Material change for a better environment

Summary Report

Material bulk densities

This document provides bulk density data for commonly collected material streams, taking into account container types and how the materials are collected (vehicle types). It provides data that will be useful in planning and managing collection and handling systems for recyclable materials.

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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Material bulk density introduction

WRAP (Waste & Resources Action Programme) commissioned research to investigate the bulk density of commonly collected materials at the kerbside. The project involved a detailed desk top assessment of data currently used in the waste sector which identified a number of gaps and potential areas of weakness. As a result a primary data gathering exercise was undertaken.

This document provides the summary data from the research. It is provided to help inform the assessment of waste and recycling options and the planning and delivery of collection and recycling services.

The data presented in this report comes from a variety of sources. The origin of the data is clearly stated to allow the reader to make a judgement on the applicability and robustness of the data on a case-by-case basis.

The data included in this summary document are set out below.

Self reported bulk density

During the desktop phase of the project numerous self reported data sets were gathered from contractors and researchers. These data sets were assessed and the data that were considered to be reliable, based on current understanding, are included in this summary document.

Fieldwork to measure bulk density

Fieldwork was carried out on various material combinations in both containers and vehicles. The fieldwork data resulted in a **material bulk density** being calculated i.e. material of a known volume and weight was used in the calculation. All bulk density figures are reported in kg/m^3.

A brief methodology follows explaining how the data was collected in each case.

Rear End Loader (REL) compacted material

Field measurements were taken by observing the loads as they came in to the depot and confirming with the driver the reason for tipping, i.e. whether the vehicle was 'full'. Where vehicle design allowed safe access, measurements were taken using a laser of the position of the back plate before and after tipping. Weighbridge weights were then obtained for all loads measured. The collection authorities and/or vehicle manufacturers were contacted to obtain specification details for each vehicle included in the study

Kerbsider

The field work measurements involved estimating the void space, where applicable, in each chamber to allow the volume of material to be calculated. To estimate the void space of the chamber, access to the top of the vehicle was required. Front (cab) to back (rear) and side to side measurements were taken for each compartment. Measurements were taken from the top of the compartment down to the surface of the material. Where the material load was not level several measurements were taken in order to provide an average figure of the depth of the void. Vehicle specifications were obtained from the collection authority and/or manufacturer to confirm the body volume, which was split proportionally based on the cab to rear measurements for each compartment.

Stillage vehicles

Internal measurements of stillage dimensions were taken. Each stillage was assessed for volume of product by levelling the material off and measuring the height to top of stillage. Stillages were weighed individually with and without material to allow the net material weight to be determined.

Household containers

The containers were weighed with and without material, and measurements of the internal dimensions taken including the depth of the void.

Often co-mingled dry recyclable materials are collected in a REL, which results in the compaction of the materials. In order to measure the bulk density of the material as it is presented by the resident on-street monitoring was undertaken. This involved weighing the bins/boxes on the street and measuring the depth of the void space, if applicable. The monitoring was done at the individual household level from a random selection of streets (from the round list provided by the authority) in order to capture a broad socio-economic profile of residents.

Bulk containers

This refers to 1,100 litre wheeled bins and bigger. Self reported bulk density data was obtained during the desktop stage of the research and where these data were assessed to be robust they are reported here.

Weighbridge data

During the course of the fieldwork historical weighbridge data was obtained at the individual round level for collections made using RELs.

Authorities operating double tip rounds were selected for inclusion in the study. The data was filtered to include the first tip weight on any given day. While it is acknowledged that there are numerous reasons for a crew returning to depot to tip, it was confirmed with all partner collection authorities that under normal circumstances the vast majority of first tips would be as a result of the vehicle being full. The weight of the first tip and the total vehicle volume were used in the calculation of a bulk density. This data is referred to as **operational bulk density** in this document.

Results

The following tables present the findings of the project on a material by material basis. The bulk density data for vehicles and containers are presented together. Two types of data are referenced:

1 **Material bulk density kg/m^3:** calculated from a known volume and weight of material.

2 **Operational bulk density kg/m^3:** derived from historical weight data and measured vehicle/container volume

The following descriptive statistics are presented for each data set in order to allow the reader to assess the robustness of the data:

- The mean is the sum of the kg/m3 values divided by the number of values.
- The No. of samples shows the number of data points used in the calculations.
- The standard deviation represents the spread of values and their variations around the mean. A low standard deviation indicates that the data points tend to be very close to the same value (the mean), while high standard deviation indicates that the data are spread over a large range of values.
- The coefficient of variance expresses the ratio of the standard deviation to the mean. When comparing between data sets the coefficient of variation should be used.
- The 95% confidence interval indicates the variation + or - from the mean that would be expected in 95% of cases.
- The 'lowest' and 'highest' data from the sample shows the range of the data.

Material specific results

Newspapers and magazines

Newspapers and magazines			
Vehicle/Container	**Kerbsider (no compaction)**	**7.5-15t Caged stillage (no compaction)**	**45/55 litre kerbside box (no compaction)**
Data type	**Field work data: Material bulk density**	**Self reported data: Material bulk density**	**Self reported data: Material bulk density**
Mean, kg/m3	305	279	294
No. samples	20	5	6
Standard Deviation	49.9	59.7	28.2
Coefficient of Variance	0.2	0.2	0.1
95% Confidence Interval +/- kg/m3	21.9	52.3	22.5
Lowest value	219	208	262
Highest value	388	330	336

Mixed paper & card

Mixed paper & card		
Vehicle/container	**Rear End Loader (compacted)**	**140 litre wheeled bin***
Data type	**Historical weighbridge data: Operational bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	431	112
No. samples	87	84
Standard Deviation	32.1	83.0
Coefficient of Variance	0.07	0.74
95% Confidence Interval +/- kg/m3	6.75	17.76
Lowest value	375	16
Highest value	495	550
		*the large range of values is a result of different amounts of cardboard in bins

Mixed paper, card & drink cartons

Mixed paper, card & drink cartons	
Vehicle/container	**Rear End Loader (compacted)**
Data type	**Field work data: Material bulk density**
Mean, kg/m3	366
No. samples	7
Standard Deviation	83.9
Coefficient of Variance	0.2
95% Confidence Interval +/- kg/m3	62.2
Lowest value	248
Highest value	444

Mixed glass

Mixed glass				
Vehicle/container	**Rear End Loader (compacted)***	**Kerbsider (no compaction)**	**1,100 litre wheeled bin (no compaction)****	**45/55 litre kerbside box (no compaction)**
Data type	**Field work: Operational bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Self reported data: Material bulk density**
Mean, kg/m3	265	456	694	276
No. samples	14	28	6	6
Standard Deviation	86.4	110.1	25.8	9.6
Coefficient of Variance	0.3	0.2	0.1	0.03
95% Confidence Interval +/- kg/m3	45.3	40.8	28.6	7.7
Lowest value	149	199	664	259
Highest value	438	734	764	287
	*due to H&S considerations data calculated based on the whole volume of the vehicle		**Filled using a 360' slew from a pile of kerbsider collected material	

Mixed cans

Mixed cans			
Vehicle/container	**Kerbsider (no compaction)**	**7.5-15t Caged stillage (no compaction)**	**45/55 litre kerbside box (no compaction)**
Data type	**Field work data: Material bulk density**	**Self reported data: Material bulk density**	**Self reported data: Material bulk density**
Mean, kg/m3	63	56	40
No. samples	20	4	6
Standard Deviation	12.9	4.4	5.1
Coefficient of Variance	0.2	0.1	0.1
95% Confidence Interval +/- kg/m3	5.7	4.3	4
Lowest value	50	50	34
Highest value	100	60	46

Plastic bottles

Plastic bottles					
Vehicle/container	**Rear end loader**	**Kerbsider (no compaction)***	**Kerbsider (with MVR compaction)****	**Stillage (builder dumpy sacks)**	**45/55 litre kerbside box (no compaction)**
Data type	**Field work data: Material bulk density**	**Historical weighbridge data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Self reported data: Material bulk density**
Mean, kg/m3	158	16	44	26	13
No. samples	3	45	15	13	6
Standard Deviation	27.0	3.3	7.4	2.8	3.7
Coefficient of Variance	0.2	0.2	0.2	0.1	0.3
95% Confidence +/- kg/m^3	30.6	1.0	3.7	1.5	2.9
Lowest value	140	10	37	22	10
Highest value	189	24	65	30	18
		*1st tip full data	**Vehicle fitted with Terberg Material Volume Reduction unit		

Mixed plastic (no film)

Mixed plastic (no film)				
Vehicle	**Rear end loader (soft pack)**	**Rear end loader (split back)**	**Kerbsider (with MVR compaction)****	**7.5-15t Caged stillage (no compaction)**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	79	106	29	25
No. samples	2	2	3	6
Standard Deviation	n/a	n/a	n/a	4.0
Coefficient of Variance	n/a	n/a	n/a	0.2
95% Confidence +/- kg/m3	n/a	n/a	n/a	3.2
Lowest value	87	92	26	18
Highest value	70	120	32	28

Mixed plastic (no film)				
Container	**1,100 litre wheeled bin (no compaction)**	**240 litre wheeled bin (no compaction)**	**140 litre wheeled bin (no compaction)**	**45/55 litre kerbside box (no compaction)**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	22	22	21	18
No. samples	15	33	27	31
Standard Deviation	4.3	4.1	4.4	3.1
Coefficient of Variance	0.2	0.2	0.2	0.2
95% Confidence +/- kg/m3	2.2	1.4	1.7	1.1
Lowest value	16	16	14	14
Highest value	29	33	14	26

Mixed plastic (with film)

Mixed plastic (with film)				
Vehicle	**Rear end loader (soft pack)**	**Rear end loader (hard back)**	**Kerbsider (with MVR compaction)****	**7.5-15t Caged stillage (no compaction)**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	116	197	47	28
No. samples	1	1	1	9
Standard Deviation	n/a	n/a	n/a	5.2
Coefficient of Variance	n/a	n/a	n/a	0.2
95% Confidence Interval +/- kg/m3	n/a	n/a	n/a	3.4
Lowest value	n/a	n/a	n/a	23
Highest value	n/a	n/a	n/a	37

Mixed plastic (with film)				
Container	**1,100 litre wheeled bin (no compaction)**	**240 litre wheeled bin (no compaction)**	**140 litre wheeled bin (no compaction)**	**45/55 litre kerbside box (no compaction)**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	34	40	23	39
No. samples	16	16	23	18
Standard Deviation	5.1	5.7	3.7	6.6
Coefficient of Variance	0.1	0.1	0.2	0.2
95% Confidence Interval +/- kg/m3	2.5	2.8	1.5	3.0
Lowest value	26	29	17	31
Highest value	45	48	30	57

Drink cartons

Drink cartons		
Vehicle/container	**7.5-15t Caged stillage (no compaction)**	**Bring banks & 1,100 litre wheeled bins**
Data type	**Field work data: Material bulk density**	**Self reported data: Material bulk density**
Mean, kg/m3	26	20
No. samples	15	n/a
Standard Deviation	3.9	n/a
Coefficient of Variance	0.1	n/a
95% Confidence Interval +/- kg/m3	2.0	n/a
Lowest value	20	n/a
Highest value	32	n/a

Food

Food		
Vehicle/container	**7.5-15t Caged stillage (no compaction)**	**23 litre kerbside caddy**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	500	290
No. samples	4	141
Standard Deviation	34.5	159.1
Coefficient of Variance	0.1	0.5
95% Confidence Interval +/- kg/m3	33.8	26.3
Lowest value	453	107
Highest value	527	887

Food and garden

Food and garden		
Vehicle/container	**Rear end loader***	**240 litre wheeled bin**
Data type	**Historical weighbridge data: Operational bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	338	157
No. samples	1,799	310
Standard Deviation	110.3	96.5
Coefficient of Variance	0.3	0.6
95% Confidence Interval +/- kg/m3	5.1	10.7
Lowest value	45	13
Highest value	711	778
	*Historical data covering 12 months. 1st tip weights only	

Food, garden and card

Food, garden and card	
Vehicle/container	**Rear end loader***
Data type	**Field work data: Material bulk density**
Mean, kg/m3	502
No. samples	12
Standard Deviation	143.9
Coefficient of Variance	0.3
95% Confidence Interval +/- kg/m3	81.4
Lowest value	312
Highest value	791
	*Measurements taken in March

Co-mingled: Plastic bottles, news & pams, cardboard and mixed cans

Plastic bottles, news & pams, cardboard and mixed cans			
Vehicle/container	**Rear end loader**	**240 litre wheeled bin (no compaction)**	**140 litre wheeled bin (no compaction)**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	310	53	70
No. samples	21	191	57
Standard Deviation	53.9	27.2	32.5
Coefficient of Variance	0.2	0.5	0.5
95% Confidence Interval +/- kg/m3	23.1	3.9	8.4
Lowest value	186	14	17
Highest value	407	207	158

Co-mingled: Plastic bottles and mixed cans

Plastic bottles and mixed cans			
Vehicle/container	**Rear end loader**	**240 litre wheeled bin**	**55 litre box**
Data type	**Field work data: Material bulk density**	**Field work data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	184	30	30
No. samples	13	19	98
Standard Deviation	36.9	3.6	8.6
Coefficient of Variance	0.2	0.1	0.3
95% Confidence Interval +/- kg/m3	20.1	1.6	1.7
Lowest value	117	24	9
Highest value	236	36	52

Co-mingled: Plastic bottles, news & pams, cardboard, mixed cans and glass

Plastic bottles, news & pams, cardboard, mixed cans and glass			
Vehicle/container	**Rear end loader**	**Rear end loader**	**240 litre wheeled bin**
Data type	**Field work data: Material bulk density**	**Self monitor data: Material bulk density**	**Field work data: Material bulk density**
Mean, kg/m3	405	413	84
No. samples	18	89	79
Standard Deviation	111.9	98.7	33.8
Coefficient of Variance	0.3	0.2	0.4
95% Confidence Interval +/- kg/m3	51.7	20.5	7.4
Lowest value	239	186	20
Highest value	758	724	171

Co-mingled: Plastic bottles, mixed cans and glass

Plastic bottles, mixed cans and glass	
Vehicle/container	**Rear end loader**
Data type	**Field work data: Material bulk density**
Mean, kg/m3	450
No. samples	24
Standard Deviation	55.9
Coefficient of Variance	0.1
95% Confidence Interval +/- kg/m3	22.4
Lowest value	364
Highest value	559

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