Environment Agency

Evidence

Product comparators for materials applied to land: non-waste biochar

Report – SC130040/R6

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Executive summary

This report details the work carried out to characterise non-waste biochar, a key comparator. This information will inform end-of-waste assessments for waste-derived materials intended to replace non-waste biochar as a material applied to land.

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 non-waste biochar 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.

Eleven samples of non-waste biochar 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 non-waste biochar which is defined as an ordinary material comparator that is currently permitted for land application.

This report provides the results from the primary analysis of 11 non-waste biochar samples.

Five other reports cover the following categories of ordinary material comparators:

- non-waste wood
- PAS100 compost
- peat
- soil improver
- straw

2 Definition

Biochar is defined as a solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment that is used for the safe and long-term storage of carbon in the environment and for soil improvement (Shackley et al. 2013).

The equipment used to create biochar can vary greatly in complexity from a simple drum of biomass heated over a fire to an automatic feed, continuous flow unit recycling heat and possibly producing bio-electricity (Shackley et al. 2013). Biochar is a form of charcoal but may be produced at a lower temperature and at a finer grade to ease application to land. Biochar is also known as horticultural charcoal.

Biochar is often used in the following market sectors (Shackley et al. 2013):

- land restoration and soft landscape operations
- domestic or professional horticulture
- agriculture and soil-grown horticulture
- forestry

Non-waste biochar is often defined by the feedstock used. This can include one of the following non-wastes:

- British hardwood (similar to charcoal production but the end product has a finer grading to allow application to land)
- wheat straw
- barley straw
- oil seed rape and other cereal straw
- forestry residues
- arboricultural arisings
- wood chip
- sawmill co-product (sawdust)
- wood pellets
- Miscanthus, switchgrass and short rotation coppice
- reed canary grass
- short rotation forestry

2.1 Material properties relevant to use

Adding biochar to soil sequesters carbon and may improve soil condition. UK agricultural benefits may come from reduced need for fertiliser through increased fertiliser efficiency and reduced drought stress in drought-prone areas (POST 2010).

Most biochars contain some nitrogen. This nitrogen may count towards the total amount that is allowed to be applied in a Nitrate Vulnerable Zone (NVZ). Some feedstocks may contain materials other than the intended feedstock such as plastics, stones, metals or glass (Shackley et al. 2013).

3 Comparator sub types

Eleven charcoal samples were obtained from a variety of suppliers across England. All feedstocks were non-waste wood and non-waste biochar was produced in the same way as charcoal in a simple drum over a fire or in a charcoal burner.

4 Material sources and sampling procedure

An internet search was used to produce a list of non-waste biochar suppliers. Non-waste biochar samples were requested from all these suppliers and samples were collected from those willing to participate.

No sampling standards for non-waste biochar were identified during the literature review. Non-waste biochar was sampled in accordance with BS EN 12579:2013 (BSI 2013).

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, 'SAL' refers to Scientific Laboratories Ltd and 'ESG' refers to Environmental Scientifics Group Limited.

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: elemental analysis

Parameter/ determinand	Test method used	Unit
Organic carbon	LE I TOC 01 – combusted with oxygen, thermal conductivity detection	%
Hydrogen	ESG documented in-house method by Exeter CE440 Elemental Analyser	%
Nitrogen	ESG documented in-house method by Exeter CE440 Elemental Analyser	%
Oxygen	ESG documented in-house method by Exeter CE440 Elemental Analyser	%
H:organic carbon	Calculated value	
C:N	Calculated value	
Sulphate	LE M acid extracted SO_4 (ICP-OES) 01 digestion block – 10% hydrochloric acid extracted under reflux determined by inductively coupled plasma optical emission spectrometry (ICP-OES)	mg/kg
Chloride	LE I halides chloride, bromide and sulphate – water extracted determined directly by ion chromatography on 'as received' sample	mg/kg
Fluoride	LE I fluoride – 1M H_2SO_4 extraction, determined by ion selective electrode on 'as received' sample.	mg/kg
Bromide	LE I halides chloride, bromide and sulphate – water extracted determined directly by ion chromatography on 'as received' sample.	mg/kg
Ammoniacal nitrogen	LE I nutrients (Kone) 01 NH_4, TON, NO_2 – 2M KCl extraction, determined colorimetrically by discrete analyser on 'as received' sample.	mg/kg
Nitrate	Parameter by calculation	mg/kg
Nitrite	LE I nutrients (Kone) 01 NH_4, TON, NO_2 – 2M KCl extraction, determined colorimetrically by discrete analyser on 'as received' sample.	mg/kg
Total oxidised nitrogen	LE I nutrients (Kone) 01 NH_4, TON, NO_2 – 2M KCl extraction, determined colorimetrically by discrete analyser on 'as received' sample.	mg/kg
Neutralising value as CaO	SAL determination of neutralising value – sample is dried and ground. Material is extracted with known volume of hydrochloric acid. A test aliquot from the extraction is titrated against phenolphthalein to the endpoint. The result is calculated from the difference in titres against a blank where the same sample has been extracted without acid.	%

Table 5.3 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 5.4 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
Dioxins and furans	LE O HRMS3 – dioxins; furans – toluene ASE; three-stage clean-up; determined by high resolution GCMS	μg/kg

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

6 Existing data

Two datasets relating to non-waste biochar were identified during the literature review. These are presented in Tables 6.1 and 6.2.

Table 6.1 Limits for quality biochar

	As	Cd	Cr	Cu	Pb	Hg	Mn	Mo	Ni	Se	Zn	PAHs (sum of USEPA16)	Dioxins/ furans	PCBs
	mg/kg												ng/kg	mg/kg 1-TEQ
Maximum limit suggested for high grade quality biochar	10	3	15	40	60	1	3,500	10	10	5	150	<20	<20	<0.5
Maximum limit suggested for standard grade quality biochar	100	39	100	1,500	500	17	Limits set by regulators	75	600	100	2,800	<20	<20	<0.5

Notes: Source: Shackley et al. (2013)
TEQ = toxic equivalence

Table 5.2 Chemical constituents of different biochars

Biochar feedstock	pH	C	N	C:N	P	K	Production temperature
		g/kg	g/kg		g/kg	g/kg	ºC
Bark: *Acacia mangium*	7.4	398	10.4	38			260–360
Coconut shell		690	9.4	73			500
Corn residue		675	9.3	73		10.4	350
Corn residue		790	9.2	86		6.7	600
Peanut shell		499	11	45	0.6	6.2	400
Pecan shell	7.6	834	3.4	245			700
Pecan shell		880	4	220			700
Rice straw		490	13.2	37			500
Sugarcane bagasse		710	17.7	40			500
Wood: unknown		708	10.9	65	6.8	0.9	
Wood: Eucalyptus	7	824	5.7	144	0.6		350
Wood: *Pinus ponderosa*, *Pseuditsuga menziesii*	6.7	740	16.6	45	13.6		Wildfire
Wood: Quercus		759	1	759		1.1	350
Wood: Quercus		884	1.2	737		2.2	600

Notes: Source: Atkinson et al. (2010)

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 calcium concentration in non-waste biochar is shown in Figure 7.1. This diagram demonstrates the issue of outliers in the dataset.

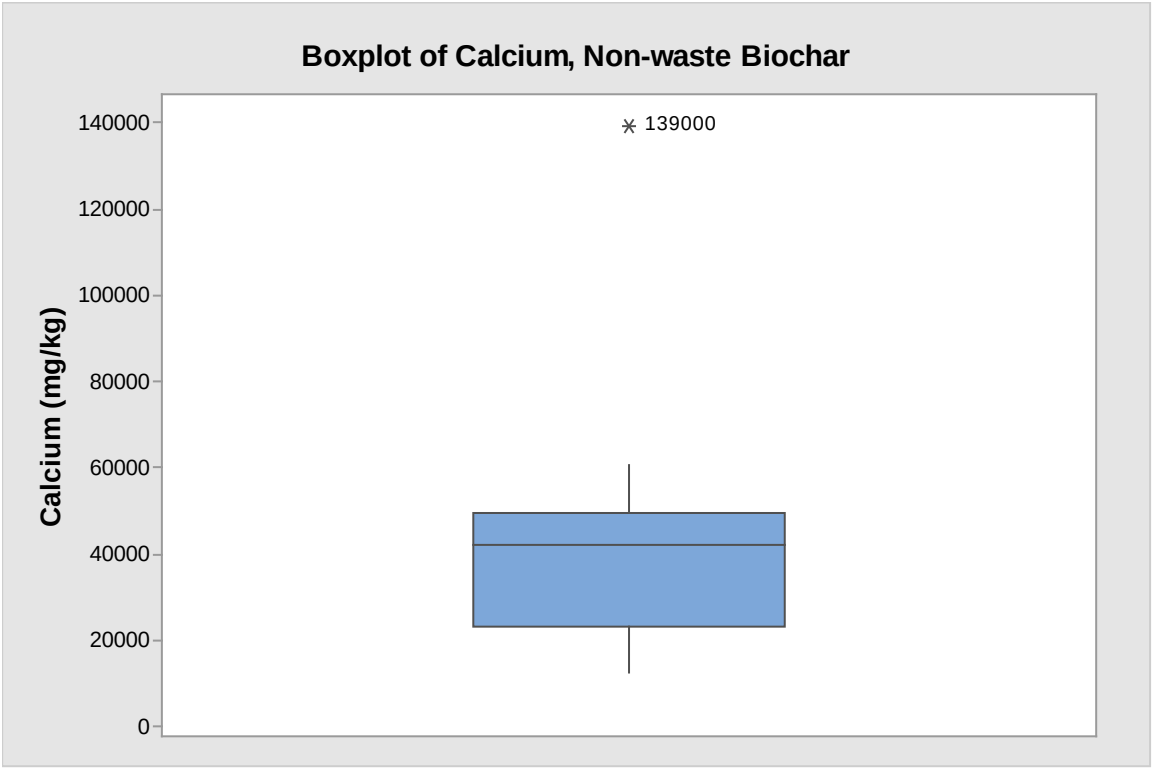

Figure 7.1 Boxplot of calcium, non-waste biochar

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.

7.2 Using the data tables

Data are presented in tables summarising:

- physical properties
- metals
- 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 7.17.

Table 6.1 Primary data for non-waste biochar: beneficial properties

Sample ID	Fluoride (acid extractable)	Bromide	Chloride	Sulphate as SO_4 (acid extractable)	Ammoniacal nitrogen	Nitrite	Nitrate	Nitrogen (total oxidised)	Organic carbon as C
	mg/kg (DW)								% (DW)
Biochar 01	<50	<0.40	17.5	<200	8.55	<0.100	<4.00	<4.00	70.2
Biochar 02	<40	3.46	96.3	1580	<3.00	<0.200	<5.00	<5.00	52.0
Biochar 03	<40	<0.50	12.2	611	<3.00	<0.200	<5.00	<5.00	56.0
Biochar 04	<40	<0.30	76.6	487	<2.00	0.192	<2.81	<3.00	80.9
Biochar 05	<60	<0.40	44.5	295	<3.00	<0.100	<18.70	18.70	58.3
Biochar 06	<40	1.46	196.0	1940	<2.00	<0.100	<16.30	16.30	43.5
Biochar 07	<40	2.06	214.0	2270	6.54	0.119	<2.88	<3.00	22.8
Biochar 08	<40	<0.30	49.3	675	<2.00	<0.100	<3.00	<3.00	68.0
Biochar 09	<50	<0.30	318.0	2590	2.22	<0.100	<9.81	9.81	55.3
Biochar 10	<40	0.69	187.0	861	<2.00	<0.100	<3.00	<3.00	55.4
Biochar 11	<50	17.20	1830.0	408	<2.00	0.250	<3.75	<4.00	29.3
Mean	45	2.46	276.5	1083	3.30	0.142	6.75	6.80	53.8
Median	40	0.50	96.3	675	2.22	0.100	4.00	4.00	55.4
Minimum	40	0.30	12.2	200	2.00	0.100	2.81	3.00	22.8
Maximum	60	17.20	1830.0	2590	8.55	0.250	18.70	18.70	80.9
No. of samples	11	11	11	11	11	11	11	11	11
90^{th} percentile	50	3.46	318.0	2270	6.54	0.200	16.30	16.30	70.2
LOD	40	0.3	3	200	2	0.1	0	3	0.3

DW = dry weight

Table 7.2 Primary data for non-waste biochar: elemental analysis

Sample ID	Carbon	Hydrogen	Nitrogen	Oxygen	C:N ratio	H:organic carbon ratio
	%	%	%	%		
Biochar 01	63.89	2.10	1.25	3.6	51	0.03
Biochar 02	30.54	0.76	0.19	3.2	161	0.01
Biochar 03	37.22	0.75	0.29	1.1	128	0.01
Biochar 04	78.92	1.44	0.77	4.5	102	0.02
Biochar 05	63.06	1.19	0.33	3.9	191	0.02
Biochar 06	53.76	0.95	0.48	1.2	112	0.02
Biochar 07	31.94	0.64	0.32	6.4	100	0.03
Biochar 08	75.44	1.51	0.66	3.9	114	0.02
Biochar 09	76.59	1.45	0.81	2.8	95	0.03
Biochar 10	58.71	2.04	0.61	6.0	96	0.04
Biochar 11	40.06	0.99	0.29	2.6	138	0.03
Mean	55.47	1.26	0.55	3.6	117	0.02
Median	58.71	1.19	0.48	3.6	112	0.02
Minimum	30.54	0.64	0.19	1.1	51	0.01
Maximum	78.92	2.10	1.25	6.4	191	0.04
No. of samples	11	11	11	11	11	11.0
90^{th} percentile	76.59	2.04	0.81	6.0	161	0.03
LOD	0.41	0.06	0.1	Calculated	Calculated	Calculated

Table 7.3 Primary data for non-waste biochar: physical properties

Sample ID	Moisture content air dried @ 105°C	Dry solids @ 30°C	Dry solids @ 105°C	LoI @ 500°C	Neutralising value as CaO	PSD 2–20 mm	PSD 20–50 mm	PSD >50 mm	Loose bulk density	Conductivity	pH
	%	%	%	%	%	%	%	%	kg/m^3	mS/cm	
Biochar 01	13.9	81.7	86.1	89.0	2.1	4.9	<0.1	<0.1	346	0.281	7.73
Biochar 02	36.7	65.7	63.3	66.7	29.8	7.5	<0.1	<0.1	514	3.980	9.79
Biochar 03	52.6	59.5	47.4	83.4	22.3	3.9	<0.1	<0.1	434	0.186	8.80
Biochar 04	6.3	95.5	93.7	91.5	14.0	4.3	<0.1	<0.1	181	1.770	9.35
Biochar 05	52.3	67.1	47.7	92.0	2.6	29.3	<0.1	<0.1	292	0.381	7.46
Biochar 06	20.3	91.0	79.7	66.7	10.0	9.6	<0.1	<0.1	340	4.550	9.31
Biochar 07	5.1	96.7	94.9	41.9	8.5	5.2	<0.1	<0.1	393	0.604	9.25
Biochar 08	8.4	94.8	91.6	90.0	6.3	1.2	<0.1	<0.1	196	1.310	8.21
Biochar 09	16.0	86.3	84.0	83.9	5.7	42.6	<0.1	<0.1	156	0.878	7.81
Biochar 10	7.6	95.1	92.4	93.4	4.9	17.1	<0.1	<0.1	424	3.160	8.87
Biochar 11	30.3	82.0	69.7	95.9	2.7	25.2	<0.1	<0.1	435	0.725	9.34
Mean	22.7	83.2	77.3	81.3	9.9	13.7	0.1	0.1	337	1.620	8.72
Median	16.0	86.3	84.0	89.0	6.3	7.5	0.1	0.1	346	0.878	8.87
Minimum	5.1	59.5	47.4	41.9	2.1	1.2	0.1	0.1	156	0.186	7.46
Maximum	52.6	96.7	94.9	95.9	29.8	42.6	0.1	0.1	514	4.550	9.79
No. of samples	11	11	11	11	11	11	11	11	11	11	11
90th percentile	52.3	95.5	93.7	93.4	22.3	29.3	0.1	0.1	435	3.980	9.35
LOD	n/a	0.5	0.5	0.5	0.1	0	0	0	n/a	0.01	0.2

n/a = not applicable

Table 7.4 Primary data for non-waste biochar: metals (mg/kg DW)

(a)

Sample ID	Al	Sb	As	Ba	Be	Bo	Cd	Ca	Cr	Cr VI	Co	Cu	Fe	Pb	Li
Biochar 01	691	<1	<0.500	31.5	<0.100	8.0	<0.200	12200	4.120	<0.6	1.080	6.96	21000	6.23	<1.00
Biochar 02	6600	<1	3.450	398.0	0.253	82.4	0.238	60400	9.810	<0.6	3.540	26.50	5220	23.10	8.98
Biochar 03	1580	<1	0.714	46.9	<0.100	39.5	<0.200	40400	3.770	<0.6	0.821	11.60	3910	5.33	1.96
Biochar 04	264	<1	<0.500	35.5	<0.100	31.1	<0.200	34200	0.672	<0.6	0.110	4.58	294	3.70	<1.00
Biochar 05	162	<1	<0.500	73.9	<0.100	17.6	<0.200	14300	2.260	<0.6	0.415	5.01	2970	5.73	<1.00
Biochar 06	4060	<20	3.220	286.0	0.182	80.7	0.392	45200	9.710	<0.6	3.550	22.70	6890	12.50	4.37
Biochar 07	5610	<20	2.790	60.8	0.342	27.4	0.523	139000	8.890	<0.6	4.050	16.70	9280	14.00	7.13
Biochar 08	718	<20	<0.500	205.0	<0.100	40.8	0.385	41700	2.840	<0.6	0.455	7.37	905	3.92	1.36
Biochar 09	1430	<1	1.740	66.5	<0.100	21.0	0.258	49500	3.520	<0.6	1.110	10.30	2400	5.06	1.08
Biochar 10	431	<1	<0.500	72.5	<0.100	43.2	<0.200	45300	1.890	<1.2	0.190	12.30	842	1.42	<1.00
Biochar 11	192	<1	1.560	21.8	<0.100	22.8	<0.200	23000	3.540	<0.6	0.222	8.40	4890	1.10	2.35
Mean	1976	6	1.452	118.0	0.143	37.7	0.272	45927	4.638	0.7	1.413	12.04	5327	7.46	2.84
Median	718	1	0.714	66.5	0.100	31.1	0.200	41700	3.540	0.6	0.821	10.30	3910	5.33	1.36
Minimum	162	1	0.500	21.8	0.100	8.0	0.200	12200	0.672	0.6	0.110	4.58	294	1.10	1.00
Maximum	6600	20	3.450	398.0	0.342	82.4	0.523	139000	9.810	1.2	4.050	26.50	21000	23.10	8.98
No. of samples	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
90^{th} percentile	5610	20	3.220	286.0	0.253	80.7	0.392	60400	9.710	0.6	3.550	22.70	9280	14.00	7.13
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
Biochar 01	397	481	<0.2	<1	5.40	277	1810	<1.0	<1.00	102	28.5	<1	<1.00	17.8	2.630	40.2
Biochar 02	7380	3040	<0.2	<1	10.30	2590	13300	1.2	<1.00	1120	267.0	<1	1.30	114.0	10.600	125.0
Biochar 03	1860	896	<0.2	<1	3.81	1050	2580	<1.0	<1.00	243	48.4	<1	<1.00	35.7	3.510	92.6
Biochar 04	1680	179	<0.2	<1	1.14	1370	7810	<1.0	<1.00	268	117.0	<1	<1.00	4.7	0.479	29.7
Biochar 05	650	849	<0.2	<1	2.60	445	2040	<1.0	<1.00	126	36.1	<1	<1.00	7.3	0.906	47.0
Biochar 06	3180	3520	<0.2	<1	6.65	1640	13300	<1.0	1.07	759	163.0	<1	<1.00	131.0	8.730	65.7
Biochar 07	1930	689	<0.2	<1	7.89	2100	4720	<1.0	<1.00	547	298.0	<1	1.03	119.0	12.500	72.7
Biochar 08	2430	1320	<0.2	<1	2.99	1140	4890	<1.0	<1.00	366	78.2	<1	<1.00	26.5	1.630	39.5
Biochar 09	1870	943	<0.2	<1	2.43	972	4650	<1.0	<1.00	704	254.0	<1	<1.00	23.2	3.450	93.7
Biochar 10	2090	113	<0.2	<1	1.37	1610	13200	<1.0	<1.00	1190	96.4	<1	<1.00	8.6	0.851	31.1
Biochar 11	778	135	<0.2	<1	1.05	1210	7060	<1.0	<1.00	395	38.5	<1	6.16	5.7	0.551	59.1
Mean	2204	1106	0.2	1	4.15	1309	6851	1.0	1.01	529	129.6	1	1.50	44.9	4.167	63.3
Median	1870	849	0.2	1	2.99	1210	4890	1	1	395	96.4	1	1.00	23.2	2.630	59.1
Minimum	397	113	0.2	1	1.05	277	1810	1	1	102	28.5	1	1.00	4.7	0.479	29.7
Maximum	7380	3520	0.2	1	10.30	2590	13300	1.2	1.07	1190	298.0	1	6.16	131.0	12.500	125.0
No. of samples	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
90^{th} percentile	3180	3040	0.2	1	7.89	2100	13300	1	1	1120	267.0	1	1.30	119.0	10.600	93.7
LOD	20	2	0.2	1	0.60	10	50	1	1	10	1	1	1	3	0.1	2

Table 7.5 Primary data for non-waste biochar: heptachlorodibenzo-*p*-dioxin

Sample ID	1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin ng/kg (ITEQ)	1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin ng/kg (DW)	Heptachlorodibenzo-*p*-dioxin ng/kg (DW) sum of isomers
Biochar 01	<0.0300	<3.00	<3
Biochar 02	0.1280	12.80	22.4
Biochar 03	<0.0300	<3.00	<3
Biochar 04	<0.0300	<3.00	<3
Biochar 05	0.0442	4.42	7.44
Biochar 06	<0.0300	<3.00	<3
Biochar 07	<0.0300	<3.00	<3
Biochar 08	<0.0300	<3.00	<3
Biochar 09	0.0731	7.31	<3
Biochar 10	<0.0300	<3.00	<3
Biochar 11	<0.0300	<3.00	<3
Mean	0.0441	4.41	5.17
Median	0.0300	3.00	3
Minimum	0.0300	3.00	3
Maximum	0.1280	12.8	22.4
No. of samples	11	11	11
90^{th} percentile	0.0731	7.31	7.44
LOD	0.03	3	3

ITEQ = International Toxicity Equivalents

Table 7.6 Primary data for non-waste biochar: hexachlorodibenzo-*p*-dioxin

Sample ID	1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin	1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin	1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin	1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin	1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin	1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin	Hexachlorodibenzo-*p*-dioxin
	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (DW) sum of isomers
Biochar 01	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 02	<0.09	<0.9	<0.07	<0.7	<0.2	<1	4.34
Biochar 03	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 04	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 05	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 06	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 07	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 08	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 09	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 10	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Biochar 11	<0.09	<0.9	<0.07	<0.7	<0.2	<1	<0.70
Mean	0.09	0.9	0.07	0.7	0.2	1	1.03
Median	0.09	0.9	0.07	0.7	0.2	1	0.7
Minimum	0.09	0.9	0.07	0.7	0.2	1	0.7
Maximum	0.09	0.9	0.07	0.7	0.2	1	4.34
No. of samples	11	11	11	11	11	11	11
90^{th} percentile	0.09	0.9	0.07	0.7	0.2	1	0.7
LOD	0.09	0.9	0.07	0.7	0.2	1	0.7

Table 7.7 Primary data for non-waste biochar: pentachlorodibenzo-*p*-dioxin

Sample ID	1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin ng/kg (ITEQ)	1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin ng/kg (DW)	Pentachlorodibenzo-*p*-dioxin ng/kg (DW) sum of isomers
Biochar 01	<0.2	<0.4	<0.4
Biochar 02	<0.2	<0.4	<0.4
Biochar 03	<0.2	<0.4	<0.4
Biochar 04	<0.2	<0.4	<0.4
Biochar 05	<0.2	<0.4	<0.4
Biochar 06	<0.2	<0.4	<0.4
Biochar 07	<0.2	<0.4	<0.4
Biochar 08	<0.2	<0.4	<0.4
Biochar 09	<0.2	<0.4	<0.4
Biochar 10	<0.2	<0.4	<0.4
Biochar 11	<0.2	<0.4	<0.4
Mean	0.2	0.4	0.4
Median	0.2	0.4	0.4
Minimum	0.2	0.4	0.4
Maximum	0.2	0.4	0.4
No. of samples	11	11	11
90^{th} percentile	0.2	0.4	0.4
LOD	0.2	0.4	0.4

Table 7.8 Primary data for non-waste biochar: tetrachlorodibenzo-*p*-dioxin

Sample ID	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin ng/kg (ITEQ)	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin ng/kg (DW)	Tetrachlorodibenzo-*p*-dioxin ng/kg (DW) sum of isomers
Biochar 01	<0.3	<0.3	<0.3
Biochar 02	<0.3	<0.3	<0.3
Biochar 03	<0.3	<0.3	<0.3
Biochar 04	<0.3	<0.3	<0.3
Biochar 05	<0.3	<0.3	<0.3
Biochar 06	<0.3	<0.3	<0.3
Biochar 07	<0.3	<0.3	<0.3
Biochar 08	<0.3	<0.3	<0.3
Biochar 09	<0.3	<0.3	<0.3
Biochar 10	<0.3	<0.3	<0.3
Biochar 11	<0.3	<0.3	<0.3
Mean	0.3	0.3	0.3
Median	0.3	0.3	0.3
Minimum	0.3	0.3	0.3
Maximum	0.3	0.3	0.3
No. of samples	11	11	11
90^{th} percentile	0.3	0.3	0.3
LOD	0.3	0.3	0.3

Table 7.9 Primary data for non-waste biochar: octachlorodibenzo-*p*-dioxin

Sample ID	Octachlorodibenzo-*p*-dioxin ng/kg (ITEQ)	Octachlorodibenzo-*p*-dioxin ng/kg (DW)
Biochar 01	<0.0030	<4.0
Biochar 02	0.1200	120.0
Biochar 03	<0.0030	<4.0
Biochar 04	<0.0030	<4.0
Biochar 05	0.0285	28.5
Biochar 06	<0.0030	<4.0
Biochar 07	<0.0030	<4.0
Biochar 08	<0.0030	<4.0
Biochar 09	0.0623	62.3
Biochar 10	<0.0030	<4.0
Biochar 11	0.0034	<4.0
Mean	0.0214	22.1
Median	0.0030	4.0
Minimum	0.0030	4.0
Maximum	0.1200	120.0
No. of samples	11	11.0
90^{th} percentile	0.0623	62.3
LOD	0.003	4

Table 7.10 Primary data for non-waste biochar: heptachlorodibenzofuran

Sample ID	1,2,3,4,6,7,8-Heptachloro dibenzofuran	1,2,3,4,6,7,8-Heptachloro dibenzofuran	1,2,3,4,7,8,9-Heptachloro dibenzofuran	1,2,3,4,7,8,9-Heptachloro dibenzofuran	Heptachlorodibenzofuran
	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (DW) sum of isomers
Biochar 01	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 02	0.0424	4.24	<0.008	<0.9	4.43
Biochar 03	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 04	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 05	<0.0200	<2.00	<0.008	<0.9	1.79
Biochar 06	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 07	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 08	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 09	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 10	<0.0200	<2.00	<0.008	<0.9	<0.90
Biochar 11	<0.0200	<2.00	<0.008	<0.9	<0.90
Mean	0.0220	2.20	0.008	0.9	1.30
Median	0.0200	2.00	0.008	0.9	0.9
Minimum	0.0200	2.00	0.008	0.9	0.9
Maximum	0.0424	4.24	0.008	0.9	4.43
No. of samples	11	11	11	11	11
90^{th} percentile	0.0200	2.00	0.008	0.9	1.79
LOD	0.02	2	0.008	0.9	1.30

Table 7.11 Primary data for non-waste biochar: hexachlorodibenzofuran

Sample ID	1,2,3,4,7,8-Hexachloro dibenzofuran	1,2,3,4,7,8-Hexachloro dibenzofuran	1,2,3,6,7,8-Hexachloro dibenzofuran	1,2,3,6,7,8-Hexachloro dibenzofuran	1,2,3,7,8,9-Hexachloro dibenzofuran	1,2,3,7,8,9-Hexachloro dibenzofuran	2,3,4,6,7,8-Hexachloro dibenzofuran	2,3,4,6,7,8-Hexachloro dibenzofuran	Hexachloro dibenzofuran
	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (DW) sum of isomers
Biochar 01	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 02	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 03	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 04	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 05	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 06	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 07	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 08	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 09	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 10	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Biochar 11	<0.07	<0.7	<0.04	<0.4	<0.08	<0.8	<0.2	<2	<0.4
Mean	0.07	0.7	0.04	0.4	0.08	0.8	0.2	2	0.4
Median	0.07	0.7	0.04	0.4	0.08	0.8	0.2	2	0.4
Minimum	0.07	0.7	0.04	0.4	0.08	0.8	0.2	2	0.4
Maximum	0.07	0.7	0.04	0.4	0.08	0.8	0.2	2	0.4
No. of samples	11	11	11	11	11	11	11	11	11
90^{th} percentile	0.07	0.7	0.04	0.4	0.08	0.8	0.2	2	0.4
LOD	0.07	0.7	0.04	0.4	0.08	0.8	0.2	2	0.4

Table 7.12 Primary data for non-waste biochar: pentachlorodibenzofuran

Sample ID	1,2,3,7,8-Pentachlorodibenzofuran	1,2,3,7,8-Pentachlorodibenzofuran	2,3,4,7,8-Pentachlorodibenzofuran	2,3,4,7,8-Pentachlorodibenzofuran	Pentachlorodibenzofuran
	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (ITEQ)	ng/kg (DW)	ng/kg (DW) sum of isomers
Biochar 01	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 02	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 03	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 04	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 05	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 06	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 07	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 08	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 09	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 10	<0.03	<0.5	<0.2	<0.4	<0.4
Biochar 11	<0.03	<0.5	<0.2	<0.4	<0.4
Mean	0.03	0.5	0.2	0.4	0.4
Median	0.03	0.5	0.2	0.4	0.4
Minimum	0.03	0.5	0.2	0.4	0.4
Maximum	0.03	0.5	0.2	0.4	0.4
No. of samples	11	11	11	11	11
90^{th} percentile	0.03	0.5	0.2	0.4	0.4
LOD	0.03	0.5	0.2	0.4	0.4

Table 7.13 Primary data for non-waste biochar: tetrachlorodibenzofuran

Sample ID	2,3,7,8-Tetrachlorodibenzofuran ng/kg (ITEQ)	2,3,7,8-Tetrachlorodibenzofuran ng/kg (DW)	Tetrachlorodibenzofuran ng/kg (DW) sum of isomers
Biochar 01	<0.09	<0.9	<0.9
Biochar 02	<0.09	<0.9	<0.9
Biochar 03	<0.09	<0.9	<0.9
Biochar 04	<0.09	<0.9	<0.9
Biochar 05	<0.09	<0.9	<0.9
Biochar 06	<0.09	<0.9	<0.9
Biochar 07	<0.09	<0.9	<0.9
Biochar 08	<0.09	<0.9	<0.9
Biochar 09	<0.09	<0.9	<0.9
Biochar 10	<0.09	<0.9	<0.9
Biochar 11	<0.09	<0.9	<0.9
Mean	0.09	0.9	0.9
Median	0.09	0.9	0.9
Minimum	0.09	0.9	0.9
Maximum	0.09	0.9	0.9
No. of samples	11	11	11
90^{th} percentile	0.09	0.9	0.9
LOD	0.09	0.9	0.9

Table 7.14 Primary data for non-waste biochar: octachlorodibenzofuran

Sample ID	Octachlorodibenzofuran ng/kg (ITEQ)	Octachlorodibenzofuran ng/kg (DW)
Biochar 01	<0.004	<3.00
Biochar 02	<0.004	<3.00
Biochar 03	<0.004	<4.00
Biochar 04	<0.004	<3.00
Biochar 05	<0.004	<3.00
Biochar 06	<0.004	<60.00
Biochar 07	<0.004	<3.00
Biochar 08	<0.004	<3.00
Biochar 09	<0.004	3.98
Biochar 10	<0.004	<3.00
Biochar 11	<0.004	<3.00
Mean	0.004	8.36
Median	0.004	3.00
Minimum	0.004	3.00
Maximum	0.004	60.00
No. of samples	11	11
90^{th} percentile	0.004	4.00
LOD	0.004	3

Table 7.15 Primary data for non-waste biochar: PCBs (μg/kg DW)

(a)

Sample ID	PCB -018	PCB -028	PCB -031	PCB -047	PCB -049	PCB -051	PCB -052	PCB -077	PCB -081	PCB -099	PCB -101	PCB -105	PCB -114
Biochar 01	0.0378	0.0275	<0.02	0.0148	0.0077	0.0062	0.0131	<0.0030	<0.0020	0.0059	0.0204	<0.0030	<0.002
Biochar 02	0.0417	<0.0200	<0.02	0.0209	<0.0050	<0.0040	0.0078	<0.0030	<0.0020	<0.0030	0.0087	<0.0030	<0.002
Biochar 03	0.0137	<0.0200	<0.02	<0.0100	<0.0050	<0.0040	<0.0060	<0.0030	<0.0020	<0.0030	<0.0050	<0.0030	<0.002
Biochar 04	<0.0100	<0.0200	<0.02	<0.0100	<0.0050	<0.0040	<0.0060	<0.0030	<0.0020	0.0083	<0.0050	<0.0030	<0.002
Biochar 05	<0.0100	<0.0200	<0.02	0.0178	0.0116	0.0091	0.0420	0.0031	<0.0020	0.0180	0.0202	0.0114	<0.002
Biochar 06	<0.0100	<0.0200	<0.02	<0.0100	<0.0050	0.0071	<0.0060	<0.0030	<0.0020	<0.0030	<0.0050	<0.0030	<0.002
Biochar 07	<0.0100	<0.0200	<0.02	<0.0100	<0.0050	0.0057	<0.0060	<0.0030	<0.0020	<0.0030	<0.0050	<0.0030	<0.002
Biochar 08	<0.0100	<0.0200	<0.02	<0.0100	<0.0050	<0.0040	<0.0060	<0.0030	<0.0020	<0.0030	<0.0050	<0.0030	<0.002
Biochar 09	<0.0100	<0.0200	<0.02	<0.0100	0.0050	0.0094	0.0387	0.0157	<0.0020	0.0168	0.0446	0.0205	<0.002
Biochar 10	<0.0100	<0.0200	<0.02	0.0534	0.0260	0.0142	0.0440	0.0121	0.0075	0.0354	0.0879	0.0216	0.013
Biochar 11	<0.0100	<0.0200	<0.02	<0.0100	<0.0050	0.0065	<0.0060	<0.0030	<0.0020	<0.0030	<0.0050	<0.0030	<0.002
Mean	0.0157	0.0207	0.02	0.0161	0.0078	0.0067	0.0165	0.0050	0.0025	0.0093	0.0193	0.0070	0.003
Median	0.0100	0.0200	0.02	0.0100	0.0050	0.0062	0.0060	0.0030	0.0020	0.0030	0.0050	0.0030	0.002
Minimum	0.0100	0.0200	0.02	0.0100	0.0050	0.0040	0.0060	0.0030	0.0020	0.0030	0.0050	0.0030	0.002
Maximum	0.0417	0.0275	0.02	0.0534	0.0260	0.0142	0.0440	0.0157	0.0075	0.0354	0.0879	0.0216	0.013
No. of samples	11	11	11	11	11	11	11	11	11	11	11	11	11
90^{th} percentile	0.0378	0.0200	0.02	0.0209	0.0116	0.0094	0.0420	0.0121	0.0020	0.0180	0.0446	0.0205	0.002
LOD	0.01	0.02	0.02	0.01	0.005	0.004	0.006	0.003	0.002	0.003	0.005	0.003	0.002

(b)

Sample ID	PCB -118	PCB -123	PCB -126	PCB -128	PCB -138	PCB -153	PCB -156	PCB -157	PCB -167	PCB -169	PCB -170	PCB -180	PCB -189
Biochar 01	<0.0040	<0.0020	<0.0030	0.0049	0.0182	0.0231	<0.0020	<0.0030	<0.0030	<0.0030	0.0064	0.0104	<0.0020
Biochar 02	<0.0040	<0.0020	<0.0030	0.0077	0.0200	0.0225	0.0035	<0.0030	<0.0030	<0.0030	0.0147	0.0148	<0.0020
Biochar 03	0.0151	<0.0020	<0.0030	0.0036	<0.0050	<0.0060	<0.0020	<0.0030	<0.0030	<0.0030	<0.0030	0.0070	<0.0020
Biochar 04	0.0124	<0.0020	<0.0030	<0.0030	<0.0050	<0.0060	<0.0020	<0.0030	<0.0030	<0.0030	<0.0030	0.0090	<0.0020
Biochar 05	0.0205	<0.0020	<0.0030	<0.0030	0.0210	0.0354	0.0041	<0.0030	<0.0030	<0.0030	0.022	0.0142	<0.0020
Biochar 06	<0.0040	<0.0020	<0.0030	<0.0030	<0.0050	0.0104	<0.0020	<0.0030	<0.0030	<0.0030	0.0106	<0.0040	<0.0020
Biochar 07	<0.0040	<0.0020	<0.0030	<0.0030	<0.0050	<0.0060	<0.0020	<0.0030	<0.0030	<0.0030	0.0047	<0.0040	<0.0020
Biochar 08	<0.0040	<0.0020	<0.0030	<0.0030	<0.0050	<0.0060	<0.0020	<0.0030	<0.0030	<0.0030	<0.0030	<0.0040	<0.0020
Biochar 09	0.0350	<0.0020	<0.0030	0.0281	0.2280	0.2790	0.0254	<0.0030	0.0081	<0.0030	0.2010	0.4240	0.0078
Biochar 10	0.0912	0.0198	0.0167	0.0252	0.1500	0.1600	0.0229	0.0139	0.0146	0.0147	0.0522	0.0925	0.0145
Biochar 11	<0.0040	<0.0020	<0.0030	<0.0030	<0.0050	<0.0060	<0.0020	<0.0030	<0.0030	<0.0030	0.0038	<0.0040	<0.0020
Mean	0.0180	0.0036	0.0042	0.0080	0.0425	0.0509	0.0064	0.0040	0.0045	0.0041	0.0295	0.0534	0.0037
Median	0.0040	0.0020	0.0030	0.0030	0.0050	0.0104	0.0020	0.0030	0.0030	0.0030	0.0064	0.0090	0.0020
Minimum	0.0040	0.0020	0.0030	0.0030	0.0050	0.0060	0.0020	0.0030	0.0030	0.0030	0.0030	0.0040	0.0020
Maximum	0.0912	0.0198	0.0167	0.0281	0.2280	0.2790	0.0254	0.0139	0.0146	0.0147	0.2010	0.4240	0.0145
No. of samples	11	11	11	11	11	11	11	11	11	11	11	11	11
90^{th} percentile	0.0350	0.0020	0.0030	0.0252	0.1500	0.1600	0.0229	0.0030	0.0081	0.0030	0.0522	0.0925	0.0078
LOD	0.004	0.002	0.003	0.003	0.005	0.006	0.002	0.003	0.003	0.003	0.003	0.004	0.002

Table 7.16 Primary data for non-waste biochar: PAHs (μg/kg DW)

(a)

Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(ghi)perylene	Benzo(k)fluoranthene
Biochar 01	56.7	93.2	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 02	75.7	188.0	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 03	143.0	199.0	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 04	266.0	307.0	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 05	50.6	45.5	95.9	93.1	79.9	87.8	78.7	22.3
Biochar 06	243.0	375.0	465.0	716.0	<300.0	372.0	149.0	<300.0
Biochar 07	11.8	166.0	1480.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 08	365.0	425.0	<400.0	743.0	1030	724.0	865.0	<400.0
Biochar 09	45.1	52.4	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 10	392.0	99.3	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Biochar 11	22.1	<20.0	<400.0	<400.0	<400.0	<400.0	<100.0	<400.0
Mean	151.9	179.1	476.4	432.0	419.1	398.5	172.1	356.6
Median	75.7	166.0	400.0	400.0	400.0	400.0	100.0	400.0
Minimum	11.8	20.0	95.9	93.1	79.9	87.8	78.7	22.3
Maximum	392.0	425.0	1480.0	743.0	1030.0	724.0	865.0	400.0
No. of samples	11	11	11.0	11	11.0	11.0	11	11
90^{th} percentile	365.0	375.0	465.0	716.0	400.0	400.0	149.0	400.0
LOD	0.1	1	20	20	20	20	6	20

(b)

Sample ID	Chrysene	Dibenzo(ah)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Biochar 01	<600.0	<60.0	<400	280.0	<600.0	339	507	<400
Biochar 02	<600.0	<60.0	<400	<200.0	<600.0	2150	1050	<400
Biochar 03	<600.0	<60.0	<400	<200.0	<600.0	5030	645	<400
Biochar 04	<600.0	<60.0	<400	229.0	<600.0	5450	<400	<400
Biochar 05	91.6	8.3	232	86.8	51.2	701	494	271
Biochar 06	662.0	<50.0	1060	<200.0	<500.0	6010	4440	1050
Biochar 07	<600.0	<60.0	<400	<200.0	<600.0	5080	1410	<400
Biochar 08	833.0	124.0	1140	331.0	573.0	5250	2120	1370
Biochar 09	<500.0	<50.0	<400	213.0	<500.0	939	494	<400
Biochar 10	<600.0	<60.0	<400	349.0	<600.0	4490	<400	<400
Biochar 11	<600.0	<60.0	<400	<200.0	<600.0	262	<400	<400
Mean	571.5	59.3	512	226.3	529.5	3246	1124	536
Median	600.0	60.0	400	200.0	600.0	4490	507	400
Minimum	91.6	8.3	232	86.8	51.2	262	400	271
Maximum	833.0	124.0	1140	349.0	600.0	6010	4440	1370
No. of samples	11	11	11	11.0	11	11	11	11
90^{th} percentile	662.0	60.0	1060	331.0	600.0	5450	2120	1050
LOD	30	3	20	10	30	10	20	20

Table 7.17 Primary data for non-waste biochar: BTEX

Sample ID	1,2-Dimethylbenzene [o-xylene]	Benzene	Dimethylbenzene	Ethylbenzene	Toluene [methylbenzene]
	µg/kg (DW)	µg/kg (DW)	µg/kg (DW) sum of (1,3- 1,4-isomers)	µg/kg (DW)	µg/kg (DW)
Biochar 01	6.68	18.60	10.1	<2	<10.00
Biochar 02	43.50	37.00	153.0	<4	85.30
Biochar 03	<7.00	15.40	13.5	<4	<20.00
Biochar 04	<5.00	<5.00	<10.0	<3	<20.00
Biochar 05	<8.00	1.34	<20.0	<4	<20.00
Biochar 06	<5.00	<5.00	<10.0	<3	<20.00
Biochar 07	<5.00	<5.00	<10.0	<3	<20.00
Biochar 08	<5.00	5.33	<10.0	<3	<20.00
Biochar 09	<6.00	13.3	<10.0	<3	3.78
Biochar 10	<5.00	1.29	<10.0	<3	<20.00
Biochar 11	<6.00	<6.00	<10.0	<3	<20.00
Mean	9.29	10.30	24.2	3	23.55
Median	6.00	5.33	10	3	20.00
Minimum	5.00	1.29	10	2	3.78
Maximum	43.50	37.00	153	4	85.30
No. of samples	11	11	11	11	11
90^{th} percentile	8.00	18.60	20	4	20.00
LOD	1	1	2	0.5	3

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List of abbreviations

1M	1 molar
2M	2 molar
Ag	Silver
Al	Aluminium
As	Arsenic
B	Boron
ASE	accelerated solvent extraction
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
DCM	dichloromethane
DW	dry weight
EC	electrical conductivity
ESG	Environmental Scientifics Group Limited
Fe	Iron
GCMS	gas chromatography–mass spectrometry
Hg	Mercury
HR	high resolution
ICP-OES	inductively coupled plasma optical emission spectrometry
ITEQ	International Toxicity Equivalents
K	Potassium
KCL	Potassium chloride
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
NH_3 as N	Ammoniacal nitrogen
NH_4	Ammonium
Ni	Nickel
NLS	National Laboratory Service [Environment Agency]
NO_2	Nitrogen dioxide
P	Phosphorus
PAHs	polycyclic aromatic hydrocarbons
Pb	Lead
PCB	polychlorinated biphenyl
PSD	particle size distribution
PTEs	Potentially Toxic Elements
SAL	Scientific Analysis Laboratories Limited
Sb	Antimony
Se	Selenium
Sn	Tin
Sr	Strontium
TC	total carbon
Ti	Titanium
Tl	Thallium
TN	total nitrogen
TOC	total organic carbon
TON	total organic nitrogen
USEPA	United States Environmental Protection Agency
V	Vanadium
Zn	Zinc

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