Environment Agency

Evidence

Material comparators for end-of-waste decisions

Animal bedding: straw

Report – SC130040/R13

Version 2

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Executive summary

This report details the work carried out to characterise straw, a key comparator. This information will inform end-of-waste assessments for waste-derived materials intended to replace straw as animal bedding.

The Waste Framework Directive (Article 6) provides criteria for identifying when a waste material has become a product and no longer needs to be regulated as a waste. Through Article 6 the case law requires the Environment Agency to consider the environmental and human health impacts from materials in comparison with their non-waste material alternatives.

> 'It should be enough that the holder has converted the waste material into a distinct, marketable product, which can be used in exactly the same way as a [non-waste material], and with no worse environmental effects.'

Market research was used to define straw as an ordinary comparator and a literature review was used to identify any existing published data.

A limited number of suitable pre-existing datasets were found during the literature review.

Ten samples of straw were collected from various suppliers across England. Analytical data from these samples are presented in this report.

We recommend comparing the concentrations of analytes in the comparators dataset to the concentrations in the waste-derived material, paying attention to the higher values. This comparison does not constitute a pass/fail test or an end of waste view. It will provide an indication of whether the waste material contains similar levels of analytes to non-waste materials and whether an end-of-waste application may be appropriate or that further analysis or improved treatment processes may be warranted.

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Contents

1 Introduction

To define end-of-waste criteria, the Environment Agency requires a set of ordinary material comparator data for use as a benchmark against which other materials and wastes can be assessed.

The Waste Framework Directive (Article 6) provides criteria for identifying when a waste material has become a product and no longer needs to be regulated as a waste. Through Article 6 the case law requires the Environment Agency to consider the environmental and human health impacts from materials in comparison with their non-waste material alternatives.

> 'It should be enough that the holder has converted the waste material into a distinct, marketable product, which can be used in exactly the same way as a [non-waste material], and with no worse environmental effects.'

The purpose of this report is to provide an evidence base of the composition and characteristics of straw which is defined as an ordinary material comparator that is currently permitted for use as animal bedding.

This report provides the results from the primary analysis of 10 straw samples.

2 Definition

Straw is defined for the purpose of this project as dried stems/stalks of plants such as wheat, rye, oats and barley. Straw is cut or shredded to provide bedding and soiling material for livestock and domestic pets. Straw may also be pelletised for use as animal bedding.

The following types of straw are available for use as animal bedding:

- winter and spring barley
- hay
- oats
- Miscanthus
- wheat straw
- oil seed rape

2.1 Material properties relevant to use

Wheat straw is cheap, easily available, absorbent, warm and easy to muck out. It rots down well, and is easy to dispose of in a muck heap and makes a good garden fertiliser (Countrywide Farmers 2013).

Wheat straw is not suitable for horses with dust allergies or respiratory problems. It can be very dusty and poorer quality straw can be mouldy too. Storage can be a problem – bales need a lot of space in a dry area. Oat straw is more expensive. It quickly becomes saturated, which makes it the least suitable straw for bedding. Some horses

will eat the straw and it can cause several problems such as allergic coughing to the dust (Countrywide Farmers 2013).

3 Comparator sub-types

Ten straw samples were obtained from a variety of suppliers across England to provide a cross-section of the main straw types used for animal bedding. The samples can be further divided into sub-types. Figure 3.1 shows a breakdown of the samples by sub-type.

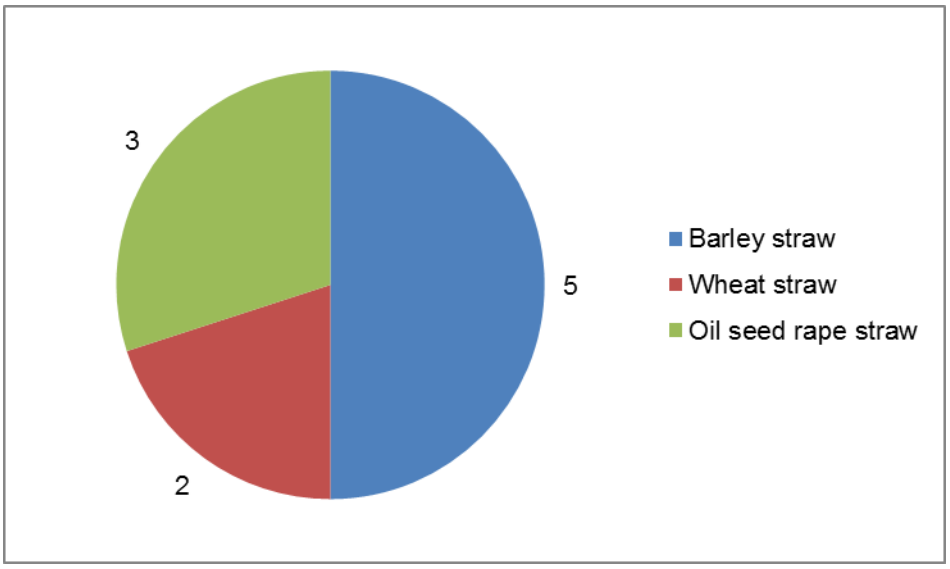

Figure 3.1 Number of samples of each straw sub-type

4 Material sources and sampling procedure

An internet search was used to produce a list of straw suppliers. Straw samples were requested from all these suppliers to ensure a cross-section of straw types were sampled. Samples were collected from those willing to participate.

No sampling standards for straw used for animal bedding were identified during the literature review. Straw samples were taken in accordance with BS EN 14778:2011 (BSI 2011).

5 Analytical parameters

The main parameters determined, together with units of measurement, are summarised in Tables 5.1 to 5.4.

Testing was carried out in accordance with in-house methods documented by the Environment Agency's National Laboratory Service (NLS) which meet the requirements of the performance standards of the Environment Agency's monitoring certification scheme (MCERTS). Specific tests used are outlined in the tables. Other test methods are available.

In the tables, 'LE' refers to the NLS Leeds laboratory and 'SAL' refers to Scientific Laboratories Ltd.

Table 5.1 Analysis: physical properties

Parameter/ determinand	Test method used	Unit
pH	LE I pH and EC 01 pH and conductivity – water extracted, determined by specific electrode from 'as received' sample	–
Conductivity	LE I pH and EC 01 pH and conductivity – water extracted, determined by specific electrode from 'as received' sample	µS/cm
Dry solids @ 30°C	LE P soil preparation 01 – sample air dried at <30ºC in a controlled environment until constant weight is achieved	%
Dry solids @ 105°C	LE I dry solids (105ºC) – thermally treated, determined by gravimetry	%
Loss on ignition (LoI) @ 500°C (organic matter content)	Loss on ignition (500ºC) – thermally treated, determined by gravimetry	%
Particle size distribution (PSD)	SAL determination of percentage particles. The particle size distribution calculates the percentage of a sample which is distributed via sieving between 2 and 20 mm, between 20 and 50 mm, and over 50 mm. The determination is performed on the >2 mm fraction of the sample (that is, the fraction of the sample that does not pass through the 2 mm sieve).	%
Bulk density	The test portion is filled into a standard container of a given size and shape, and is weighed afterwards. The density is calculated from the net weight per standard volume and reported.	kg/m^3
Moisture content	Parameter by calculation	%

Table 5.2 Analysis: metals

Parameter/ determinand	Test method used	Unit
Aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, thallium, tin, titanium, vanadium, zinc	LE I metals (ICP-OES) 01– digestion block aqua regia extracted under reflux; determined by ICP-OES	mg/kg
Chromium VI	Hexavalent chromium by spectrophotometry	mg/kg

Table 5.3 Analysis: organic contaminants

Parameter/ determinand	Test method used	Unit
Polycyclic aromatic hydrocarbons (PAHs) (USEPA16)[1]	Organics dichloromethane (DCM) extracted; hexane exchange determined by gas chromatography–mass spectrometry (GCMS) (scan mode)	μg/kg
Benzene, toluene, ethylbenzene and xylenes (BTEX)	Organics DCM extracted; hexane exchange determined by GCMS (scan mode)	μg/kg
Polychlorinated biphenyls (PCBs)	LE O HRMS3 – dioxins; furans – toluene accelerated solvent extraction (ASE); three-stage clean-up; determined by high resolution GCMS	μg/kg
Halogenated organics (including lindane, pentachlorophenol)	Organics DCM extracted; hexane exchange determined by GCMS (scan mode) and LE O Phenols (HPLC) 01 – methanol extracted; determined by high performance liquid chromatography (HPLC) with diode array detection (DAD) from 'as received' sample	μg/kg

Notes: [1] List of 16 PAHs classified by the US Environmental Protection Agency (USEPA) as priority pollutants.

Table 5.4 Analysis: microbiological contaminants

Parameter/ determinand	Test method used	Unit
Escherichia coli (E. coli)	NLS B ECOLI ENV – Enumeration of *Escherichia coli* by membrane filtration (confirmed) NLS B ECOLI ENV – Enumeration of *Escherichia coli* by membrane filtration (Presumptive)	Number present per g wet weight (WW) of sample

Parameter/ determinand	Test method used	Unit
Salmonella spp.	NLS B SAL PA – Qualitative analysis for *Salmonella* spp. (not *S. typhi*) by membrane filtration	Present or absent

6 Existing data

Only one dataset relating to straw for animal bedding were identified during the literature review. This is presented in Table 6.1.

Primary data from another report in this series, 'Product comparators for materials applied to land: straw' (Environment Agency 2014), are reproduced in Tables 6.2 to 6.4. The straw sampled in that project had the potential to be used as animal bedding.

Table 6.1 Straw analysis

	Dry matter	Pb	Ni	Zn	Cd	Hg	Cr	Cu
	% m/m	mg/kg						
Straw	88.2	5*	2*	4.8	0.1*	0.01*	1*	2.2

Notes: * Below limit of measurement
Source: WRAP (2007)

Table 6.2 Physical properties of straw

Sample ID	pH	Conductivity	Dry solids @ 30°C	Dry solids @ 105°C	LoI @ 500°C (organic matter content)
		mS/cm	%	%	%
Straw 01a	8.56	1.97	91.5	86.9	93.2
Straw 02a	7.76	2.50	91.6	85.8	90.3
Straw 03a	8.12	1.60	83.8	81.7	92.6
Straw 04a	7.03	1.94	95.8	86.3	90.1
Straw 05a	6.83	2.76	90.8	85.8	87.9
Straw 06a	7.72	1.86	76.8	83.5	93.9
Straw 07a	7.94	1.99	95.8	86.6	93.1
Straw 08a	7.06	1.29	89.1	82.1	90.3
Straw 09a	7.90	2.73	97.3	87.7	92.8
Straw 10a	8.01	3.02	97.0	87.2	90.1
Mean	7.69	2.17	91.0	85.4	91.4
Median	7.83	1.98	91.6	86.1	91.5
Minimum	6.83	1.29	76.8	81.7	87.9
Maximum	8.56	3.02	97.3	87.7	93.9
No. of samples	10	10	10	10	10
90th percentile	8.16	2.79	97.0	87.3	93.3
LOD	0.2	10	0.5	0.5	0.5

Notes: Source: Environment Agency (2014)

Table 6.3 Primary data for straw: metals (mg/kg DW)

(a)

Sample ID	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cr VI	Co	Cu	Fe	Pb	Li
Straw 01a	346.0	<1.00	0.70	42.2	<0.100	4.45	<0.200	3950	0.94	<0.70	0.13	4.42	414	1.48	<1.00
Straw 02a	<50.0	<1.00	0.52	37.0	<0.100	2.78	<0.200	4280	0.58	<0.70	<0.10	4.49	<200	<1.00	<1.00
Straw 03a	<50.0	<1.00	<0.50	22.5	<0.100	2.84	<0.200	1880	<0.50	<0.40	<0.10	3.39	<200	<1.00	<1.00
Straw 04a	<50.0	<1.00	0.52	38.9	<0.100	1.48	<0.200	2010	<0.50	<0.70	<0.10	3.53	<200	<1.00	<1.00
Straw 05a	<50.0	<1.00	<0.50	82.6	<0.100	3.72	<0.200	2840	0.63	<0.70	<0.10	2.55	<200	<1.00	<1.00
Straw 06a	<60.0	<1.00	<0.60	30.1	<0.100	3.97	<0.200	1560	<0.60	<0.90	<0.10	5.88	<200	<1.00	<1.00
Straw 07a	<50.0	<1.00	3.66	55.6	<0.100	3.28	0.207	3480	<0.50	<0.70	<0.10	2.80	<200	<1.00	<1.00
Straw 08a	53.5	<1.00	3.71	66.8	<0.100	4.02	0.332	3310	0.73	<0.80	<0.10	3.30	<200	1.03	<1.00
Straw 09a	<60.0	<1.00	3.99	49.8	<0.100	4.28	0.297	3160	<0.60	<0.70	<0.10	2.50	<200	<1.00	<1.00
Straw 10a	<50.0	<1.00	3.53	39.9	<0.100	1.46	0.222	1830	0.91	<0.70	<0.10	3.78	<200	<1.00	<1.00
Mean	82.0	1.00	1.82	46.5	0.100	3.23	0.226	2830	0.65	0.70	0.10	3.66	221	1.05	1.00
Median	50.0	1.00	0.65	41.1	0.100	3.50	0.200	3000	0.60	0.70	0.10	3.46	200	1.00	1.00
Minimum	50.0	1.00	0.50	22.5	0.100	1.46	0.200	1560	0.50	0.40	0.10	2.50	200	1.00	1.00
Maximum	346.0	1.00	3.99	82.6	0.100	4.45	0.332	4280	0.94	0.90	0.13	5.88	414	1.48	1.00
No. of samples	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90th percentile	88.6	1.00	3.74	68.4	0.100	4.30	0.301	3983	0.91	0.81	0.10	4.63	221	1.08	1.00
LOD	50	1	0.5	0.5	0.1	1	0.2	60	0.5	0.3	0.1	1	1	1	1

(b)

Sample ID	Mg	Mn	Hg	Mo	Ni	P	K	Se	Ag	Na	Sr	Tl	Sn	Ti	V	Zn
Straw 01a	882	20.9	<0.20	1.01	<0.70	870	4960	1.23	<1.00	235.0	11.10	<1.00	<1.00	6.71	0.87	25.70
Straw 02a	1260	10.1	<0.20	1.72	<0.70	826	11100	1.20	<1.00	149.0	14.70	<1.00	<1.00	<3.00	0.15	13.50
Straw 03a	576	16.6	<0.20	<1.00	<0.60	993	6220	1.11	<1.00	82.1	3.47	<1.00	<1.00	<3.00	<0.10	9.09
Straw 04a	536	7.7	<0.20	6.73	<0.60	1280	18300	1.32	<1.00	61.6	3.89	<1.00	<1.00	<3.00	<0.10	13.70
Straw 05a	1020	13.4	<0.20	<1.00	<0.60	1250	8220	1.26	<1.00	51.8	80.50	<1.00	<1.00	<3.00	0.16	8.81
Straw 06a	692	17.8	<0.20	1.10	<0.70	1570	9670	1.20	<1.00	150.0	7.51	<1.00	<1.00	<3.00	<0.10	9.84
Straw 07a	949	16.7	<0.20	1.03	<0.60	1200	9780	<1.00	<1.00	66.9	10.60	2.90	<1.00	<3.00	0.18	9.65
Straw 08a	943	37.4	<0.20	<1.00	<0.60	1420	6850	<1.00	<1.00	119.0	10.40	2.95	<1.00	<3.00	0.34	15.80
Straw 09a	833	30.4	<0.20	<1.00	<0.70	1750	10800	<1.00	<1.00	53.0	7.91	3.29	<1.00	<3.00	0.23	20.70
Straw 10a	751	12.0	<0.20	1.17	<0.60	1230	12400	<1.00	<1.00	55.6	5.24	2.75	<1.00	<3.00	0.18	19.80
Mean	844	18.3	0.20	1.68	0.64	1239	9830	1.13	1.00	102.0	15.5	1.79	1.00	3.37	0.24	14.70
Median	858	16.7	0.20	1.02	0.60	1240	9725	1.16	1.00	74.5	9.16	1.00	1.00	3.00	0.17	13.60
Minimum	536	7.7	0.20	1.00	0.60	826	4960	1.00	1.00	51.8	3.47	1.00	1.00	3.00	0.10	8.81
Maximum	1260	37.4	0.20	6.73	0.70	1750	18300	1.32	1.00	235.0	80.50	3.29	1.00	6.71	0.87	25.70
No. of samples	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90th percentile	1044	31.1	0.20	2.22	0.70	1588	12990	1.27	1.00	159.0	21.30	2.98	1.00	3.37	0.39	21.20
LOD	20	2	0.2	1	0.6	10	50	1	1	10	1	1	1	3	0.1	2.0

Notes: Source: Environment Agency (2014)
DW = dry weight

Table 6.4 Primary data for straw: GCMS semi-volatile screen [1,2] (mg/kg DW)

(a)

Sample ID	1-hexacosene	1,19-eicosadiene	13-octadecanal	14,16-hentriacontanedione	1-nonadecene	1-octadecene	4,22-stigmastadiene-3-one	beta-sitosterol	boscalid	camasterol	campesterol	cyclooctacosane	eicosane	ergosta-4,22-dien--3-one	ergosterol	gamma-sitosterol	hentriacontane
Straw 01a		12				79			11		14					57	
Straw 02a		91					12		20							30	92
Straw 03a	53	31					16									32	13
Straw 04a				120			12				14	134				43	
Straw 05a				110			24				14	400				45	
Straw 06a							26				13				11	30	19
Straw 07a		14			66		22				13					34	
Straw 08a		23				30										26	
Straw 09a							29				15		33			54	58
Straw 10a			26		158			42		11			36	19			

(b)

Sample ID	heptacosane	heptacosyl acetate	hexadecane	hexatriacontane	lup-20(29)-ene-3-one	nonacosane	octacosane	octacosyl acetate	octadecanal	octadecane	oxirane,heptadecyl-	pentatriacontane	squalene	stigmast-3,6-dione, (5.alpha.)-cane	stigmast-4-en-3-one	stigmasten-4-en-3-one	stigmasterol	tetracosane
Straw 01a			22				82	154	73		27	17			40		15	
Straw 02a		14				50	25	90							27			
Straw 03a					13						11		12		42		22	49
Straw 04a					10	31									29		25	
Straw 05a	20			28	11	85									59		21	
Straw 06a					25									16	48		21	21
Straw 07a					25	30									41		27	
Straw 08a		61			15										33		18	
Straw 09a					15	30									70		18	
Straw 10a					11											53	14	

Notes: [1] Analytes >10 mg/kg (DW) only; analytes not detected or those with <10mg/kg (DW) have not been reported.
[2] The compounds identified at concentrations greater than the detection level during the GCMS screen are believed to be, in the vast majority of cases, naturally occurring substances within the sample matrix, rather than pollutants.
Source: Environment Agency (2014, Table 8.5)

7 Primary data

7.1 Statistical analysis of data

All 'less than' values were taken as the measured value. The mean, median, minimum, maximum and 90th percentile were calculated for each analyte.

Box plots can be used to graphically represent groups of quantitative data. The sample minimum, lower quartile (Q1), median (Q2), upper quartile (Q3) and sample maximum are used. The median is indicated by the horizontal line that runs across the box. The top of the box is 75th percentile (upper quartile or Q3). The bottom of the box is the 25th percentile (lower quartile or Q1). The interquartile range is represented by the height of the box (Q3 – Q1). A smaller interquartile range indicates less variability in the dataset while a larger interquartile range indicates a variable dataset. Whiskers extend out of the box to represent the sample minimum and maximum. Outliers are plotted as asterisks and are defined as data points that are 1.5 times the interquartile range.

Outliers can adversely affect the statistical analysis by:

- giving serious bias or influence to estimates that may be of less interest
- increasing the error variance and reducing the power of statistical tests
- decreasing normality (if non-random) and altering the odds of type I and II errors

A box and whisker plot of phosphorus concentration in straw is shown in Figure 7.1. This diagram demonstrates the issue of outliers in the dataset.

It is important to provide a reasonable sized dataset for comparison purposes. Where there is sufficient sample size (≥10) to calculate a 90th percentile of the data, the 90th percentile has been calculated.

7.1.1 Organics analytical data

Due to difficulties encountered during sample preparation, the limit of detection (LOD) for some analytes was elevated above the target limit of detection. This was particularly the case for many of the organics analyses where all the analytical results were less than a LOD. Due to the difficult nature of the matrices the LODs achieved varied across different samples.

The Environment Agency considers that these natural, non-waste materials do not contain the substances analysed for. A decision has been taken that in these cases the 90th percentile has been replaced by a target concentration corresponding to the lowest LOD actually achieved for any of the comparators for that substance. Those results are highlighted in red in the tables 7.1 to 7.8.

We consider this a reasonable and proportionate position.

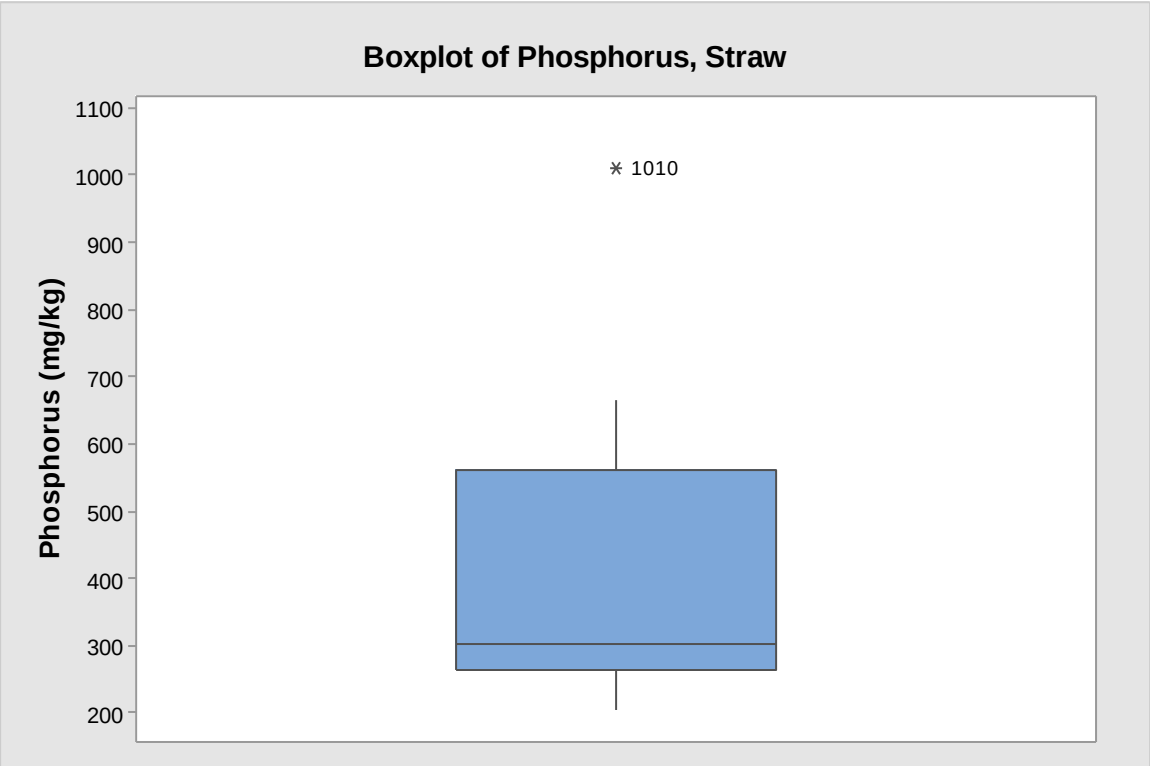

Figure 7.1 Boxplot of phosphorus, straw

7.2 Using the data tables

Data are presented in tables summarising:

- physical properties
- metals
- microbiological contaminants
- organic contaminants

We recommend comparing the concentrations of analytes in the comparators dataset to the concentrations in the waste-derived material, paying attention to the higher values. This comparison does not constitute a pass/fail test or an end of waste view. It will provide an indication of whether the waste material contains similar levels of analytes to non-waste materials and whether an end-of-waste application may be appropriate or that further analysis or improved treatment processes may be warranted.

Due to difficulties encountered during sample preparation, the limit of detection (LOD) for some analytes was elevated above the target limit of detection.

7.3 Primary data tables

Primary data are shown in Tables 7.1 to 7.8.

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Table 7.1 Primary data for straw: physical properties

Sample ID	Moisture content air dried @ 105°C	Dry solids @ 30°C	Dry solids @ 105°C	LoI @ 500°C	PSD 2–20 mm	PSD 20–50 mm	PSD > 50 mm	Loose bulk density	Conductivity	pH
	%	%	%	%	%	%	%	kg/m^3	mS/cm	
Straw 01	15.8	92.5	84.2	94.3	94.8	<0.1	<0.1	31	3.890	7.83
Straw 02	16.6	92.3	83.4	95.2	40.0	<0.1	<0.1	62	2.910	6.32
Straw 03	10.5	91.4	89.5	96.4	100.0	<0.1	<0.1	35	9.990	7.22
Straw 04	9.9	92.2	90.1	94.1	100.0	<0.1	<0.1	43	12.200	8.19
Straw 05	16.6	89.9	83.4	92.7	100.0	<0.1	<0.1	77	18.200	6.94
Straw 06	16.2	85.6	83.8	95.7	100.0	<0.1	<0.1	58	3.680	7.37
Straw 07	10.4	90.5	89.6	95.7	100.0	<0.1	<0.1	36	10.200	7.72
Straw 08	13.5	88.9	86.5	91.7	100.0	<0.1	<0.1	39	11.800	7.22
Straw 09	10.9	92.1	89.1	95.2	100.0	<0.1	<0.1	37	3.070	6.86
Straw 10	10.8	91.0	89.2	96.6	99.8	<0.1	<0.1	17	7.640	7.63
Mean	13.1	90.6	86.9	94.8	93.5	0.1	0.1	44	8.358	7.33
Median	12.2	91.2	87.8	95.2	100.0	0.1	0.1	38	8.815	7.30
Minimum	9.9	85.6	83.4	91.7	40.0	0.1	0.1	17	2.910	6.32
Maximum	16.6	92.5	90.1	96.6	100.0	0.1	0.1	77	18.200	8.19
No. of samples	10	10	10	10	10	10	10	10	10	10
90th percentile	16.6	92.3	89.7	96.4	100.0	0.1	0.1	64	12.800	7.87
LOD	n/a	0.5	0.5	0.5	n/a	n/a	n/a	n/a	0.01	0.2

n/a = not applicable

Table 7.2 Primary data for straw: metals (mg/kg DW)

(a)

Sample ID	Al	Sb	As	Ba	Be	Bo	Cd	Ca	Cr	Cr VI	Co	Cu	Fe	Pb	Li
Straw 01	<50.0	<1	0.738	35.5	<0.1	2.30	<0.200	2060	<0.5	<0.6	<0.1	2.57	<200	<1	<1
Straw 02	53.8	<1	0.764	22.3	<0.1	24.30	0.262	11400	<0.5	<0.6	<0.1	2.13	<200	<1	<1
Straw 03	89.6	<1	0.912	16.7	<0.1	3.02	<0.200	3700	<0.5	<1.2	<0.1	1.70	<200	<1	<1
Straw 04	<50.0	<1	0.839	46.4	<0.1	4.11	<0.200	3890	<0.5	<1.2	<0.1	1.77	<200	<1	<1
Straw 05	70.7	<1	0.940	12.5	<0.1	19.20	<0.200	12300	<0.5	<0.6	<0.1	1.66	<200	<1	<1
Straw 06	67.9	<1	0.973	32.5	<0.1	22.30	0.283	13400	<0.5	<1.2	<0.1	4.17	<200	<1	<1
Straw 07	<50.0	<1	0.798	15.8	<0.1	5.07	<0.200	4450	<0.5	<0.6	<0.1	2.49	<200	<1	<1
Straw 08	<50.0	<1	0.898	18.3	<0.1	4.08	<0.200	3580	<0.5	<1.2	<0.1	1.45	<200	<1	<1
Straw 09	<50.0	<1	0.798	14.0	<0.1	2.94	<0.200	2730	<0.5	11	<0.1	1.62	<200	<1	<1
Straw 10	<50.0	<1	0.592	34.1	<0.1	4.22	<0.200	4460	<0.5	<0.6	<0.1	3.13	<200	<1	<1
Mean	58.2	1	0.825	24.8	0.1	9.15	0.215	6197	0.5	1.9	0.1	2.27	200	1	1
Median	50.0	1	0.819	20.3	0.1	4.17	0.200	4170	0.5	0.9	0.1	1.95	200	1	1
Minimum	50.0	1	0.592	12.5	0.1	2.30	0.200	2060	0.5	0.6	0.1	1.45	200	1	1
Maximum	89.6	1	0.973	46.4	0.1	24.30	0.283	13400	0.5	11	0.1	4.17	200	1	1
No. of samples	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90th percentile	72.6	1	0.943	36.6	0.1	22.50	0.264	12410	0.5	2.2	0.1	3.23	200	1	1
LOD	50	1	0.5	0.5	0.1	1	0.2	60	0.5	0.6	0.1	1	200	1	1

(b)

Sample ID	Mg	Mn	Hg	Mo	Ni	P	K	Se	Ag	Na	Sr	Tl	Sn	Ti	V	Zn
Straw 01	708	5.04	<0.2	<1.00	<0.6	1010	13000	<1	<1	289.0	4.36	<1	<1	<3	0.108	12.70
Straw 02	953	31.40	<0.2	<1.00	<0.6	301	8830	<1	<1	209.0	19.50	<1	<1	<3	0.120	11.10
Straw 03	357	11.30	<0.2	<1.00	<0.6	380	11100	<1	<1	159.0	4.68	<1	<1	<3	0.186	4.04
Straw 04	575	7.39	<0.2	1.65	<0.6	346	14600	<1	<1	1770.0	14.70	<1	<1	<3	<0.100	2.90
Straw 05	1040	7.65	<0.2	<1.00	<0.6	272	16200	<1	<1	465.0	46.10	<1	<1	<3	0.159	9.37
Straw 06	1180	10.10	<0.2	<1.00	<0.6	666	3470	<1	<1	151.0	47.90	<1	<1	<3	0.136	10.90
Straw 07	196	12.30	<0.2	<1.00	<0.6	262	15700	<1	<1	228.0	16.60	<1	<1	<3	<0.100	2.22
Straw 08	506	23.80	<0.2	3.47	<0.6	304	13100	<1	<1	41.1	12.00	<1	<1	<3	<0.100	2.93
Straw 09	748	5.01	<0.2	<1.00	<0.6	291	12300	<1	<1	24.2	8.10	<1	<1	<3	<0.100	3.98
Straw 10	460	7.91	<0.2	<1.00	<0.6	620	16800	<1	<1	341.0	9.31	<1	<1	<3	<0.100	4.81
Mean	672	12.19	0.2	1.31	0.6	445.2	12510	1	1	367.7	18.33	1	1	3	0.121	6.50
Median	642	9.01	0.2	1.00	0.6	325	13050	1	1	218.5	13.35	1	1	3	0.104	4.43
Minimum	196	5.01	0.2	1.00	0.6	262	3470	1	1	24.2	4.36	1	1	3	0.100	2.22
Maximum	1180	31.40	0.2	3.47	0.6	1010	16800	1	1	1770.0	47.90	1	1	3	0.186	12.70
No. of samples	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90th percentile	1054	24.56	0.2	1.83	0.6	700.4	16260	1	1	595.5	46.28	1	1	3	0.162	11.26
LOD	20	2	0.2	1	0.6	10	50	1	1	10	1	1	1	3	0.1	2

Table 7.3 Primary data for straw: microbiological contaminants

Sample ID	E. coli confirmed	E. coli presumptive	Salmonella
	No. per g WW	No. per g WW	Present/Absent (WW)
Straw 01	1	1	Abs
Straw 02	<1	<1	Abs
Straw 03	<9	<9	Abs
Straw 04	380	380	Abs
Straw 05	<9	<9	Abs
Straw 06	<9	18	Abs
Straw 07	<9	<9	Abs
Straw 08	<9	<9	Abs
Straw 09	<9	<9	Abs
Straw 10	<1	<1	Abs
Mean	43.7	44.6	n/a
Median	9	9	n/a
Minimum	1	1	n/a
Maximum	380	380	n/a
No. of samples	10	10	10
90^{th} percentile	46.1	54.2	n/a
LOD	1	1	n/a

Abs = absent; n/a = not applicable

Table 7.4 Primary data for straw: PAHs (USEPA 16) (μg/kg DW)

(a)

Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(ghi)perylene	Benzo(k)fluoranthene
Straw 01	2.67	<20	<400	<400	<400	<400	<100	<400
Straw 02	5.64	<9	<200	<200	<200	<200	<50	<200
Straw 03	6.16	<20	<400	<400	<400	<400	<30	<400
Straw 04	9.92	<20	<400	<400	<400	<400	<20	<400
Straw 05	<1.00	<10	<300	<300	<300	<300	<10	<300
Straw 06	11.00	<20	<300	<300	<300	<300	<20	<300
Straw 07	<2.00	<20	<400	<400	<400	<400	<100	<400
Straw 08	<2.00	<20	<300	<300	<300	<300	<30	<300
Straw 09	<2.00	<20	<400	<400	<400	<400	<100	<400
Straw 10	<2.00	<20	<400	<400	<400	<400	<100	<400
Mean	4.44	18	350	350	350	350	56	350
Median	2.34	20	400	400	400	400	40	400
Minimum	1.00	9	200	200	200	200	10	200
Maximum	11.00	20	400	400	400	400	100	400
No. of samples	10	10	10	10	10	10	10	10
90th percentile	10.03	9	200	200	200	200	10	200
LOD	0.1	1	20	20	20	20	6	20

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(b)

Sample ID	Chrysene	Dibenzo(ah)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Straw 01	<600	<60	<400	<200	<600	<200	<400	<400
Straw 02	<300	<30	<200	<90	<300	<90	<200	<200
Straw 03	<500	<50	<400	<200	<500	<200	<400	<400
Straw 04	<500	<50	<400	<200	<500	<200	<400	<400
Straw 05	<400	<40	<300	<100	<400	<100	<300	<300
Straw 06	<500	<50	<300	<200	<500	<200	<300	<300
Straw 07	<700	<70	<400	<200	<700	<200	<400	<400
Straw 08	<500	<50	<300	<200	<500	<200	<300	<300
Straw 09	<600	<60	<400	<200	<600	<200	<400	<400
Straw 10	<600	<60	<400	<200	<600	<200	<400	<400
Mean	520	52	350	179	520	179	350	350
Median	500	50	400	200	500	200	400	400
Minimum	300	30	200	90	300	90	200	200
Maximum	700	70	400	200	700	200	400	400
No. of samples	10	10	10	10	10	10	10	10
90th percentile	300	30	200	90	300	90	200	200
LOD	30	3	20	10	30	10	20	20

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

Table 7.5 Primary data for straw: organochlorine pesticides (OCPs) (μg/kg DW)

(a)

Sample ID	1,2,3-Trichlorobenzene	1,2,4-Trichlorobenzene	1,3,5-Trichlorobenzene	2,3,5,6-Tetrachloroaniline	2,3,5,6-Tetrachlorothioanisole	Aldrin	Chlordane -cis [Chlordane – alpha]	Chlordane -trans [Chlordane - gamma]
Straw 01	<20	<20	<20	<40	<20	<40	<40	<40
Straw 02	<7	<7	<9	<20	<9	<20	<20	<20
Straw 03	<10	<10	<20	<40	<20	<40	<40	<40
Straw 04	<10	<10	<20	<40	<20	<40	<40	<40
Straw 05	<10	<10	<10	<30	<10	<30	<30	<30
Straw 06	<10	<10	<20	<30	<20	<30	<30	<30
Straw 07	<20	<20	<20	<40	<20	<40	<40	<40
Straw 08	<10	<10	<20	<30	<20	<30	<30	<30
Straw 09	<20	<20	<20	<40	<20	<40	<40	<40
Straw 10	<20	<20	<20	<40	<20	<40	<40	<40
Mean	14	14	18	35	18	35	35	35
Median	10	10	20	40	20	40	40	40
Minimum	7	7	9	20	9	20	20	20
Maximum	20	20	20	40	20	40	40	40
No. of samples	10	10	10	10	10	10	10	10
90th percentile	7	7	9	20	9	20	20	20
LOD	0.8	0.8	1	2	1	2	2	2

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(b)

Sample ID	Chlorpropham	DDD -op	DDE -op	DDE -pp	DDT -op + DDD pp	DDT -pp	Dichlobenil	Dieldrin
Straw 01	<40	<40	<40	<40	<2	<40	<20	<40
Straw 02	<20	<20	<20	<20	<2	<20	<8	<20
Straw 03	<40	<40	<40	<40	<40	<40	<20	<40
Straw 04	<40	<40	<40	<40	<40	<40	<20	<40
Straw 05	<30	<30	<30	<30	<2	<30	<10	<30
Straw 06	<30	<30	<30	<30	<2	<30	<20	<30
Straw 07	<40	<40	<40	<40	<2	<40	<20	<40
Straw 08	<30	<30	<30	<30	<2	<30	<10	<30
Straw 09	<40	<40	<40	<40	<2	<40	<20	<40
Straw 10	<40	<40	<40	<40	<2	<40	<20	<40
Mean	35	35	35	35	10	35	17	35
Median	40	40	40	40	2	40	20	40
Minimum	20	20	20	20	2	20	8	20
Maximum	40	40	40	40	40	40	20	40
No. of samples	10	10	10	10	10	10	10	10
90th percentile	20	20	20	20	2	20	8	20
LOD	2	2	2	2	2	2	0.9	2

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(c)

Sample ID	Endosulfan A	Endosulfan B	Endrin	HCH -alpha	HCH -beta	HCH -delta	HCH -epsilon	HCH -gamma [lindane]
Straw 01	<40	<40	<40	<40	<40	<40	<40	<40
Straw 02	<20	<20	<20	<20	<20	<20	<20	<20
Straw 03	<40	<40	<40	<40	<40	<40	<40	<40
Straw 04	<40	<40	<40	<40	<40	<40	<40	<40
Straw 05	<30	<30	<30	<30	<30	<30	<30	<30
Straw 06	<30	<30	<30	<30	<30	<30	<30	<30
Straw 07	<40	<40	<40	<40	<40	<40	<40	<40
Straw 08	<30	<30	<30	<30	<30	<30	<30	<30
Straw 09	<40	<40	<40	<40	<40	<40	<40	<40
Straw 10	<40	<40	<40	<40	<40	<40	<40	<40
Mean	35	35	35	35	35	35	35	35
Median	40	40	40	40	40	40	40	40
Minimum	20	20	20	20	20	20	20	20
Maximum	40	40	40	40	40	40	40	40
No. of samples	10	10	10	10	10	10	10	10
90th percentile	20	20	20	20	20	20	20	20
LOD	2	2	2	2	2	2	2	2

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(d)

Sample ID	Heptachlor	Heptachlor epoxide -cis	Heptachlor epoxide - trans	Hexachlorobenzene	Hexachlorobutadiene	Isodrin	Metazachlor	Methoxychlor
Straw 01	<40	<40	<40	<20	<20	<40	<40	<40
Straw 02	<20	<20	<20	<8	<8	<20	<20	<20
Straw 03	<40	<40	<40	<20	<20	<40	<40	<40
Straw 04	<40	<40	<40	<20	<20	<40	<40	<40
Straw 05	<30	<30	<30	<10	<10	<30	<30	<30
Straw 06	<30	<30	<30	<20	<20	<30	<30	<30
Straw 07	<40	<40	<40	<20	<20	<40	<40	<40
Straw 08	<30	<30	<30	<10	<10	<30	<30	<30
Straw 09	<40	<40	<40	<20	<20	<40	<40	<40
Straw 10	<40	<40	<40	<20	<20	<40	<40	<40
Mean	35	35	35	17	17	35	35	35
Median	40	40	40	20	20	40	40	40
Minimum	20	20	20	8	8	20	20	20
Maximum	40	40	40	20	20	40	40	40
No. of samples	10	10	10	10	10	10	10	10
90th percentile	20	20	20	8	8	20	20	20
LOD	2	2	2	0.9	0.9	2	2	2

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(e)

Sample ID	Pendimethalin	Permethrin -cis	Permethrin -trans	Propachlor	Tecnazene	Trifluralin	Vinclozolin
Straw 01	<40	<40	<40	<40	<40	<20	<40
Straw 02	<20	<20	<20	<20	<20	<8	<20
Straw 03	<40	<40	<40	<40	<40	<20	<40
Straw 04	<40	<40	<40	<40	<40	<20	<40
Straw 05	<30	<30	<30	<30	<30	<10	<30
Straw 06	<30	<30	<30	<30	<30	<20	<30
Straw 07	<40	<40	<40	<40	<40	<20	<40
Straw 08	<30	<30	<30	<30	<30	<10	<30
Straw 09	<40	<40	<40	<40	<40	<20	<40
Straw 10	<40	<40	<40	<40	<40	<20	<40
Mean	35	35	35	35	35	17	35
Median	40	40	40	40	40	20	40
Minimum	20	20	20	20	20	8	20
Maximum	40	40	40	40	40	20	40
No. of samples	10	10	10	10	10	10	10
90th percentile	20	20	20	20	20	8	20
LOD	2	2	2	2	2	0.9	2

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

Table 7.6 Primary data for straw: PCBs (μg/kg DW)

(a)

Sample ID	PCB-008	PCB-020	PCB-028	PCB-035	PCB-052	PCB-077	PCB-101	PCB-105	PCB-118
Straw 01	<40	<40	<2	<40	<20	<40	<40	<20	<20
Straw 02	<20	<20	<2	<20	<9	<20	<20	<9	<9
Straw 03	<40	<40	<40	<40	<20	<40	<40	<20	<20
Straw 04	<40	<40	<40	<40	<20	<40	<40	<20	<20
Straw 05	<30	<30	<20	<30	<10	<30	<30	<10	<10
Straw 06	<30	<30	<20	<30	<20	<30	<30	<20	<20
Straw 07	<40	<40	<40	<40	<20	<40	<40	<20	<20
Straw 08	<30	<30	<20	<30	<20	<30	<30	<20	<20
Straw 09	<40	<40	<40	<40	<20	<40	<40	<20	<20
Straw 10	<40	<40	<2	<40	<20	<40	<40	<20	<20
Mean	35	35	23	35	18	35	35	18	18
Median	40	40	20	40	20	40	40	20	20
Minimum	20	20	2	20	9	20	20	9	9
Maximum	40	40	40	40	20	40	40	20	20
No. of samples	10	10	10	10	10	10	10	10	10
90th percentile	20	20	2	20	9	20	20	9	9
LOD	2	2	2	2	1	2	2	1	1

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(b)

Sample ID	PCB-126	PCB-128	PCB-138	PCB-149	PCB-153	PCB-156	PCB-169	PCB-170	PCB-180
Straw 01	<20	<20	<20	<20	<20	<20	<20	<2	<20
Straw 02	<9	<9	<9	<9	<9	<8	<8	<2	<9
Straw 03	<20	<20	<20	<20	<20	<20	<20	<40	<20
Straw 04	<20	<20	<20	<20	<20	<20	<20	<40	<20
Straw 05	<10	<10	<10	<10	<10	<10	<10	<20	<10
Straw 06	<20	<20	<20	<20	<20	<20	<20	<20	<20
Straw 07	<20	<20	<20	<20	<20	<20	<20	<2	<20
Straw 08	<20	<20	<20	<20	<20	<10	<10	<20	<20
Straw 09	<20	<20	<20	<20	<20	<20	<20	<40	<20
Straw 10	<20	<20	<20	<20	<20	<20	<20	<2	<20
Mean	18	18	18	18	18	17	17	19	18
Median	20	20	20	20	20	20	20	20	20
Minimum	9	9	9	9	9	8	8	2	9
Maximum	20	20	20	20	20	20	20	40	20
No. of samples	10	10	10	10	10	10	10	10	10
90th percentile	9	9	9	9	9	8	8	2	9
LOD	1	1	1	1	1	0.9	0.9	2	1

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

Table 7.7 Primary data for straw: phenols (μg/kg DW)

(a)

Sample ID	2,3,4,6-Tetrachlorophenol	2,4,5-Trichlorophenol	2,4-Dichlorophenol	2,4-Dinitrophenol	2-Nitrophenol	3,4-Dimethylphenol [3,4-Xylenol]	3,5-Dimethylphenol [3,5-Xylenol]
Straw 01	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 02	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 03	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 04	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 05	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 06	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 07	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 08	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 09	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 10	<5000	<5000	<5000	<5000	<5000	<5000	<5000
Mean	18500	18500	18500	18500	18500	18500	18500
Median	20000	20000	20000	20000	20000	20000	20000
Minimum	5000	5000	5000	5000	5000	5000	5000
Maximum	20000	20000	20000	20000	20000	20000	20000
No. of samples	10	10	10	10	10	10	10
90th percentile	5000	5000	5000	5000	5000	5000	5000
LOD	1000	1000	1000	1000	1000	1000	1000

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

(b)

Sample ID	4-Chloro-3-methylphenol [*p*-chloro-*m*-cresol]	4-Methylphenol [*p*-Cresol]	DNOC	Dinoseb [2-Methyl-n-propyl-4,6-dinitrophenol]	Pentachlorophenol	Phenol	Resorcinol [1,3-Dihydroxybenzene]
Straw 01	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 02	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 03	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 04	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 05	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 06	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 07	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 08	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 09	<20000	<20000	<20000	<20000	<20000	<20000	<20000
Straw 10	<5000	<5000	<5000	<5000	<5000	<5000	<5000
Mean	18500	18500	18500	18500	18500	18500	18500
Median	20000	20000	20000	20000	20000	20000	20000
Minimum	5000	5000	5000	5000	5000	5000	5000
Maximum	20000	20000	20000	20000	20000	20000	20000
No. of samples	10	10	10	10	10	10	10
90th percentile	5000	5000	5000	5000	5000	5000	5000
LOD	1000	1000	1000	1000	1000	1000	1000

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

Table 7.8 Primary data for straw: BTEX (μg/kg DW)

Sample ID	1,2-Dimethylbenzene [o-Xylene]	Benzene	Dimethylbenzene sum of (1,3- 1,4-)	Ethylbenzene	Toluene [Methylbenzene]
Straw 01	<10	<10	<20	<5	<30
Straw 02	<9	<9	<20	<4	<30
Straw 03	<10	<10	2.48	0.849	6.02
Straw 04	<7	<7	<10	0.834	3.86
Straw 05	<5	<5	<10	<3	<20
Straw 06	<6	<6	<10	<3	<20
Straw 07	<6	<6	<10	<3	<20
Straw 08	<9	<9	<20	<5	3.31
Straw 09	1.44	<10	4.03	0.799	5.98
Straw 10	<20	<20	<40	<10	<60
Mean	8.34	9	14.65	3.548	19.92
Median	8	9	10	3	20
Minimum	1.44	5	2.48	0.799	3.31
Maximum	20	20	40	10	60
No. of samples	10	10	10	10	10
90th percentile	11	5	22	5.5	33
LOD	1	1	2	0.5	3

Numbers in red represent target concentrations, see Section 7.1.1 above for the full explanation

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List of abbreviations

Ag	Silver
Al	Aluminium
As	Arsenic
B	Boron
Ba	Barium
Be	Beryllium
BTEX	Benzene, toluene, ethylbenzene, xylene
C	Carbon
Ca	Calcium
Cd	Cadmium
Chromium VI	Chromium Hexavalent
Co	Cobalt
Cr	Chromium
Cu	Copper
DAD	diode array detection
DCM	dichloromethane
DW	dry weight
EC	electrical conductivity
Fe	Iron
GCMS	gas chromatography–mass spectrometry
Hg	Mercury
HPLC	high performance liquid chromatography
ICP	inductively coupled plasma
HR	high resolution
ICP-OES	inductively coupled plasma optical emission spectrometry
ITEQ	International Toxicity Equivalents
K	Potassium
LE	Leeds laboratory of NLS
Li	Lithium
LOD	limit of detection
LoI	loss on ignition
MCERTS	Environment Agency's Monitoring Certification Scheme

Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
Na	Sodium
Ni	Nickel
NLS	National Laboratory Service [Environment Agency]
NO_2	Nitrogen dioxide
OCP	organochlorine pesticide
P	Phosphorus
PAH	polycyclic aromatic hydrocarbon
Pb	Lead
PCB	polychlorinated biphenyl
PSD	particle size distribution
SAL	Scientific Analysis Laboratories Limited
Sb	Antimony
Se	Selenium
Sn	Tin
Sr	Strontium
TC	total carbon
Ti	Titanium
Tl	Thallium
TN	total nitrogen
USEPA	United States Environmental Protection Agency
V	Vanadium
WW	wet weight
Zn	Zinc

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