Phase 3</b>  |                    |          |                       |
| Beddington      | London             | Viridor  | 4 – 8 July 2011       |
| Erin            | Derbyshire         | Viridor  | 18 – 22 July 2011     |
| Redhill         | Surrey             | Biffa    | 25 – 29 July 2011     |
| Brookhurst Wood | West Sussex        | Biffa    | 1 – 5 August 2011     |
| Broadpath       | Devon              | Viridor  | 8 – 12 August 2011    |
| Skelton Grange  | Yorkshire          | Biffa    | 15 – 19 August 2011   |
| Pilsworth       | Greater Manchester | Viridor  | 22 – 26 August 2011   |

## 2.3 Sorting the material

Sorting the material was conducted on site, in an area designated for the use of Resource Futures staff. In cases where a covered sorting area was not available, a marquee was used to provide shelter.

All cases were sorted on a wooden sort table fitted with a 10mm screen to remove the fines fraction. Material was sorted to a pre-agreed category list, which is reproduced in Appendix 1.

This category list was altered slightly as the phases progressed, with the addition of wood and wood composite in Phase 2 (rather than packaging and non-packaging wood in Phase 1) and corrugated board in Phase 3 (sorted as card in Phases 1 and 2). The primary reason for changing the categories was that the project steering group considered that this would result in a more accurate laboratory analysis.

The material categories were then weighed off on calibrated digital scales and the results recorded on paper for later entry into Excel.

**Figure 1: Location of sites included in the analysis**



Source: Google maps

|   |              |   |                 |
|---|--------------|---|-----------------|
| A | Walpole      | I | Trecatti        |
| B | Rochester TS | J | Redhill         |
| C | Erin         | K | Skelton Grange  |
| D | Pilsworth    | L | Roxby           |
| E | Beddington   | M | Tipton TS       |
| F | Masons       | N | Brookhurst Wood |
| G | Lean Quarry  | O | Broadpath       |
| H | Parkwood     |   |                 |

## 2.4 Collection of samples for laboratory analysis

Samples for laboratory analysis were collected from the sort at Brookhurst Wood landfill site, between 1 and 5 August 2011.

Laboratory analysis of mixed residual waste poses a range of challenges. Selecting a representative sample from mixed waste is problematic, since different loads will have different characteristics, and particular materials in a pile of waste may tend to cluster together. Any attempt to select a single sample (say 20kg) of waste is likely to omit bulky items, and to either completely miss (due to their low frequency) or grossly over-represent rarer materials such as batteries. In addition, the preparation and milling of samples from mixed materials can be very difficult.

In order to manage this, samples were selected from the sorted material rather than from mixed waste, to represent 25 material types agreed in advance with the laboratory. Where lab samples were composed of more than one waste analysis category, the materials were combined in proportions determined by the data from the study to date.

Adopting this approach helps to ensure a representative sample, and ensures that the lab is supplied with a homogeneous material that its equipment can manage. The laboratory can then conduct a separate analysis on each material, with the final characteristics of the waste being modelled through combining the compositional analysis with the laboratory results. This approach has a significant additional benefit in that, by providing data for each component of the waste, it is possible to model the effects of changing waste composition.

The sample materials selected for laboratory testing and the suite of lab tests used are shown and discussed in Appendices 4 and 5.

## 2.5 Data analysis

The collected data was input into Excel spreadsheets and double checked before being imported into SPSS. All data analysis was conducted using Excel or SPSS.

Prior to statistical analysis, variables were derived for estimated biodegradability, estimated recyclability and estimated combustibility. The derivation of these variables is shown in appendix 2.

The main analytical methods used were:

- Modelling of a combined composition based on a weighted average
- Derivation of a variable for overall biodegradability, using a modified version of the ready-reckoner in the Environment Agency's LATS guidance
- Use of one-sample t tests to determine confidence intervals for the compositional variables
- Analysis of variation (single factor) and Tukey HSD to examine differences between the sites analysed
- Correlation matrices to look for relationships between different compositional variables

### 3. Results

#### 3.1 Sampling results

Over the course of the study, 504 cases were sorted, comprising 312 cases of EWC 20.03.01 and 192 of EWC 19.12.12.

The breakdown of cases sorted by phase is shown in Table 3, while Table 4 shows the breakdown of cases sorted by EWC code, phase and site.

**Table 3: Cases sorted by EWC code and phase**

|              |   | EWC        |            |            |
|--------------|---|------------|------------|------------|
|              |   | 19.12.12   | 20.03.01   | Total      |
| Phase        | 1 | 70         | 130        | 200        |
|              | 2 | 107        | 28         | 135        |
|              | 3 | 15         | 154        | 169        |
| <b>Total</b> |   | <b>192</b> | <b>312</b> | <b>504</b> |

**Table 4: Cases sorted by EWC code, site and phase**

| Phase | Site            | EWC        |            | Total      |
|-------|-----------------|------------|------------|------------|
|       |                 | 19.12.12   | 20.03.01   |            |
| 1     | Beddington      | 18         | 34         | 52         |
|       | Erin            | 8          | 17         | 25         |
|       | Lean Quarry     | 10         | 10         | 20         |
|       | Masons          | 12         | 14         | 26         |
|       | Parkwood        | 11         | 14         | 25         |
|       | Rochester       | 0          | 27         | 27         |
|       | Walpole         | 11         | 14         | 25         |
|       | <b>Total</b>    | <b>70</b>  | <b>130</b> | <b>200</b> |
| 2     | Lean Quarry     | 31         | 0          | 31         |
|       | Redhill         | 20         | 5          | 25         |
|       | Roxby           | 9          | 12         | 21         |
|       | Skelton Grange  | 19         | 6          | 25         |
|       | Tipton          | 8          | 0          | 8          |
|       | Trecatti        | 20         | 5          | 25         |
|       | <b>Total</b>    | <b>107</b> | <b>28</b>  | <b>135</b> |
| 3     | Beddington      | 2          | 23         | 25         |
|       | Broad Path      | 2          | 23         | 25         |
|       | Brookhurst Wood | 2          | 23         | 25         |
|       | Erin            | 4          | 20         | 24         |
|       | Pilsworth       | 2          | 20         | 22         |
|       | Redhill         | 2          | 23         | 25         |
|       | Skelton Grange  | 1          | 22         | 23         |
|       | <b>Total</b>    | <b>15</b>  | <b>154</b> | <b>169</b> |

The origin of the material sub-sampled is shown in Table 5, broken down by EWC code. The predominance of mixed material in the 19.12.12 case reflects cases where trade and domestic material was mixed at a transfer station or waste treatment plant, or cases where the driver was unsure of whether or not this was the case.

**Table 5: Samples sorted by EWC, origin and phase**

|     |          |            | Phase 1 | Phase 2 | Phase 3 | Combined phase |
|-----|----------|------------|---------|---------|---------|----------------|
| EWC | 19.12.12 | Domestic   | 1       | 0       | 0       | 1              |
|     |          | HWRC       | 2       | 0       | 0       | 2              |
|     |          | Mixed      | 41      | 59      | 13      | 113            |
|     |          | Trade      | 26      | 48      | 2       | 76             |
|     | 20.03.01 | Domestic   | 60      | 0       | 82      | 142            |
|     |          | Flytip     | 0       | 0       | 2       | 2              |
|     |          | HWRC       | 8       | 0       | 15      | 23             |
|     |          | Mixed      | 9       | 0       | 14      | 23             |
|     |          | Street bin | 1       | 0       | 0       | 1              |
|     |          | Trade      | 52      | 28      | 41      | 121            |

## 3.2 Compositional results

### 3.2.1 Describing the composition of the waste by EWC code

Table 6 shows the disaggregated composition of the two EWC codes side by side, along with confidence intervals.

**Table 6: Composition of EWC codes 19.12.12 and 20.03.01**

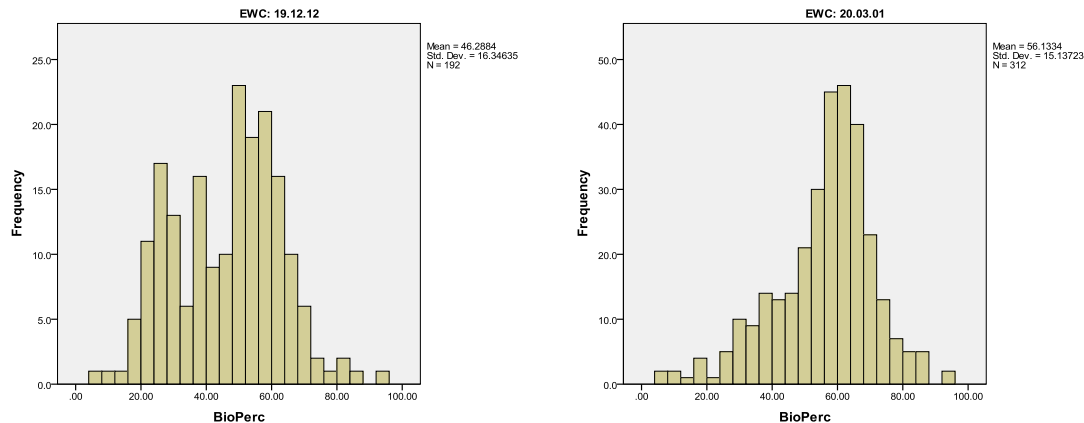
|  | 19.12.12 N=192 |             |             | 20.03.01 N=312 |             |             |
|--|----------------|-------------|-------------|----------------|-------------|-------------|
|  | Mean (%)       | 95% CI      |             | Mean (%)       | 95% CI      |             |
|  |                | Lower       | Upper       |                | Lower       | Upper       |
| Paper                                    | 10.3           | 9.1         | 11.5        | 10.6           | 9.7         | 11.5        |
| Card                                     | 9.1            | 7.8         | 10.3        | 7.7            | 6.6         | 8.7         |
| Plastic film                             | 9.4            | 8.7         | 10.2        | 8.4            | 7.7         | 9.1         |
| Dense plastics                           | 13.2           | 11.6        | 14.8        | 9.6            | 8.9         | 10.2        |
| Sanitary waste                           | 1.3            | 0.8         | 1.7         | 3.1            | 2.7         | 3.6         |
| Wood                                     | 10.0           | 8.7         | 11.3        | 5.3            | 3.9         | 6.6         |
| Textiles and shoes                       | 5.9            | 4.7         | 7.0         | 5.6            | 4.8         | 6.4         |
| Glass                                    | 1.3            | 1.0         | 1.6         | 3.0            | 2.7         | 3.4         |
| Food waste                               | 8.2            | 6.5         | 9.8         | 21.3           | 19.6        | 22.9        |
| Garden waste                             | 1.8            | 1.3         | 2.3         | 3.5            | 2.8         | 4.1         |
| Other organic                            | 1.3            | 0.6         | 2.0         | 2.1            | 1.6         | 2.6         |
| Metals                                   | 3.2            | 2.8         | 3.5         | 3.7            | 3.3         | 4.0         |
| WEEE                                     | 1.4            | 1.1         | 1.7         | 1.5            | 1.1         | 1.8         |
| Haz waste and batteries                  | 1.1            | 0.6         | 1.5         | 0.9            | 0.7         | 1.2         |
| Carpet, underlay & furniture             | 7.0            | 5.6         | 8.5         | 5.0            | 3.6         | 6.4         |
| Other combustibles                       | 2.7            | 2.0         | 3.4         | 1.4            | 1.0         | 1.7         |
| Bricks, plaster and soil                 | 7.9            | 6.4         | 9.5         | 4.1            | 3.0         | 5.2         |
| Other non-combustible                    | 1.7            | 1.1         | 2.3         | 1.5            | 1.1         | 1.9         |
| Fines <10mm                              | 3.3            | 2.7         | 3.9         | 1.8            | 1.3         | 2.3         |
| <b>Est. biodegradability<sup>1</sup></b> | <b>46.3</b>    | <b>44.0</b> | <b>48.6</b> | <b>56.1</b>    | <b>54.4</b> | <b>57.8</b> |
| <b>Est. combustibility</b>               | <b>84.4</b>    | <b>82.6</b> | <b>86.1</b> | <b>86.1</b>    | <b>84.8</b> | <b>87.4</b> |
| <b>Est. recyclability</b>                | <b>23.8</b>    | <b>21.8</b> | <b>25.9</b> | <b>27.2</b>    | <b>25.8</b> | <b>28.5</b> |

The results show that 19.12.12 waste had lower mean levels of biodegradability, combustibility and recyclability than material coded 20.03.01. These differences appear to be significant for biodegradability and recyclability, as neither code's confidence interval for the statistic encompasses the mean of the other code. Combustibility is also likely to be significantly different, although the upper confidence level for 19.12.12 combustibility equals the mean for 20.03.01. These differences are consistent with what one would expect from residue from treatment or recycling processes, since these will primarily be aimed at removing material suitable for composting, recycling or incineration.

<sup>1</sup> If biodegradability is calculated using the unmodified LATS model, the figure is  $34.3 \pm 2.7\%$  for 19.12.12 and  $49.3 \pm 2.0\%$  for 20.03.01 material. It seems likely, however, that these are substantial underestimates, since materials such as disposable nappies and fines are considered as completely non-biodegradable.

The distribution of the estimated biodegradability statistic is shown for each EWC code in Figure 2.

**Figure 2: Histograms of biodegradability by EWC code**



The histograms show that the estimated biodegradability is not normally distributed in the sample, and, given the reasonably large sample size, it is likely that this observation applies to the population.

The 20.03.01 distribution is slightly positively skewed – the biodegradability is clustered around the 58.6% mark, with a tail in the lower values (left hand side of the chart) reducing the mean below this level (i.e. there is a larger number of samples with higher biodegradability than the mean, but the mean is pulled down by a smaller number of samples with much lower biodegradability).

The 19.12.12 material seems to exhibit a flatter distribution that is less tightly clustered around the mean and may even be bimodal, with a smaller peak around the 20% biodegradability level. This could simply be a visual artefact due to the flatter distribution, or it could reflect two different waste types within the 19.12.12 material (e.g. it could reflect a difference in biodegradability between the two site operators and/or origin of the waste included in the study).

Anecdotally, in the course of the study, a difference was noted between 19.12.12 material that appeared similar to normal household waste and material that was more obviously residue from a process (e.g. MRF residue). This anecdotal evidence is consistent with the follow-up enquiries on the origins of 19.12.12 waste outlined in Appendix 2, and could account for the two peaks in the distribution.

Table 7 below provides further description of the biodegradability statistic, and illustrates the points made above. It is important to note that, while the statistic is not normally distributed, this should not affect the calculation of confidence intervals given the sample sizes involved.

**Table 7: Selected descriptive statistics for biodegradability of waste by EWC code**

|                | 19.12.12 | 20.03.01 |
|----------------|----------|----------|
| Minimum        | 7.43     | 6.11     |
| Lower quartile | 31.4064  | 48.3451  |
| Median         | 49.3268  | 58.5888  |
| Upper quartile | 58.1187  | 65.5179  |
| Maximum        | 92.70    | 95.12    |



### 3.2.2 Describing the composition of waste coded 20.03.01 by origin

The samples attained for the domestic and trade waste coded 20.03.01 are sufficiently large to enable comparison of these streams by origin. The compositional data for the 20.03.01 domestic and trade wastes are compared in Table 8.

**Table 8: Comparison of domestic and trade waste code 20.03.01**

|                              | 20.03.01 domestic N=142 |             |             | 20.03.01 trade N=121 |             |             |
|------------------------------|-------------------------|-------------|-------------|----------------------|-------------|-------------|
|                              | Mean                    | 95% CI      |             | Mean                 | 95% CI      |             |
|                              |                         | Lower       | Upper       |                      | Lower       | Upper       |
| Paper                        | 10.1                    | 9.3         | 10.8        | 12.9                 | 10.9        | 14.9        |
| Card                         | 5.7                     | 5.0         | 6.3         | 11.8                 | 9.5         | 14.1        |
| Plastic film                 | 8.5                     | 7.8         | 9.1         | 9.3                  | 7.9         | 10.8        |
| Dense plastics               | 9.1                     | 8.5         | 9.7         | 9.9                  | 8.5         | 11.3        |
| Sanitary waste               | 5.2                     | 4.5         | 5.8         | 1.3                  | 0.8         | 1.7         |
| Wood                         | 2.6                     | 1.4         | 3.8         | 6.5                  | 4.3         | 8.7         |
| Textiles and shoes           | 6.1                     | 5.4         | 6.7         | 4.4                  | 2.7         | 6.1         |
| Glass                        | 3.6                     | 3.2         | 4.0         | 2.5                  | 1.9         | 3.1         |
| Food waste                   | 26.2                    | 24.4        | 28.0        | 19.8                 | 16.7        | 22.9        |
| Garden waste                 | 4.3                     | 3.3         | 5.3         | 2.2                  | 1.4         | 2.9         |
| Other organic                | 3.5                     | 2.5         | 4.4         | 0.9                  | 0.5         | 1.3         |
| Metals                       | 3.6                     | 3.3         | 3.9         | 4.0                  | 3.1         | 4.9         |
| WEEE                         | 1.5                     | 1.1         | 1.8         | 1.6                  | 0.8         | 2.4         |
| Haz waste and batteries      | 0.7                     | 0.5         | 0.9         | 1.1                  | 0.5         | 1.6         |
| Carpet, underlay, furniture  | 2.9                     | 1.5         | 4.3         | 3.6                  | 1.7         | 5.6         |
| Other combustibles           | 1.2                     | 0.9         | 1.6         | 1.3                  | 0.7         | 1.9         |
| Bricks, plaster and soil     | 2.6                     | 1.4         | 3.8         | 3.7                  | 1.9         | 5.5         |
| Other non-combustible        | 1.3                     | 1.0         | 1.6         | 1.7                  | 0.8         | 2.5         |
| Fines <10mm                  | 1.6                     | 1.3         | 1.9         | 1.6                  | 1.1         | 2.0         |
| <b>Est. biodegradability</b> | <b>59.5</b>             | <b>58.0</b> | <b>60.9</b> | <b>56.7</b>          | <b>53.3</b> | <b>60.2</b> |
| <b>Est. combustibility</b>   | <b>87.4</b>             | <b>86.1</b> | <b>88.6</b> | <b>86.3</b>          | <b>83.9</b> | <b>88.7</b> |
| <b>Est. recyclability</b>    | <b>26.7</b>             | <b>25.5</b> | <b>28.0</b> | <b>31.7</b>          | <b>29.0</b> | <b>34.3</b> |

The results show that domestic waste had a higher biodegradability and combustibility, and a lower recyclability, than trade waste, though only the difference in recyclability appears to be significant. This is accounted for by the higher proportion of paper and particularly card in the trade waste.

When comparing this table with Table 6, it will be noted that the average biodegradability of the 20.03.01 material (56.1%) falls outside the range of the trade and household material. This is due to a small number of sample cases from other origins, the calculated biodegradability of which are shown below.

**Table 9: Key figures for other reported origins, 20.03.01**

| Origin of waste  | N  | Biodegradability (%) | Combustibility (%) | Recyclability (%) |
|------------------|----|----------------------|--------------------|-------------------|
| Mixed origin     | 23 | 51.0                 | 82.8               | 22.9              |
| HWRC             | 23 | 39.3                 | 82.9               | 11.2              |
| Flytip           | 2  | 44.9                 | 78.1               | 21.6              |
| Street cleansing | 1  | 33.8                 | 53.0               | 22.4              |



### 3.2.3 Variation between sites

Table 10 compares sites on the derived measures of biodegradability, combustibility and recyclability.

**Table 10: Comparison of mean biodegradability, combustibility and recyclability by site**

| Site            | EWC             | Number of Samples | Mean Biodegradable % | Mean Combustible % | Mean Recyclable % |
|-----------------|-----------------|-------------------|----------------------|--------------------|-------------------|
| Beddington      | <b>19.12.12</b> | <b>20</b>         | <b>26.1</b>          | <b>79.9</b>        | <b>20.1</b>       |
|                 | <b>20.03.01</b> | <b>57</b>         | <b>60.7</b>          | <b>83.0</b>        | <b>28.7</b>       |
| Broadpath       | 19.12.12        | 2                 | 32.1                 | 83.1               | 8.6               |
|                 | <b>20.03.01</b> | <b>23</b>         | <b>55.0</b>          | <b>86.6</b>        | <b>35.7</b>       |
| Brookhurst Wood | 19.12.12        | 2                 | 48.2                 | 91.6               | 26.9              |
|                 | <b>20.03.01</b> | <b>23</b>         | <b>52.0</b>          | <b>86.2</b>        | <b>21.4</b>       |
| Erin            | 19.12.12        | 12                | 39.4                 | 83.0               | 19.4              |
|                 | <b>20.03.01</b> | <b>37</b>         | <b>53.3</b>          | <b>89.8</b>        | <b>25.2</b>       |
| Lean Quarry     | <b>19.12.12</b> | <b>41</b>         | <b>42.0</b>          | <b>77.9</b>        | <b>14.0</b>       |
|                 | 20.03.01        | 10                | 61.1                 | 88.9               | 23.8              |
| Masons          | 19.12.12        | 12                | 47.3                 | 88.3               | 24.7              |
|                 | 20.03.01        | 14                | 61.8                 | 89.2               | 26.2              |
| Parkwood        | 19.12.12        | 11                | 48.1                 | 87.5               | 24.5              |
|                 | 20.03.01        | 14                | 61.0                 | 93.4               | 32.9              |
| Pilsworth       | 19.12.12        | 2                 | 39.1                 | 90.2               | 21.6              |
|                 | <b>20.03.01</b> | <b>20</b>         | <b>51.0</b>          | <b>85.9</b>        | <b>25.9</b>       |
| Redhill         | <b>19.12.12</b> | <b>22</b>         | <b>56.6</b>          | <b>88.1</b>        | <b>28.7</b>       |
|                 | <b>20.03.01</b> | <b>28</b>         | <b>57.1</b>          | <b>84.4</b>        | <b>24.8</b>       |
| Rochester       | <b>20.03.01</b> | <b>27</b>         | <b>51.9</b>          | <b>85.6</b>        | <b>21.6</b>       |
| Roxby           | 19.12.12        | 9                 | 48.6                 | 85.2               | 23.0              |
|                 | 20.03.01        | 12                | 51.9                 | 87.3               | 26.7              |
| Skelton Grange  | <b>19.12.12</b> | <b>20</b>         | <b>49.4</b>          | <b>88.3</b>        | <b>28.3</b>       |
|                 | <b>20.03.01</b> | <b>28</b>         | <b>59.7</b>          | <b>85.8</b>        | <b>28.7</b>       |
| Tipton          | 19.12.12        | 8                 | 52.6                 | 88.2               | 22.3              |
| Trecatti        | <b>19.12.12</b> | <b>20</b>         | <b>55.2</b>          | <b>85.8</b>        | <b>29.1</b>       |
|                 | 20.03.01        | 5                 | 47.0                 | 78.9               | 30.0              |
| Walpole         | 19.12.12        | 11                | 58.0                 | 88.2               | 47.9              |
|                 | 20.03.01        | 14                | 52.9                 | 82.5               | 32.8              |

Analysis of variation was used to assess the significance of variability in biodegradability. In order to enable some degree of post hoc comparison of sites, only sites where 20 or more samples were taken from a given EWC code were included in each ANOVA (shown as **bold italic** in the table above). This resulted in eight sites being included in the 20.03.01 and five sites in the 19.12.12 ANOVA calculations.

Table 11 shows the output of the ANOVA for 20.03.01 material, and shows that the mean of the biodegradability is significantly different between sites at the 95% level.

**Table 11: Anova of variation in biodegradability by site, 20.03.01**

|                | Sum of Squares | Df     | Mean Square | F    | Sig. |
|----------------|----------------|--------|-------------|------|------|
| Between Groups | 3272.15        | 7.00   | 467.45      | 2.20 | .04  |
| Within Groups  | 49727.50       | 234.00 | 212.51      |      |      |
| Total          | 52999.65       | 241.00 |             |      |      |

Tukey's Honestly Significant Difference (HSD) test was calculated following the ANOVA<sup>2</sup>. This returned an HSD value (i.e. the difference between any pair of means that would be regarded as significant at the 95% level) of 12.1<sup>3</sup>, which means that, although the overall variability in biodegradability across sites is significant at the 95% level, no single pair of sites exhibited an honestly significant difference. If the means between two sites had been different by more than 12.1% points then they could have been considered significantly different; this was not the case between any pair of sites.

This means that, while we can be quite confident that site, as a whole, has a significant effect on biodegradability, we cannot attribute a significant difference to any specific pair of sites. This finding is unusual, and reflects a distribution of site mean biodegradability that is not clustered centrally.

Table 12 presents the differences in mean biodegradability between each site. Green highlighting denotes that the site on the row has a higher biodegradability than the column site, and red denotes a lower value. For example using the Erin row, the green cells Roc, Brook, Pilsworth indicate that the mean value of biodegradability for the Erin site is greater, by the values in the cell. Conversely the pink cells indicate that the mean biodegradability of the Erin site was lower than Bed, Redhill, Skelton and Broad sites, indicated by a negative figure.

**Table 12: Difference in mean biodegradability by site, 20.03.01**

|            | Bed  | Erin | Redhill | Roc  | Skelton | Brook | Broad | Pilsworth |
|------------|------|------|---------|------|---------|-------|-------|-----------|
| Bed        | NA   | 7.4  | 3.6     | 8.8  | 1.0     | 8.7   | 5.7   | 9.7       |
| Erin       | -7.4 | NA   | -3.7    | 1.4  | -6.4    | 1.4   | -1.7  | 2.3       |
| Redhill    | -3.6 | 3.7  | NA      | 5.1  | -2.7    | 5.1   | 2.1   | 6.0       |
| Rochester  | -8.8 | -1.4 | -5.1    | NA   | -7.8    | 0.0   | -3.1  | 0.9       |
| Skelton    | -1.0 | 6.4  | 2.7     | 7.8  | NA      | 7.8   | 4.7   | 8.7       |
| Brookhurst | -8.7 | -1.4 | -5.1    | 0.0  | -7.8    | NA    | -3.0  | 0.9       |
| Broadpath  | -5.7 | 1.7  | -2.1    | 3.1  | -4.7    | 3.0   | NA    | 4.0       |
| Pilsworth  | -9.7 | -2.3 | -6.0    | -0.9 | -8.7    | -0.9  | -4.0  | NA        |

<sup>2</sup> A harmonic mean sample size of 27.52 was used.

<sup>3</sup> The calculated HSD is approximate and should not be relied upon, as there are differences in sample size between conditions (the harmonic mean sample size has been used). Note that this value of the HSD applies only to the eight sites that were included in the analysis, and cannot be generalised to other sites, including the other sites in Table 8 that were not included in the ANOVA.

Table 13 shows the output of the ANOVA for 19.12.12 material, and shows that the variation in mean biodegradability between sites is significant at the 99% level.

**Table 13: Anova of variation in biodegradability by site, 19.12.12**

|                | Sum of Squares | Df  | Mean Square | F      | Sig. |
|----------------|----------------|-----|-------------|--------|------|
| Between Groups | 12920.776      | 4   | 3230.194    | 16.238 | .000 |
| Within Groups  | 23473.666      | 118 | 198.929     |        |      |
| Total          | 36394.442      | 122 |             |        |      |

Table 14 again shows the significance of differences between each individual site, using Tukey's HSD.

Beddington was significantly different from all other sites, with lower than average biodegradability. Lean Quarry, the site with the second lowest biodegradability in the ANOVA, was significantly lower than Redhill or Trecatti, but not Skelton Grange.

The HSD was calculated at approximately 11.6 (using a harmonic mean sample size of 22.74 and a  $q$  of 3.93). Note that this value applies only to the five sites that were included in the analysis, and cannot be generalised to other sites, including the other sites in Table 8 that were not included in the ANOVA.

**Table 24: Difference in mean biodegradability by site, 19.12.12**

|          | Bed   | Lean   | Redhill | Skelton | Trecatti |
|----------|-------|--------|---------|---------|----------|
| Bed      | NA    | -15.9* | -30.5*  | -23.3*  | -29.1*   |
| Lean     | 15.9* | NA     | -14.6*  | -7.3    | -13.2*   |
| Redhill  | 30.5* | 14.6*  | NA      | 7.2     | 1.4      |
| Skelton  | 23.3* | 7.3    | -7.2    | NA      | -5.9     |
| Trecatti | 29.1* | 13.2   | -1.4    | 5.9     | NA       |

\* Significant at 95% level.

### 3.3 Variation by operator

The finding that the mean biodegradability for material coded 20.03.01 is not clustered around the centre of the distribution, and the highly significant difference produced by the ANOVA for material coded 19.12.12, raises the possibility that the biodegradable statistic may vary by site operator (Viridor or Biffa). T-tests were carried out by operator, for three subsamples (20.03.01 domestic, 20.03.01 trade and 19.12.12 all), selected on the basis of subsample size. The results are shown in Table 15.

**Table 15: t-test results for variation in biodegradability by site operator**

|                   | Viridor      | Biffa       | Diff  | Sig   |
|-------------------|--------------|-------------|-------|-------|
| 20.03.01 Domestic | 59.1 (n=109) | 60.7 (n=33) | -1.6  | 0.35  |
| 20.03.01 Trade    | 56.9 (n=79)  | 56.5 (n=42) | 0.4   | 0.90  |
| 19.12.12 All      | 41.4 (n=111) | 53.0 (n=81) | -11.6 | 0.001 |

The results show clearly that there is no significant variation by operator for 20.03.01 material of either origin, while 19.12.12 material varies significantly.

### 3.4 Correlations between material categories

By examining correlations between the different components of the waste, we can discern groupings of different types of waste, which could correspond to different waste origins, treatment options or industry sectors.

Analysis was carried out using Pearson's correlation, with 20.03.01 and 19.12.12 waste examined separately<sup>4</sup>.

Table 16 shows the correlation between the overall biodegradability and certain key components of the biodegradable waste for the 19.12.12 material. Values closer to 1 or -1 show the strongest positive or negative correlation, while a figure of 0 would show no correlation at all. Positive correlations are highlighted in green, negative correlations in pink.

**Table 16: Correlation of biodegradable waste components, 19.12.12**

|                  |                 | Bio   | Paper | Card  | Food  | Garden | Wood  |
|------------------|-----------------|-------|-------|-------|-------|--------|-------|
| Biodegradability | Correlation     |       | 0.55  | 0.51  | 0.60  | 0.08   | -0.21 |
|                  | Sig. (2-tailed) |       | 0.00  | 0.00  | 0.00  | 0.25   | 0.00  |
| Paper            | Correlation     | 0.55  |       | 0.38  | 0.22  | -0.10  | -0.26 |
|                  | Sig. (2-tailed) | 0.00  |       | 0.00  | 0.00  | 0.18   | 0.00  |
| Card             | Correlation     | 0.51  | 0.38  |       | 0.05  | -0.06  | -0.12 |
|                  | Sig. (2-tailed) | 0.00  | 0.00  |       | 0.50  | 0.39   | 0.11  |
| Food             | Correlation     | 0.60  | 0.22  | 0.05  |       | -0.05  | -0.29 |
|                  | Sig. (2-tailed) | 0.00  | 0.00  | 0.50  |       | 0.47   | 0.00  |
| Garden           | Correlation     | 0.08  | -0.10 | -0.06 | -0.05 |        | -0.10 |
|                  | Sig. (2-tailed) | 0.25  | 0.18  | 0.39  | 0.47  |        | 0.15  |
| Wood             | Correlation     | -0.21 | -0.26 | -0.12 | -0.29 | -0.10  |       |
|                  | Sig. (2-tailed) | 0.00  | 0.00  | 0.11  | 0.00  | 0.15   |       |

Paper, card and food waste all show a high level of correlation with biodegradability, with food being the most strongly correlated. Garden waste exhibits a slight, but not significant positive correlation, while wood shows a strong negative correlation with biodegradability overall (suggesting that while wood itself is biodegradable, it tends to appear in loads with non-biodegradable materials, as is borne out by the next table). Paper and food waste show a strong positive correlation (i.e. they tend to appear in the same loads), and card is also strongly correlated with paper. As with the previous phase, cardboard and food were not strongly correlated, though both had a strong positive correlation with biodegradability.

<sup>4</sup> Note that the significance values for this analysis will not be accurate, since the variables are percentage compositional data and thus not strictly independent. If all variables were truly random, we would actually expect to see a slight negative correlation, in that a higher percentage of one category would by necessity result in a lower percentage of something else.

Table 17 shows the correlation between the biodegradable categories and other selected categories of material.

**Table 17: Correlation of selected waste categories, 19.12.12**

|                                |                 | Paper | Card  | Food  | Garden | Wood  | Carpet & Furniture | Bricks, Blocks, Plaster & Soil |
|--------------------------------|-----------------|-------|-------|-------|--------|-------|--------------------|--------------------------------|
| Paper                          | Correlation     |       | 0.38  | 0.22  | -0.10  | -0.26 | -0.26              | -0.37                          |
|                                | Sig. (2-tailed) |       | 0.00  | 0.00  | 0.18   | 0.00  | 0.00               | 0.00                           |
| Card                           | Correlation     | 0.38  |       | 0.05  | -0.06  | -0.12 | -0.21              | -0.24                          |
|                                | Sig. (2-tailed) | 0.00  |       | 0.50  | 0.39   | 0.11  | 0.00               | 0.00                           |
| Food                           | Correlation     | 0.22  | 0.05  |       | -0.05  | -0.29 | -0.20              | -0.34                          |
|                                | Sig. (2-tailed) | 0.00  | 0.50  |       | 0.47   | 0.00  | 0.00               | 0.00                           |
| Garden                         | Correlation     | -0.10 | -0.06 | -0.05 |        | -0.10 | 0.02               | 0.10                           |
|                                | Sig. (2-tailed) | 0.18  | 0.39  | 0.47  |        | 0.15  | 0.79               | 0.16                           |
| Wood                           | Correlation     | -0.26 | -0.12 | -0.29 | -0.10  |       | -0.06              | 0.21                           |
|                                | Sig. (2-tailed) | 0.00  | 0.11  | 0.00  | 0.15   |       | 0.40               | 0.00                           |
| Carpet & Furniture             | Correlation     | -0.26 | -0.21 | -0.20 | 0.02   | -0.06 |                    | -0.10                          |
|                                | Sig. (2-tailed) | 0.00  | 0.00  | 0.00  | 0.79   | 0.40  |                    | 0.19                           |
| Bricks, Blocks, Plaster & Soil | Correlation     | -0.37 | -0.23 | -0.34 | 0.10   | 0.21  | -0.10              |                                |
|                                | Sig. (2-tailed) | 0.00  | 0.00  | 0.00  | 0.16   | 0.00  | 0.19               |                                |

Carpet and furniture shows a strong negative correlation with paper, card and food waste. Bricks, blocks, plaster and soil shows a significant negative correlation with the same materials. Carpet and furniture and bricks, blocks, plaster and soil are not themselves correlated, however, and bricks, blocks, plaster and soil shows a significant correlation with wood waste (possibly representing waste from DIY construction and demolition activities).

This suggests that carpet and furniture and bricks, blocks, plaster and soil tend to appear in loads that contain less food waste, paper and card, perhaps reflecting different origins or treatment options.

Table 18 shows the correlation between the overall biodegradability and certain key components of the biodegradable waste for the 20.03.01 material.

**Table 18: Correlation of biodegradable waste components, 20.03.01**

|                  |                 | Bio   | Paper | Card  | Food  | Garden | Wood  |
|------------------|-----------------|-------|-------|-------|-------|--------|-------|
| Biodegradability | Correlation     |       | 0.38  | 0.36  | 0.68  | 0.19   | -0.28 |
|                  | Sig. (2-tailed) |       | 0.00  | 0.00  | 0.00  | 0.00   | 0.00  |
| Paper            | Correlation     | 0.38  |       | 0.05  | 0.09  | -0.12  | -0.24 |
|                  | Sig. (2-tailed) | 0.00  |       | 0.35  | 0.11  | 0.03   | 0.00  |
| Card             | Correlation     | 0.36  | 0.05  |       | -0.04 | -0.04  | -0.07 |
|                  | Sig. (2-tailed) | 0.00  | 0.35  |       | 0.52  | 0.48   | 0.19  |
| Food             | Correlation     | 0.68  | 0.09  | -0.04 |       | -0.09  | -0.41 |
|                  | Sig. (2-tailed) | 0.00  | 0.11  | 0.52  |       | 0.10   | 0.00  |
| Garden           | Correlation     | 0.19  | -0.12 | -0.04 | -0.09 |        | -0.05 |
|                  | Sig. (2-tailed) | 0.00  | 0.03  | 0.48  | 0.10  |        | 0.42  |
| Wood             | Correlation     | -0.28 | -0.24 | -0.07 | -0.41 | -0.05  |       |
|                  | Sig. (2-tailed) | 0.00  | 0.00  | 0.19  | 0.00  | 0.42   |       |

Biodegradability shows a strong positive correlation with paper, card, food waste and garden waste, with food waste being the strongest correlate. Paper, card and food do not, however, exhibit any strong or significant correlation (i.e. they are not strongly associated with one another, positively or negatively). Garden waste appears to have a significant negative correlation with paper, but not with card or food waste. As with the 19.12.12 material, wood is negatively correlated with biodegradability, and also with paper, card, food and wood waste.

Table 19 shows the correlation between the biodegradable categories and other selected categories of material.

**Table 19: Correlation of selected waste categories, 20.03.01**

|                                |                 | Paper | Card  | Food  | Garden | Wood  | Carpet & Furniture | Bricks, Blocks, Plaster & Soil |
|--------------------------------|-----------------|-------|-------|-------|--------|-------|--------------------|--------------------------------|
| Paper                          | Correlation     |       | 0.05  | 0.09  | -0.12  | -0.24 | -0.23              | -0.21                          |
|                                | Sig. (2-tailed) |       | 0.35  | 0.11  | 0.03   | 0.00  | 0.00               | 0.00                           |
| Card                           | Correlation     | 0.05  |       | -0.04 | -0.04  | -0.07 | -0.18              | -0.07                          |
|                                | Sig. (2-tailed) | 0.35  |       | 0.52  | 0.48   | 0.19  | 0.00               | 0.20                           |
| Food                           | Correlation     | 0.09  | -0.04 |       | -0.09  | -0.41 | -0.40              | -0.34                          |
|                                | Sig. (2-tailed) | 0.11  | 0.52  |       | 0.10   | 0.00  | 0.00               | 0.00                           |
| Garden                         | Correlation     | -0.12 | -0.04 | -0.09 |        | -0.05 | -0.04              | -0.04                          |
|                                | Sig. (2-tailed) | 0.03  | 0.48  | 0.10  |        | 0.42  | 0.47               | 0.51                           |
| Wood                           | Correlation     | -0.24 | -0.07 | -0.41 | -0.05  |       | 0.05               | 0.10                           |
|                                | Sig. (2-tailed) | 0.00  | 0.19  | 0.00  | 0.42   |       | 0.39               | 0.08                           |
| Carpet & Furniture             | Correlation     | -0.23 | -0.18 | -0.40 | -0.04  | 0.05  |                    | 0.02                           |
|                                | Sig. (2-tailed) | 0.00  | 0.00  | 0.00  | 0.47   | 0.39  |                    | 0.76                           |
| Bricks, Blocks, Plaster & Soil | Correlation     | -0.21 | -0.07 | -0.34 | -0.04  | 0.10  | 0.02               |                                |
|                                | Sig. (2-tailed) | 0.00  | 0.20  | 0.00  | 0.51   | 0.08  | 0.76               |                                |

Carpet and furniture and bricks, blocks plaster and soil are negatively correlated with paper, card, food and garden waste, indicating that these tend to appear in different types of loads. Both are positively correlated with one another, and also with wood, though not significantly so.

## 4. Discussion

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Overall, the study succeeded in obtaining accurate and reliable composition data on waste landfilled under the EWC codes 19.12.12 and 20.03.01, and obtaining reasonable confidence intervals for this data. In particular, the aggregated biodegradability figure for each code should provide a firm basis for reporting on the amount of biodegradable municipal waste sent to landfill.

The data on the 20.03.01 waste code showed narrow confidence intervals for both the domestic and trade components. While the biodegradability was shown to vary between sites, no single pair of sites showed a difference significant at the 95% level of confidence, and the composition of the material did not differ significantly by operator.

The data for the 19.12.12 material also produced relatively narrow confidence intervals, but showed a higher degree of variation by site, and a significant difference in biodegradability by operator. Such a variation by operator is intuitive, since 19.12.12 material, as residue from mechanical treatment processes, will vary according to treatment type and will thus reflect the investment decisions of waste management companies.

With the above in mind, while we can have a reasonable degree of confidence about the overall composition of both waste codes, the data for EWC code 19.12.12 may be less robust, since it is more variable by site and operator. There may be value in further investigation of the impact of operator on the composition of 19.12.12 material through the inclusion of another landfill operator in the study.

### 4.1 Seasonal variation

It was not possible to conduct an analysis of seasonal variation using the data produced by this study. As the project developed, specific EWC codes were targeted in particular phases in order to obtain tight confidence intervals for both EWC codes and for both the domestic and trade waste 20.03.01 material. As a result, no 20.03.01 domestic material was sampled during the second phase. In addition, a change of site operator between the first and second phases, and a different set of landfill sites, precludes comparison of the 19.12.12 material across phases 1 and 2. Since Phase 3 was conducted at a similar time of year to the Phase 1, this does not provide a basis for a seasonal comparison with Phase 1, while a comparison with Phase 2 is not possible because Phase 3 concentrated almost entirely on waste coded 20.03.01.

Existing data on seasonal variation is uncertain, and it is highly likely that the degree of seasonal variation in the biodegradability of municipal residual waste is declining as the number of local authorities collecting kitchen waste and garden waste at the kerbside increases.

Recent (as yet unpublished) work by Resource Futures on behalf of DEFRA, modelling national waste arisings based on a large number of local authority compositional studies, has concluded that variation in food waste in the residual waste stream does show some seasonal variation. The range of this variation as a percentile of the waste stream is only significant between the summer and autumn phases, and accounts for only a small percentage of waste arisings. Garden waste also seems to show seasonal variation using this data, averaging 3% in winter, 4% in spring, 7% in summer and 6% in Autumn. The majority of the 20.03.01 domestic waste analysed in the current study was sampled during the later summer and early autumn, so it may be that the garden waste results slightly over-estimate the proportion of garden waste arising. The overall impact of such variation on the biodegradability of municipal solid waste as a whole however, is likely to be negligible, as the variations tend to offset one another (for example, the lower garden waste percentage in winter is offset by a higher food waste percentage, while summer, which has the highest garden waste percentage, has the lowest food waste).

If additional data on seasonal variation were required, this would best be obtained through a follow up study, carrying out two (Summer and Winter) phases at the same sites in each phase, or an additional winter phase at some of the landfills already covered in phases 1 and 3.

## 4.2 Calculation of overall biodegradability of MSW

The data from the waste analysis study were weighted according to the tonnage arisings for each EWC code in order to calculate an average composition of the combined 19.12.12 and 20.03.01 codes<sup>5</sup>. This material accounts for around 96% of the mixed waste codes that could be regarded as municipal waste, as shown in Table 20.

**Table 20: EWC codes covering mixed municipal waste**

| EWC      | Type                            | Definition   | Tonnes (2011) |
|----------|---------------------------------|--|---------------|
| 19.05.01 | Waste from aerobic treatment    | non-composted fraction of municipal & similar wastes | 5,004         |
| 19.05.03 | Waste from aerobic treatment    | off-specification compost                            | 84,532        |
| 19.12.12 | Waste from mechanical treatment | other wastes from mechanical treatment of wastes     | 8,431,131     |
| 20.03.01 | Other municipal wastes          | mixed municipal waste                                | 9,088,763     |
| 20.03.02 | Other municipal wastes          | waste from markets                                   | 1,898         |
| 20.03.03 | Other municipal wastes          | street-cleaning residues                             | 196,651       |
| 20.03.07 | Other municipal wastes          | bulky waste  | 210,012       |
| 20.03.99 | Other municipal wastes          | municipal wastes not otherwise specified             | 90            |

Source: Environment Agency RATS data

The results of the weighting are shown in Table 21. These results suggest that the combined biodegradability of material landfilled under these two codes is around 51%.

<sup>5</sup> This was done by multiplying each percentage figure by the tonnage of its waste code, adding the figure for both codes together and dividing by total tonnage. For example, paper is calculated as  $(10.3 \times 8,431,131 + 10.6 \times 9,088,763) / 17,519,894 = 10.5$ .



**Table 21: Calculated composition of municipal solid waste to landfill**

|                                | Mean<br>19.12.12 | Mean<br>20.03.01 | Weighted<br>average |
|--------------------------------|------------------|------------------|---------------------|
| <b>Tonnes per annum (2011)</b> | <b>8,431,131</b> | <b>9,088,763</b> | <b>17,519,894</b>   |
| Paper                          | 10.3             | 10.6             | 10.5                |
| Card                           | 9.1              | 7.7              | 8.4                 |
| Plastic film                   | 9.4              | 8.4              | 8.9                 |
| Dense plastics                 | 13.2             | 9.6              | 11.3                |
| Sanitary waste                 | 1.3              | 3.1              | 2.2                 |
| Wood                           | 10               | 5.3              | 7.6                 |
| Textiles and shoes             | 5.9              | 5.6              | 5.7                 |
| Glass                          | 1.3              | 3                | 2.2                 |
| Food waste                     | 8.2              | 21.3             | 15.0                |
| Garden waste                   | 1.8              | 3.5              | 2.7                 |
| Other organic                  | 1.3              | 2.1              | 1.7                 |
| Metals                         | 3.2              | 3.7              | 3.5                 |
| WEEE                           | 1.4              | 1.5              | 1.5                 |
| Haz waste and batteries        | 1.1              | 0.9              | 1.0                 |
| Carpet, underlay & furniture   | 7                | 5                | 6.0                 |
| Other combustibles             | 2.7              | 1.4              | 2.0                 |
| Bricks, plaster and soil       | 7.9              | 4.1              | 5.9                 |
| Other non-combustible          | 1.7              | 1.5              | 1.6                 |
| Fines <10mm                    | 3.3              | 1.8              | 2.5                 |
| <b>Est. biodegradability</b>   | <b>46.3</b>      | <b>56.1</b>      | <b>51.4</b>         |
| <b>Est. combustibility</b>     | <b>84.4</b>      | <b>86.1</b>      | <b>85.3</b>         |
| <b>Est. recyclability</b>      | <b>23.8</b>      | <b>27.2</b>      | <b>25.6</b>         |

## Appendix 1: Waste analysis category list

**Table 22: Category list used during the waste analysis**

|                                     |  |
|-------------------------------------|--|
| <b>Paper</b>                        |  |
| Newspapers                          | Newspapers and other newsprint.                        |
| Magazines                           | Magazines and other glossy magazine type paper.        |
| Recyclable paper                    | Other recyclable paper (household & envelopes etc).    |
| Other paper                         | Non recyclable paper, including compostable            |
| <b>Card</b>                         |  |
| Card packaging                      | All <b>card and cardboard</b> packaging material.      |
| Other card                          | All other card and cardboard (except Phase 3).         |
| Corrugated board (Phase 3)          | Cardboard  |
| <b>Plastic film</b>                 |  |
| Plastic bags                        | Plastic bags including bin bags.                       |
| Plastic film packaging              | Film packaging.  |
| Other plastic film                  | All other plastic film.                                |
| <b>Dense plastic</b>                |  |
| Plastic drinks bottles              | Plastic bottles – for drinks.                          |
| Other plastic bottles               | Plastic bottles – not for drinks.                      |
| Other dense plastic packaging       | Yogurt pots etc.                                       |
| Dense plastic non-packaging         | Toys and other plastic material that is not packaging. |
| <b>Textiles</b>                     |  |
| Artificial textiles                 | Nylon, rayon and other artificial fabrics              |
| Natural textiles                    | Wool, cotton etc.                                      |
| <b>Absorbent hygiene products</b>   |  |
| Disposable nappies                  | Nappies.   |
| Other                               | Sanitary pads, tampons etc.                            |
| <b>Wood</b>                         |  |
| Wood packaging (phase 1)            | Wooden packaging, including pallets                    |
| Other wood (phase 1)                | All other wood   |
| Wood (phases 2-3)                   | Treated and untreated wood (timber, pallets etc)       |
| Wood composite (phases 2-3)         | Wood composites (chipboard, MDF etc).                  |
| <b>Glass</b>                        |  |
| Green bottles                       | Green and blue glass bottles.                          |
| Clear bottles                       | Clear glass bottles.                                   |
| Brown bottles                       | Brown and yellow glass bottles.                        |
| Jars                                | Jars – regardless of colour.                           |
| Non-packaging glass                 | Drinking glasses, plate glass etc.                     |
| <b>Organic</b>                      |  |
| Garden waste                        | Grass, branches, plants etc.                           |
| Food waste                          | Meat, vegetables, cakes etc.                           |
| Organic pet bedding/litter          | Hamster bedding, etc. Not cat litter.                  |
| Other organics                      | Anything else organic (dead animals etc).              |
| <b>Ferrous metal</b>                |  |
| Ferrous cans                        | Steel cans.  |
| Other ferrous metal                 | All other ferrous metal.                               |
| <b>Non-ferrous metal</b>            |  |
| Aluminium <b>drinks</b> (only) cans | Not food cans.   |
| Foil                                | Aluminium foil.  |
| Other non-ferrous                   | All other metal that is not ferrous.                   |
| <b>WEEE</b>                         |  |
| White goods                         | Fridges, freezers, dishwashers etc.                    |

|                               |  |
|-------------------------------|--|
| Large electronic goods        | Flat screen TVs and monitors, Hi Fi, computers.  |
| CRT                           | CRT TVs and monitors.                            |
| Other WEEE                    | All other electrical and electronic goods        |
| <b>Hazardous HHW</b>          |  |
| Batteries                     | Household and car batteries.                     |
| Clinical                      | Pills, dressings etc.                            |
| Paint/varnish                 | All paint, varnish and brush cleaners.           |
| Oil                           | Oil and brake fluid.                             |
| Herbicides and pesticides     | Herbicides and pesticides.                       |
| <b>Combustibles</b>           |  |
| Shoes                         | Shoes, slippers and other footwear.              |
| Carpet/underlay               | Carpet and underlay.                             |
| Furniture                     | Chairs, tables, sideboards etc.                  |
| Other combustibles            | Anything else that will burn (includes tetrapak) |
| <b>Non-combustibles</b>       |  |
| Bricks, blocks, plaster       | Includes cement.                                 |
| Soil                          | Soil and sand.                                   |
| Inorganic pet litter          | Cat litter etc.                                  |
| Other non-combustibles        | All other non combustibles.                      |
| <b>Fine material &lt;10mm</b> |  |
| Fine material <10mm           | Anything that falls through the 10mm screen.     |

## Appendix 2: Origins of waste coded 19.12.12

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The EWC code 19.12.12 refers to “other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19.12.11”.

“Other” in this context refers to waste not covered by previous non-mixed Chapter 19 codes (e.g. wastes from aerobic treatment, landfill leachate, wastes from incineration or pyrolysis), while 19.12.11 refers to wastes containing dangerous substances. We may therefore take 19.12.12 material as mixed wastes from mechanical treatment not containing dangerous materials.

This still leaves considerable leeway for a definition of what such waste might contain, and it was felt to be important to have an idea of what the 19.12.12 code contains in order to provide some context to this report. A series of interviews was conducted with staff at sites producing 19.12.12 material which were identified using the weighbridge tickets obtained during the study, with the aim of obtaining information on the origin of the material (domestic or non-domestic) and the type of treatment (if any) that the waste had been subjected to.

Overall, 22 unique sites were successfully contacted, accounting for 67 analysis samples. In terms of the origin of the material, the following information was obtained:

- 19 of the sites described themselves as taking mixed input, including waste from domestic and non-domestic sources
- 1 site took only domestic waste
- 1 site took only commercial waste
- 1 site was not able to supply an answer to this question

Since 19.12.12 material is overwhelmingly bulked and delivered in artics, it is not usually possible in the case of mixed sites to attribute either a domestic or a non-domestic origin to the material.

The following information was obtained on treatment:

- 8 of the sites described the waste as either MBT or baling plant residue
- 2 further sites used manual sorting only
- 11 further sites used mechanical sorting with some level of manual intervention. This varies from sorting manually and with a transfer station grapple to running picking lines with a mixture of manual and mechanical sorting equipment.

1 site said that the waste was not subjected to any particular treatment. In addition, senior managers were contacted from two large waste management companies and asked about their perception about how the code was used and how it was intended to be used. The following responses were obtained:

- Both managers saw 19.12.12 material as applying mostly to transfer waste.
- Both identified the major treatment as hand picking and sorting with a grab or loading shovel to remove metals and wood. While these materials have some value, the primary aim is to reduce the weight of the material being sent to landfill.
  - Waste may also be screened with a trommel – it was noted by one that trommel screenings from mixed municipal waste are usually landfilled under the Chapter 17 codes for trommel screenings, and are thus classified as inert waste (despite potentially being of a high organic content).
- Both were of the opinion that the majority of the waste that is actively picked to remove dry recyclables is commercial and industrial in origin, since this material is likely to contain materials that can be readily removed.
- Both interviewees expressed the view that material is often shipped under the 19.12.12 code without being picked to remove recyclables.
- One interviewee noted that there could be several reasons why the above takes place:
  - Waste can be tipped with the intention of picking and then not picked, either for logistical reasons or because it is not readily treated in this way (this is especially the case with black-bag domestic waste or trade waste that contains a lot of food).
  - Waste that has not been treated may need to be bulked with waste that has been treated in order to be transported to the landfill. Since the result is a mixed waste that has been subjected to (some) treatment, the appropriate code is 19.12.12.
  - Emphasis on pre-treatment of waste encourages use of 19.12.12 code even when only minimal treatment has been carried out.

In general, both senior managers seemed in agreement that there was insufficient guidance on the correct use of the 19.12.12 code, and one noted that 2006 Environment Agency guidance (which appears not to have been superseded) actually states that all compacted domestic waste should be disposed of under this code<sup>6</sup>.

Overall, it would appear that 19.12.12 is a very diverse code, as one would expect for a mixed waste code, and that there is no clear boundary between this material and material coded 20.03.01. However, 19.12.12 waste that is not MRF residue is likely to have been bulked at a transfer station, and at least some of the material is likely to have been subjected to manual or mechanical picking to remove recyclables or inert materials.

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<sup>6</sup> Environment Agency (2006) Using the list of wastes to code waste.

## Appendix 3: Calculation of biodegradability, recyclability and combustibility

The table below shows the multipliers used to calculate the estimated biodegradability, recyclability and combustibility of the waste.

The biodegradability estimates used in this report were produced by multiplying the percentage of each material in the waste by a figure (1, 0.5 or 0) that serves as a rough measure of the material's biodegradability. This method is a slightly modified version of that set out in the LATS guidance on estimating the %BMW. It should *not* be regarded as an accurate calculation of biodegradability, which would require the laboratory analysis scheduled for subsequent phases. The figure does, however, serve to provide a general indicator that allows us to aggregate the potentially biodegradable materials in order to produce a single variable that samples can be compared against. Where the original Environment Agency method of calculating biodegradability differs from the one used during this project, the EA value is shown in brackets.

The estimate for recyclability is based on those materials **commonly accepted for recycling at the kerbside**, and makes no attempt to account for materials that may be partially recyclable (e.g. furniture, textiles or wood waste). Only multipliers of 0 or 1 have been used. The actually recyclable proportion of the waste is likely to be higher in most cases.

The estimate for combustibility is based on whether or not the large majority of material in the category is flammable. Again, only multipliers of 0 or 1 have been used.

**Table 23: Figures for biodegradability, recyclability and combustibility**

|                                   | Biodegradability | Recyclability | Combustibility |
|-----------------------------------|------------------|---------------|----------------|
| <b>Paper</b>                      |                  |               |                |
| Newspapers                        | 1                | 1             | 1              |
| Magazines                         | 1                | 1             | 1              |
| Recyclable paper                  | 1                | 1             | 1              |
| Other paper                       | 1                | 1             | 1              |
| <b>Card</b>                       |                  |               |                |
| Card packaging                    | 1                | 1             | 1              |
| Other card                        | 1                | 1             | 1              |
| Corrugated board (Phase 3)        | 1                | 1             | 1              |
| <b>Plastic film</b>               |                  |               |                |
| Plastic bags                      | 0                | 0             | 1              |
| Plastic film packaging            | 0                | 0             | 1              |
| Other plastic film                | 0                | 0             | 1              |
| <b>Dense plastic</b>              |                  |               |                |
| Plastic drinks bottles            | 0                | 1             | 1              |
| Other plastic bottles             | 0                | 1             | 1              |
| Other dense plastic packaging     | 0                | 1             | 1              |
| Dense plastic non-packaging       | 0                | 0             | 1              |
| <b>Textiles</b>                   |                  |               |                |
| Artificial textiles               | 0 (0.5)          | 0             | 1              |
| Natural textiles                  | 1 (0.5)          | 0             | 1              |
| <b>Absorbent hygiene products</b> |                  |               |                |
| Disposable nappies                | 0.5 (0)          | 0             | 1              |
| Other                             | 0.5 (0)          | 0             | 1              |
| <b>Wood</b>                       |                  |               |                |
| Wood packaging (phase 1)          | 0.5 (0)          | 0             | 1              |

|                               | Biodegradability | Recyclability | Combustibility |
|-------------------------------|------------------|---------------|----------------|
| Other wood (phase 1)          | 0.5 (0)          | 0             | 1              |
| Wood (phases 2-3)             | 0.5 (0)          | 0             | 1              |
| Wood composite (phases 2-3)   | 0.5 (0)          | 0             | 1              |
| <b>Glass</b>                  |                  |               |                |
| Green bottles                 | 0                | 1             | 0              |
| Clear bottles                 | 0                | 1             | 0              |
| Brown bottles                 | 0                | 1             | 0              |
| Jars                          | 0                | 1             | 0              |
| Non-packaging glass           | 0                | 0             | 0              |
| <b>Organic</b>                |                  |               |                |
| Garden waste                  | 1                | 0             | 1              |
| Food waste                    | 1                | 0             | 1              |
| Organic pet bedding/litter    | 1 (0)            | 0             | 1              |
| Other organics                | 1                | 0             | 1              |
| <b>Ferrous metal</b>          |                  |               |                |
| Ferrous cans                  | 0                | 1             | 0              |
| Other ferrous metal           | 0                | 1             | 0              |
| <b>Non-ferrous metal</b>      |                  |               |                |
| Aluminium drinks (only) cans  | 0                | 1             | 0              |
| Foil                          | 0                | 1             | 0              |
| Other non-ferrous             | 0                | 1             | 0              |
| <b>WEEE</b>                   |                  |               |                |
| White goods                   | 0                | 1             | 0              |
| Large electronic goods        | 0                | 1             | 0              |
| CRT                           | 0                | 1             | 0              |
| Other WEEE                    | 0                | 1             | 0              |
| <b>Hazardous HHW</b>          |                  |               |                |
| Batteries                     | 0                | 1             | 0              |
| Clinical                      | 0.5 (0)          | 0             | 1              |
| Paint/varnish                 | 0                | 0             | 1              |
| Oil                           | 0                | 0             | 1              |
| Herbicides and pesticides     | 0                | 0             | 0              |
| <b>Combustibles</b>           |                  |               |                |
| Shoes                         | 0.5              | 0             | 1              |
| Carpet/underlay               | 0.5 (0)          | 0             | 1              |
| Furniture                     | 0.5              | 0             | 1              |
| Other combustibles            | 0.5 (0)          | 0             | 1              |
| <b>Non-combustibles</b>       |                  |               |                |
| Bricks, blocks, plaster       | 0                | 0             | 0              |
| Soil                          | 0                | 0             | 0              |
| Inorganic pet litter          | 0.5 (0)          | 0             | 0              |
| Other non-combustibles        | 0                | 0             | 0              |
| <b>Fine material &lt;10mm</b> |                  |               |                |
| Fine material <10mm           | 0.5 (0)          | 0             | 1              |

## Appendix 4: Laboratory analysis of waste samples

Samples were selected for analysis by WRc, in order to establish the degradable organic carbon (DOC) and dissimilable degradable organic carbon (DDOC) content of the waste<sup>7</sup>. The primary reason for this additional element was to inform the Greenhouse Gas Inventory, since the results will contribute to an understanding of the contribution of landfill to UK methane emissions.

Samples were selected from a range of materials in the waste, and these were analysed separately. This has three principal advantages over attempting to analyse mixed waste samples:

- It is easier to select a more representative sample of material
- Milling and sample preparation is quicker and more straightforward
- It is possible to model the effects of changing waste composition.

The materials selected for analysis and the tests applied to each material are shown in Table 24 below.

**Table 24: Materials sampled for analysis and tests used**

| Material               | Dry matter | Loss on ignition | Gross CV | Carbon | Organic carbon | Hydrogen | Nitrogen | Sulphur | BM100 | Biomass (C14) | Fibre analysis |
|------------------------|------------|------------------|----------|--------|----------------|----------|----------|---------|-------|---------------|----------------|
| Newspapers             | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Magazines              | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Other recyclable paper | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Other paper            | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Flat card packaging    | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Other flat card        | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Corrugated board       | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Plastic bags           | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Plastic film packaging | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Other plastic film     | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| All dense plastics     | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Textiles               | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     | ✓             | ✓              |
| All AHP                | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     | ✓             | ✓              |
| Wood                   | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Wood composites        | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Garden waste           | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Food waste             | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     |               | ✓              |
| Organic pet waste      | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| All other organics     | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Shoes and accessories  | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     | ✓             | ✓              |
| Carpet and underlay†   | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     | ✓             | ✓              |
| Other combustible      | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Soil and sand          | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Inorganic pet litter   | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       |       |               |                |
| Fines‡                 | ✓          | ✓                | ✓        | ✓      | ✓              | ✓        | ✓        | ✓       | ✓     | ✓             | ✓              |

† The carpet sample was supplied by WRc, from materials retained from a previous sampling exercise at landfill facilities.

‡ The fines were MBT fines supplied by WRc.

<sup>7</sup> For more detailed results and methodology, the WRc analysis report – WRc (2012) *Laboratory analysis of mixed municipal waste streams to determine DOC, DDOC and rate of decay* – is available separately.



The results for the main analysis suite are shown in Table 25.

**Table 25: Main analysis results**

| Material               | Dry matter (%) | Loss on ignition (%DM) | Gross CV (MJ/kg) | Carbon (% dry weight) | Organic carbon (% dry weight) | Hydrogen (% dry weight) | Nitrogen (% dry weight) | Sulphur (% dry weight) |
|------------------------|----------------|------------------------|------------------|-----------------------|-------------------------------|-------------------------|-------------------------|------------------------|
| Newspapers             | 69.4           | 86.3                   | 16.7             | 40.7                  | 37.9                          | 6.01                    | 0.31                    | <0.001                 |
| Magazines              | 88.9           | 64.2                   | 12.6             | 32.3                  | 28.7                          | 4.33                    | 0.11                    | <0.001                 |
| Other recyclable paper | 76.3           | 87.6                   | 14.7             | 35.4                  | 31.7                          | 5.20                    | 0.22                    | <0.001                 |
| Other paper            | 44.8           | 87.8                   | 19.0             | 42.2                  | 29.2                          | 6.34                    | 0.85                    | <0.001                 |
| Flat card packaging    | 59.7           | 84.7                   | 17.3             | 40.1                  | 37.9                          | 3.61                    | 0.49                    | <0.001                 |
| Other flat card        | 85.1           | 81.2                   | 16.0             | 37.8                  | 34.1                          | 5.41                    | 0.47                    | <0.001                 |
| Corrugated board       | 86.2           | 86.6                   | 16.3             | 40.6                  | 32.7                          | 5.56                    | 0.24                    | <0.001                 |
| Plastic bags           | 56.2           | 85.7                   | 32.6             | 69.8                  | 53.7                          | 11.1                    | 0.59                    | <0.001                 |
| Plastic film packaging | 65.7           | 89.7                   | 33.8             | 77.0                  | 52.3                          | 6.36                    | 0.47                    | <0.001                 |
| Other plastic film     | 70.8           | 89.8                   | 29.9             | 60.7                  | 56.4                          | 7.02                    | 0.77                    | <0.001                 |
| All dense plastics     | 88.5           | 87.5                   | 31.3             | 55.1                  | 49.2                          | 5.26                    | 0.99                    | <0.001                 |
| Textiles               | 95.2           | 93.4                   | 16.9             | 47.5                  | 44.3                          | 5.80                    | 1.14                    | <0.001                 |
| All AHP                | 24.4           | 79.0                   | 22.2             | 50.7                  | 46.2                          | 6.32                    | 0.83                    | <0.001                 |
| Wood                   | 83.9           | 98.2                   | 19.4             | 48.1                  | 45.5                          | 6.29                    | 0.13                    | <0.001                 |
| Wood composites        | 90.6           | 97.4                   | 18.7             | 45.2                  | 44.2                          | 5.99                    | 3.67                    | <0.001                 |
| Garden waste           | 34.3           | 48.2                   | 9.18             | 43.3                  | 41.8                          | 3.30                    | 1.56                    | <0.001                 |
| Food waste             | 41.1           | 86.3                   | 17.5             | 37.3                  | 26.3                          | 5.61                    | 2.82                    | <0.001                 |
| Organic pet waste      | 71.0           | 92.9                   | 18.6             | 42.0                  | 40.7                          | 5.95                    | 1.64                    | <0.001                 |
| All other organics     | 42.5           | 66.9                   | 20.4             | 47.0                  | 43.3                          | 6.20                    | 2.52                    | <0.001                 |
| Shoes and accessories  | 89.4           | 79.7                   | 22.5             | 56.7                  | 52.8                          | 7.01                    | 1.56                    | <0.001                 |
| Carpet and underlay†   | 96.4           | 53.8                   | 16.0             | 44.9                  | 33.6                          | 5.53                    | 2.59                    | <0.001                 |
| Other combustible      | 70.5           | 82.3                   | 24.0             | 4.9                   | 3.6                           | 1.43                    | 0.28                    | <0.001                 |
| Soil and sand          | 73.8           | 14.0                   | 1.93             | 4.7                   | 3.7                           | 1.89                    | 0.35                    | <0.001                 |
| Inorganic pet litter   | 69.8           | 13.7                   | 4.51             | 5.1                   | 4.3                           | 0.70                    | 0.24                    | <0.001                 |
| Fines‡                 | 83.3           | 35.9                   | 8.32             | 17.9                  | 15.5                          | 2.26                    | 1.17                    | <0.001                 |

Results for the fibre analysis, BMc and C14 tests are shown in Tables 26-28.

**Table 26: Fibre analysis results (%DW)**

|                     | Neutral detergent fibre | Acid detergent fibre | Fat   |
|---------------------|-------------------------|----------------------|-------|
| Paper               | 76.2                    | 65.8                 | 7.34  |
| Flat card           | 75.4                    | 65.0                 | 6.82  |
| Corrugated board    | 81.8                    | 67.7                 | 6.21  |
| Textiles            | 91.0                    | 81.8                 | 4.72  |
| AHP                 | 73.6                    | 84.0                 | 6.39  |
| Wood                | 88.6                    | 77.1                 | 5.18  |
| Wood composites     | 79.9                    | 66.7                 | 5.19  |
| Garden waste        | 67.4                    | 67.5                 | 23.23 |
| Food waste          | 25.3                    | 19.0                 | 19.95 |
| Shoes & accessories | 72.7                    | 62.2                 | 11.84 |
| Carpet & underlay   | 61.3                    | 45.4                 | 6.59  |
| Fines               | 71.5                    | 73.5                 | 4.18  |

**Table 27: BMc test results (l/kg LOI)**

|                     | Mean result |
|---------------------|-------------|
| Paper               | 304         |
| Flat card           | 350         |
| Corrugated board    | 301         |
| Textiles            | 312         |
| AHP                 | 243         |
| Wood                | 25.9        |
| Wood composites     | 54.9        |
| Garden waste        | 71.8        |
| Food waste          | 587         |
| Shoes & accessories | 90.1        |
| Carpet & underlay   | 29.4        |
| Fines               | 231         |

**Table 28: C14 test results**

|                     | Biogenic carbon | Fossil carbon |
|---------------------|-----------------|---------------|
| Textiles            | 54              | 46            |
| AHP                 | 47              | 53            |
| Shoes & accessories | 37              | 63            |
| Carpet & underlay   | 22              | 78            |
| Fines               | 78              | 22            |

A number of observations can be made about these results:

- The results represent samples taken from a single landfill site in Autumn 2011, and may not be representative of these materials as a whole. If policy decisions are to be based on this data it would be prudent to repeat the analysis suite on materials taken from a different location.
- The BMc results for some of the materials analysed seem low, particularly for garden waste and wood. This may be due to the high lignin content of these materials, which will not have biodegraded over the period of the BMc test. This in itself highlights a problem with attempting to assign an overall “biodegradability figure to a material”, since the answer is always relative to a particular time period and set of conditions.
- The moisture content and loss on ignition data indicate that the majority of the material landfilled by weight is not biodegradable, being composed primarily of water and inorganic materials.

The laboratory data also serve to highlight some of the issues with the LATS-guidance based method of calculating biodegradable material that has been used elsewhere in this report in order to ensure comparability with previous work. The LATS-guidance approach is based very much on deciding whether or not a material is biodegradable (and then introducing the 0.5 multiplier in an attempt to take account of varying biodegradability), while the lab analysis concerns itself with *how* biodegradable a material is. This not only produces very different figures, but produces a different type of figure, since this concept of biodegradability will vary depending on timescale.

In order to illustrate the level of difference that basing our analysis on lab data makes, we have presented below a model of the biodegradability of combined 19.12.12 and 20.03.01 waste, using the laboratory data for loss on ignition and moisture content. This approach is based on multiplying the percentage of dry matter by the percentage loss on ignition, to obtain the percentage of organic material in the waste (by *wet weight*). Since this approach does not distinguish between fossil carbon and more readily dissimilable forms, this approach is used only to calculate the biodegradability of items that are biological in origin, with plastics, metals and glass omitted. This approach will still tend to overestimate biodegradability – for example, mixed materials such as textiles will include all carbon as organic, even for artificial textiles based on fossil carbon. Results based on this approach represent the upper limit of the biodegradability of this material.

We begin by working out the biodegradability “factors” for each material category, as shown in Table 29.

**Table 29: Lab based biodegradability factors for waste analysis categories.**

| Material                  | Dry matter | LOI  | DM x LOI<br>(Organic matter) |
|---------------------------|------------|------|------------------------------|
| Paper and flat card (ave) | 0.70       | 0.82 | 0.57                         |
| Cardboard                 | 0.77       | 0.84 | 0.65                         |
| Plastics                  | 0.70       | 0.88 | 0.62                         |
| Textiles                  | 0.95       | 0.93 | 0.89                         |
| AHP                       | 0.24       | 0.79 | 0.19                         |
| Wood                      | 0.84       | 0.98 | 0.82                         |
| Wood composite            | 0.91       | 0.97 | 0.88                         |
| Garden waste              | 0.34       | 0.48 | 0.17                         |
| Food waste                | 0.41       | 0.86 | 0.35                         |
| Organic pet litter        | 0.71       | 0.93 | 0.66                         |
| Other organic waste       | 0.43       | 0.67 | 0.28                         |
| Shoes and accessories     | 0.89       | 0.80 | 0.71                         |
| Carpet and underlay       | 0.96       | 0.54 | 0.52                         |
| Other combustibles        | 0.70       | 0.82 | 0.58                         |
| Soil and sand             | 0.74       | 0.14 | 0.10                         |
| Inorganic pet litter      | 0.70       | 0.14 | 0.10                         |
| Fines                     | 0.83       | 0.36 | 0.30                         |

With the factors calculated, we can present the biodegradability based on this approach, which is shown in Table 30 (some averaging of results has taken place, with textiles based on textiles, shoes and accessories and wood based on wood and wood composites).

**Table 30: Biodegradability of MSW based on lab data**

| Material                     | Combined waste | Biodegradability |
|------------------------------|----------------|------------------|
| Paper                        | 10.5           | 5.96             |
| Card                         | 8.4            | 5.43             |
| Plastic film                 | 8.9            | 0.00             |
| Dense plastics               | 11.3           | 0.00             |
| Sanitary waste               | 2.2            | 0.43             |
| Wood                         | 7.6            | 6.45             |
| Textiles and shoes           | 5.7            | 4.60             |
| Glass                        | 2.2            | 0.00             |
| Food waste                   | 15.0           | 5.32             |
| Garden waste                 | 2.7            | 0.44             |
| Other organic                | 1.7            | 0.49             |
| Metals                       | 3.5            | 0.00             |
| WEEE                         | 1.5            | 0.00             |
| Haz waste and batteries      | 1.0            | 0.00             |
| Carpet, underlay & furniture | 6.0            | 3.09             |
| Other combustibles           | 2.0            | 1.18             |
| Bricks, plaster and soil     | 5.9            | 0.00             |
| Other non-combustible        | 1.6            | 0.00             |
| Fines <10mm                  | 2.5            | 0.76             |
| <b>Total</b>                 | <b>100.1†</b>  | <b>34.1</b>      |

†This is a rounding artefact.

It can be seen that these two methods produce quite different results in terms of estimating biodegradability (it is worth noting that Method 1 also gives the combustibility of the material by wet weight, assuming that the water content is not counted as being combusted). These results are clearly not comparable with the results based on LATS-guidance data, and are presented here for consideration of what an evidence based measurement of the biodegradability might look like should this approach be adopted in future.