Environment Agency

Evidence

Material comparators for end-of-waste decisions

Materials for fuels: coal

Report – SC130040/R9

Version 2

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Executive summary

This report details the work undertaken to characterise coal, a key comparator. This information will inform end-of-waste assessments for waste-derived materials intended to replace coal as a fuel.

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 coal 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.

Twenty samples of coal 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 coal which is defined as an ordinary material comparator that is currently permitted for use as a fuel.

This report provides the results from the primary analysis of 20 coal samples.

Three other reports cover ordinary material comparators for fuel:

- biomass
- charcoal
- natural gas

2 Definition

2.1 Material properties relevant to use

Coal is a fossil fuel. It is a combustible rock, composed of lithified plant remains. It is formed by the alteration of dead plant material that initially accumulates as a surficial deposit of peat and is then buried beneath layers of younger sediment. The initial peat may be sequentially altered by the process of coalification through brown coals, which include lignite and sub-bituminous coals, to black coals or hard coals that comprise bituminous coal, semi anthracite and anthracite (BGS 2010a).

The chemical and physical properties (or ‘coal quality’) determine whether and how a coal can be used commercially. The most fundamental property (as for any fuel) is calorific value (CV), the energy given off by a unit quantity of fuel. Peat has a CV of around 15 MJ/kg, brown coals have a CV of around 25 MJ/Kg and black coals (bituminous and anthracite) have a CV of around 35 MJ/Kg (BGS 2010b).

Chlorine is detrimental in coal as it causes corrosion in boilers as well as causing pollution. Sulphur is another serious impurity in coal, causing both corrosion and atmospheric pollution when released as sulphur dioxide. The sulphur content of English coals is relatively high compared with world traded coals and those found in Scotland and Wales (BGS 2010b).

2.1.1 Origin

All the coal produced in the UK and imported into the UK is bituminous, semi-anthracite or anthracite. The UK has deposits of lignite but deposits are not mined.

Based on the physical properties of different bituminous coals, a fundamental distinction is made worldwide between steam coal (thermal coal), used for burning in boilers (chiefly for electricity generation) and coking coal, which is used for the metallurgical industries (BGS 2010b).

Around 71% (in 2009) of the UK coal market was supplied by imports; the remaining 29% came from indigenous sources. In 2008 the chief sources (82%) of steam coal in the UK were Russia, Columbia and South Africa. Australia provided 49.5% of coking coal imports (BGS 2010b). Anthracite is imported from Indonesia, South Africa, Vietnam and Russia.[1] House coal is imported from Poland and Columbia.[2]

2.1.2 Uses

The main uses of coal are:

- electricity generation
- industrial heat generation
- coke manufacture
- blast furnaces
- patent fuel manufacture
- domestic heating

2.1.3 Lignite/sub-bituminous coal/brown coal

Lignite and sub-bituminous coals are brown coals. There are about 500 million tonnes of lignite resources in the UK, mainly in Northern Ireland, although none is mined or consumed at present (Eurocoal 2013). The low calorific value of lignite makes transport uneconomic over longer distances and lignite power stations are only developed adjacent to lignite mines (Eurocoal 2013).

2.1.4 Bituminous coal

Bituminous coal is known as black or hard coal and is split into two main categories: steam coal and coking coal. Total UK coal supply, predominantly bituminous (imports and indigenous production) totalled 64 million tonnes in 2012 (DECC 2013), of which:

- steam coal consumption for electricity generation totalled 54.8 million tonnes
- coking coal consumption for coke manufacture totalled 4.9 million tonnes

Bituminous coal for domestic consumption is referred to as house coal. The total consumption of all coal types for domestic (that is, household) purposes in the UK in

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[1] http://www.coalmerchantsfederation.co.uk/products/imported-boiler-fuel
[2] http://www.coalmerchantsfederation.co.uk/products/house-coal

2012 was 0.68 million tonnes. Note that this figure includes bituminous coal and anthracite.

2.1.5 Semi-anthracite

Semi-anthracite coal is a black or hard coal. Semi-anthracite has a higher calorific value than bituminous coal but a lower calorific value than anthracite. It tends to be used for domestic purposes.

Welsh dry steam coal is a naturally occurring semi-smokeless fuel currently produced in South Wales and is sold for domestic use as well as in steam-powered vehicles.[3]

2.1.6 Anthracite

Anthracite coal is a black or hard coal, and is a naturally occurring smokeless fuel, extremely slow burning with a high heat output used in the domestic environment. The largest UK anthracite producer is located in South Wales, but there are also several private anthracite producers which supply fuel for the domestic market. Various sizes of anthracite are available (large nuts, small nuts, beans and grains).[4]

2.1.7 Manufactured smokeless fuels

Manufactured smokeless fuels, also known as smokeless ovoids or smokeless ovals, are a smokeless anthracite based solid fuel for use on open fires and in multi-fuel stoves and selected cookers. There are a number of smokeless fuel products available on the market.[5] Some manufactured smokeless fuels include renewable materials (for example, Ecoal50).

2.1.8 Manufactured non-smokeless fuels

Economy non-smokeless ovoids or ovals are a solid fuel which generally lights easily. They are most suitable for burning on open fires that are not in smoke-controlled areas, or on multi-fuel stoves and suitable room heaters. There are several economy non-smokeless fuel products available on the market.[6]

3 Comparator sub-types

Twenty coal samples were obtained from a variety of suppliers across England to provide a cross-section of coal types. Sampling was split evenly between domestic and industrial use. Figures 3.1 to 3.3 show breakdowns of the samples by sub-type.

[3] http://www.coalmerchantsfederation.co.uk/products/welsh-dry-steam
[4] http://www.coalmerchantsfederation.co.uk/products/anthracite
[5] http://www.coalmerchantsfederation.co.uk/products/smokeless-ovoids
[6] http://www.coalmerchantsfederation.co.uk/products/economy-non-smokeless-ovoids

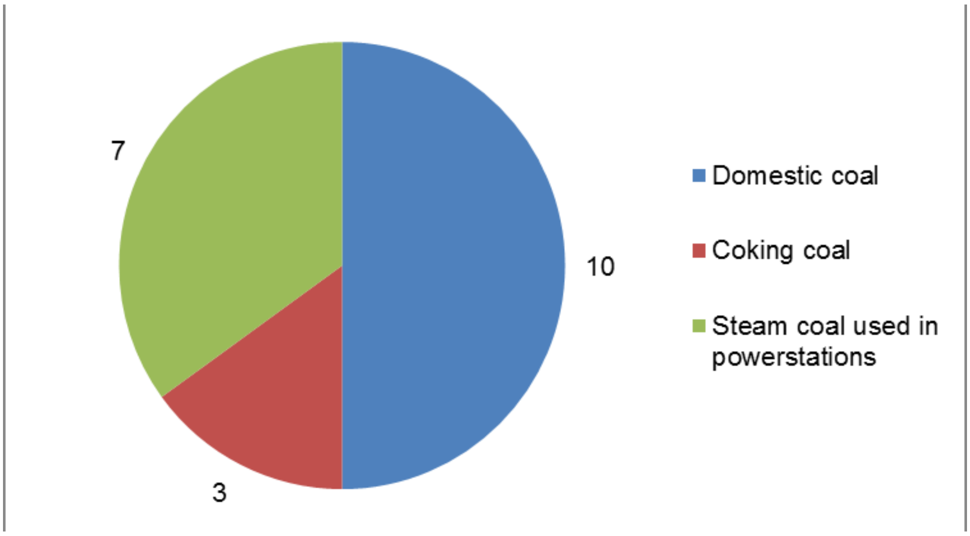

Figure 3.1 Number of coal samples by sub-type

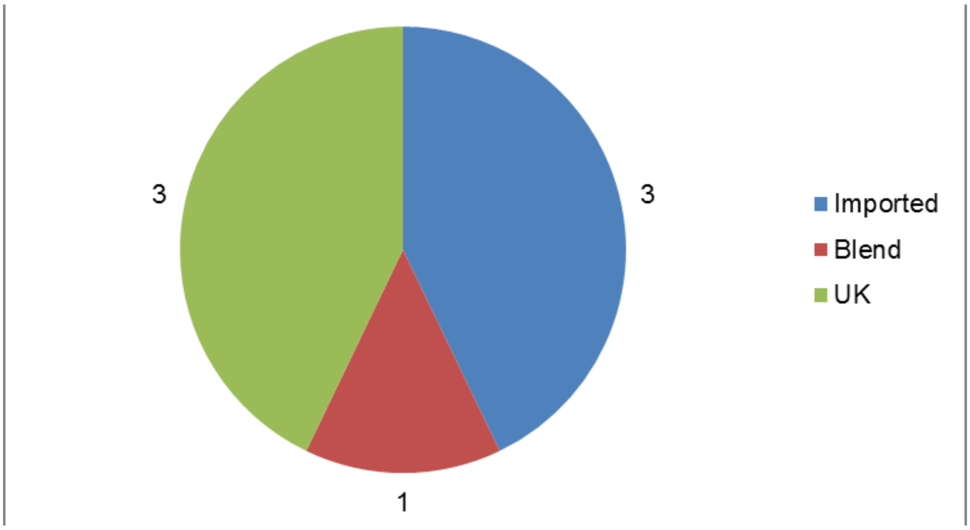

Figure 3.2 Number of steam coal samples by origin

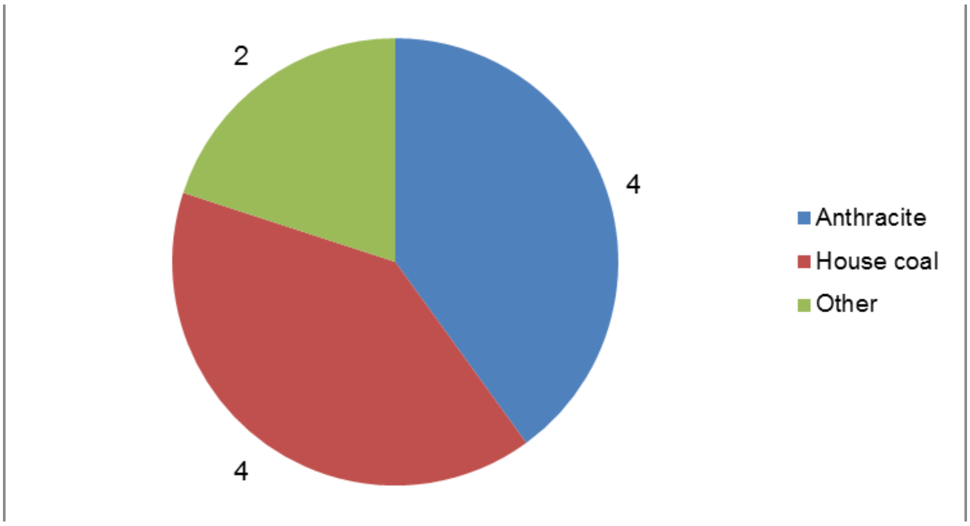

Figure 3.3 Number of domestic coal samples by sub-type

4 Material sources and sampling procedure

An internet search and the Coal Merchants Federation approved coal merchant map (Coal Merchants Federation 2013) were used to produce a list of coal suppliers. Coal samples were requested from all these suppliers to ensure a cross-section of coal types were sampled. Samples were collected from those willing to participate.

Coal samples were taken in accordance with BS 4845-2:1979 (BSI 1979) and BS ISO 18283:2006 (BSI 2006).

5 Analytical parameters

The main parameters determined, together with units of measurement, are summarised in Tables 5.1 to 5.5.

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
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

Table 5.2 Proximate analysis (composition) and calorific value

Parameter/ determinand	Test method used	Unit
Moisture content	ESG documented in-house method based on ISO 687 and ISO11722	%
Ash content	ESG documented in-house method based on ISO 1171:2010	%
Volatile matter	ESG documented in-house method based on ISO 562:2010	%
Fixed carbon	Parameter by calculation	%
Net calorific value (LHV)	ESG documented in-house method based on ISO 1928	kJ/kg
Gross calorific value (HHV)	ESG documented in-house method based on ISO 1928	kJ/kg

Table 5.3 Ultimate (elemental) analysis

Parameter/ determinand	Test method used	Unit
Carbon	ESG documented in-house method by Exeter CE440 elemental analyser	%
Hydrogen	ESG documented in-house method by Exeter CE440 elemental analyser	%
Nitrogen	ESG documented in-house method by Exeter CE440 elemental analyser	%
Oxygen	Calculated	%
Sulphur	ESG documented in-house methods by instrumental analysis using Eltra Helios sulphur analyser	%
Chlorine	ESG documented in-house method based on method described in Vol. 115 of the *Analyst* (November 1990) using wavelength dispersive X-ray fluorescence (XRF)	%
Fluorine	Following calorific value test (see Table 5.2) – the washings from the bomb calorimeter are submitted for analysis.	%
Bromine	Following calorific value test (see Table 5.2) – the washings from the bomb calorimeter are submitted for analysis by ion-selective electrode.	%

Table 5.4 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 inductively coupled plasma optical emission spectrometry (ICP-OES)	mg/kg
Chromium VI	Hexavalent chromium by spectrophotometry	mg/kg

Table 5.5 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

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

6 Existing data

A limited number of existing datasets relating to coal were identified during the literature review. These are presented in Tables 6.1 to 6.3.

Table 6.1 Calorific value, proximate and ultimate analysis: coal

	Net CV	Bulk density	Moisture content	Ash content	Volatile matter	Fixed carbon	Total carbon	Hydrogen	Nitrogen	Sulphur	Oxygen
	MJ/kg	kg/m³	%								
Range lignite and hard coal[1]	7–38		3–60	3–17	17–60	19	60–80	3–9	0.5–2	0.5–3	
Black lignite[2]	17.8		29.2	10.25							
Lignite[3]			30–70	5–40	40–66	35–60	60–80	4.5–6.5		0.5–4.7	12–30
Bituminous coal[3]	26–32		2–20	1–30	>22	55–85	80–95	4.5–6.5		0.3–4.5	1.5–14
Low volatile bituminous and semi anthracite[3]	25–32.3		2–20	1–30	8–22	85–92	90–95	3.5–4.5		0.5–1	1.2–6
Steam coal (Polish)[4]	28.7	1350	10	14	25–35				1	<1	
Coal [5]			7–15	10–22						0.1–3	
Coal[6]									0.5 – 2		
House coal[7]	25.0										
House coal[8]	29	850									
Anthracite and dry steam coal[7]	28.7										
Anthracite[8]	32.1	1100									
Anthracite[3]	30–31.4		2–20	1–30	<8	>92	92–95	3–8		0.5–0.8	1.2–5

Notes:
[1] UBA (2000)
[2] European Commission (2006)
[3] Eurelectric (2001)
[4] Finnish Environment Institute (2001)
[5] Data supplied by the Environment Agency
[6] Joint Research Centre (2013)
[7] DECC (2012)
[8] Carbon Trust (2009)

Table 6.2 Chlorine, fluorine and metal analysis: coal (mg/kg DW)

	Cl	F	As	Be	Cd	Co	Cr	Cu	Mn
Range of lignite and hard coal[1]	200–300	16–20	0.4–18	0.1	0.02–5	0.6–21	1.4–39.1	1–33	88–160
Coal[2]	0–0.3		<1–14		<0.2–0.3		15–63	<5–26	

Notes: [1] UBA (2000)
[2] Data supplied by the Environment Agency

Table 6.3 Metal analysis: coal (mg/kg DW)

	Country	Ni	Hg	Pb	Sb	Th	V	Sn	Zn
Range lignite and hard coal[1]		1.6–40.5	0.1–0.3	0.4–50	1–5	0.1–0.3	1–105	4	5–60
Coal[2]		<14–44	<0.2–3.5	<6–83			<22–50		<15–58
Coal[3]	Indonesia		7						
Coal[3]	New Zealand		1						
Coal[3]	Columbia		7						
Coal[3]	Russia		1						
Coal[3]	Australia		17						
Coal[3]	Venezuela		2						
Coal[3]	South Africa		12						
Coal[3]	Blend		36						
Coal[3]	Egypt		1						
Coal[3]	Norway		2						
Coal[3]	US		15						
Coal[3]	China		2						
Coal[3]	Germany		1						
Coal[3]	Poland		10						

Notes: [1] UBA (2000)
[2] Data supplied by the Environment Agency
[3] Eurelectric (2001)

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 coal 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.

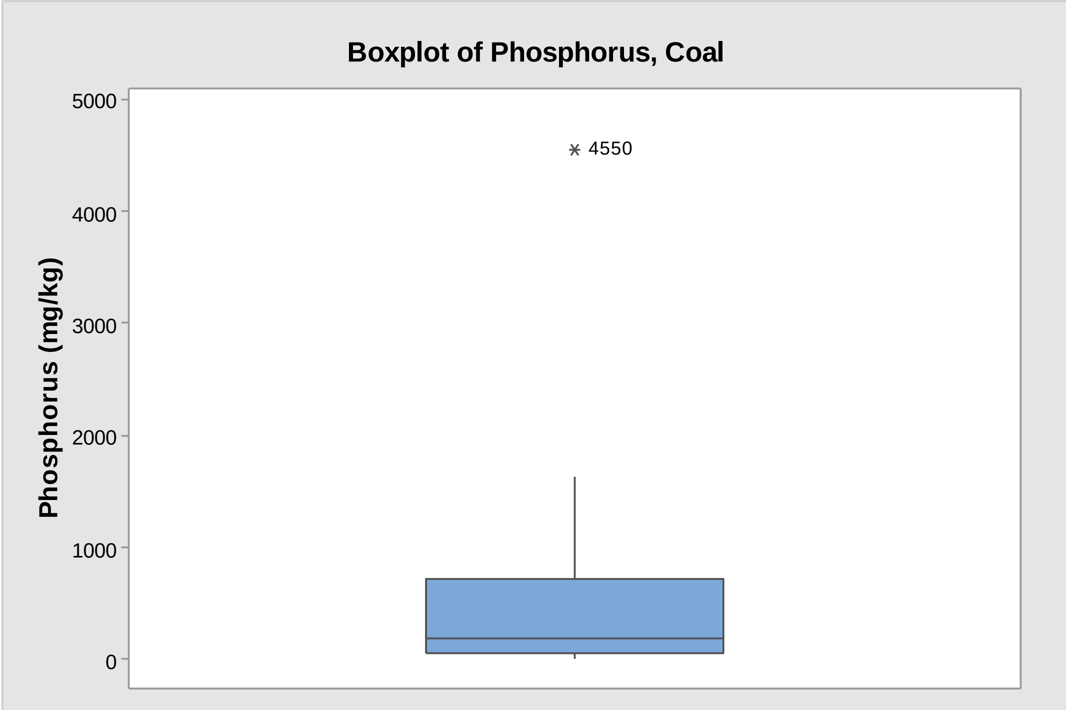

Figure 7.1 Boxplot of phosphorus, coal

7.2 Using the data tables

Data are presented in tables summarising:

- physical properties
- metals
- organic contaminants
- calorific value, proximate (composition) and ultimate (elemental) analysis

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 as follows:

- domestic coal – Tables 7.1 to 7.6
- steam coal – Tables 7.7 to 7.12
- coking coal – Tables 7.13 to 7.18.

Table 3.1 Primary data for domestic coal: physical properties

Sample ID	Dry solids @ 30°C	PSD 2–20 mm	PSD 20–50 mm	PSD >50 mm	Loose bulk density
	%	%	%	%	kg/m^3
Coal 01	98.6	26.2	<0.1	<0.1	–
Coal 02	97.4	14.1	<0.1	<0.1	–
Coal 03	95.2	39.6	<0.1	<0.1	663
Coal 04	97.4	22.2	<0.1	<0.1	756
Coal 05	97.9	27.4	<0.1	<0.1	715
Coal 06	95.9	38.7	<0.1	<0.1	–
Coal 07	96.9	34.4	<0.1	<0.1	–
Coal 08	91.7	17.0	<0.1	<0.1	679
Coal 09	98.2	24.6	<0.1	<0.1	730
Coal 10	97.3	31.8	<0.1	<0.1	–
Mean	96.7	27.6	0.1	0.1	709
Median	97.4	26.8	0.1	0.1	715
Minimum	91.7	14.1	0.1	0.1	663
Maximum	98.6	39.6	0.1	0.1	756
No. of samples	10	10	10	10	5
90^{th} percentile	98.2	38.8	0.1	0.1	n/a
LOD	0.5	n/a	n/a	n/a	n/a

Notes: – Particle size reduced, loose bulk density test not conducted
n/a = not applicable

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

(a)

Sample ID	Al	Sb	As	Ba	Be	Bo	Cd	Ca	Cr	Cr VI	Co	Cu	Fe	Pb	Li
Coal 01	1900	<1.00	0.673	35.1	0.159	52.20	<0.200	7710	0.772	<0.6	0.337	3.70	518	1.05	1.54
Coal 02	1620	<1.00	5.820	69.5	0.376	10.60	<0.200	2520	3.440	<0.6	3.040	16.10	2610	9.59	4.06
Coal 03	2250	<5.00	2.460	91.6	0.176	11.20	0.661	11000	15.000	<0.6	5.950	116.00	2520	65.80	3.64
Coal 04	792	<1.00	4.720	105.0	0.153	4.97	<0.200	1580	1.470	<0.6	1.340	17.90	1980	7.01	1.64
Coal 05	363	<1.00	2.900	19.5	0.124	2.37	<0.200	480	0.800	<0.6	1.960	13.90	760	3.98	<1.00
Coal 06	2040	<1.00	1.100	167.0	0.420	28.90	<0.200	1960	3.120	<0.6	0.940	17.30	842	10.50	2.09
Coal 07	129	<1.00	<0.500	10.3	<0.100	45.70	<0.200	537	1.020	<0.6	0.483	7.68	269	1.99	<1.00
Coal 08	1150	1.24	3.420	58.4	0.201	4.78	0.301	5020	5.230	<0.6	4.280	43.50	1520	20.40	3.03
Coal 09	295	<1.00	1.700	14.7	<0.100	1.25	<0.200	510	0.530	<0.6	1.710	13.40	1560	6.62	<1.00
Coal 10	860	<1.00	4.330	131.0	<0.100	74.10	<0.200	409	1.270	<0.6	0.452	3.13	612	1.35	<1.00
Mean	1140	1.42	2.762	70.2	0.191	23.61	0.256	3173	3.265	0.6	2.049	25.26	1319	12.83	2.00
Median	1005	1.00	2.680	64.0	0.156	10.90	0.200	1770	1.370	0.6	1.525	15.00	1181	6.82	1.59
Minimum	129	1.00	0.500	10.3	0.100	1.25	0.200	409	0.530	0.6	0.337	3.13	269	1.05	1.00
Maximum	2250	5.00	5.820	167.0	0.420	74.10	0.661	11000	15.000	0.6	5.950	116.00	2610	65.80	4.06
No. of samples	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90th percentile	2061	1.62	4.830	134.6	0.380	54.39	0.337	8039	6.207	0.6	4.447	50.75	2529	24.94	3.68
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
Coal 01	96.9	3.77	<0.2	<1.00	1.07	4550.0	99.6	<1.00	<1	164.0	85.80	<1	<1.00	18.2	2.820	3.62
Coal 02	668.0	77.20	<0.2	2.16	9.77	310.0	373.0	1.21	<1	251.0	79.20	<1	<1.00	12.4	145.000	13.50
Coal 03	1300.0	104.00	<0.2	2.16	21.00	1630.0	5790.0	<1.00	<1	946.0	59.30	<1	11.90	209.0	163.000	228.00
Coal 04	437.0	25.30	<0.2	<1.00	2.25	423.0	78.0	<1.00	<1	48.9	60.50	<1	<1.00	6.0	1.700	11.90
Coal 05	113.0	8.23	<0.2	<1.00	2.08	56.7	59.9	<1.00	<1	43.4	11.90	<1	<1.00	6.0	2.500	11.30
Coal 06	245.0	48.30	<0.2	<1.00	4.52	580.0	213.0	<1.00	<1	246.0	261.00	<1	1.23	64.3	4.930	30.10
Coal 07	103.0	7.12	<0.2	<1.00	1.23	24.0	<50.0	<1.00	<1	151.0	3.40	<1	<1.00	13.4	0.514	18.70
Coal 08	1000.0	49.40	<0.2	9.50	17.40	1030.0	5330	<1.00	<1	477.0	47.90	<1	2.64	67.6	55.800	75.20
Coal 09	205.0	27.50	<0.2	1.45	2.10	103.0	<50.0	<1.00	<1	43.5	7.93	<1	<1.00	5.4	1.140	9.64
Coal 10	140.0	2.48	<0.2	<1.00	2.00	37.2	249.0	<1.00	<1	176.0	26.60	<1	<1.00	42.6	3.130	12.60
Mean	430.8	35.33	0.2	2.13	6.34	874.4	1229.3	1.02	1	254.7	64.35	1	2.28	44.5	38.053	41.46
Median	225.0	26.40	0.2	1.00	2.18	366.5	156.3	1.00	1	170.0	53.60	1	1.00	15.8	2.975	13.05
Minimum	96.9	2.48	0.2	1.00	1.07	24.0	50.0	1.00	1	43.4	3.40	1	1.00	5.4	0.514	3.62
Maximum	1300.0	104.00	0.2	9.50	21.00	4550.0	5790.0	1.21	1	946.0	261.00	1	11.90	209.0	163.000	228.00
No. of samples	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
90^{th} percentile	1030.0	79.88	0.2	2.89	17.76	1922.0	5376.0	1.02	1	523.9	103.32	1	3.57	81.7	146.800	90.48
LOD	20	2	0.2	1	0.6	10	50	1	1	10	1	1	1	3	0.1	2

DW = dry weight

Table 7.3 Primary data for domestic coal: 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
Coal 01	59.4	<20.0	<400	835	<400	845	204	<400
Coal 02	182.0	105.0	1070	7930	12400	5190	10000	962
Coal 03	38.2	22.4	<400	1380	2090	1230	1770	<400
Coal 04	14.8	<20.0	<400	<400	<400	<400	<100	<400
Coal 05	12.6	<20.0	<400	<400	<400	<400	165	<400
Coal 06	230.0	132.0	632	1140	477	904	565	<400
Coal 07	469.0	259.0	2020	1080	459	472	268	<400
Coal 08	58.6	<20.0	428	2460	5220	2920	18100	594
Coal 09	12.5	<20.0	<400	<400	<400	<400	103	<400
Coal 10	162.0	67.9	574	<400	<400	<400	<100	<400
Mean	123.9	68.6	672	1643	2265	1316	3138	476
Median	59.0	21.2	414	958	430	659	236	400
Minimum	12.5	20.0	400	400	400	400	100	400
Maximum	469.0	259.0	2020	7930	12400	5190	18100	962
No. of samples	10	10	10	10	10	10	10	10
90th percentile	253.9	144.7	1165	3007	5938	3147	10810	631
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
Coal 01	<600	60.5	3070	<200	<600	<200	<400	1450
Coal 02	11800	4700.0	2330	906	3680	4340	7290	10300
Coal 03	2240	707.0	<400	<200	581	1280	1870	1120
Coal 04	<600	<60.0	<400	<200	<600	258	<400	<400
Coal 05	<600	<60.0	<400	<200	<600	353	547	<400
Coal 06	1010	84.2	3560	1390	<500	680	6110	2000
Coal 07	904	<60.0	1690	1020	<600	<300	4170	2100
Coal 08	4480	2830.0	444	259	2550	1940	2530	2140
Coal 09	<600	<60.0	<400	<200	<600	<200	<400	<400
Coal 10	<600	<60.0	532	910	<600	6150	1060	<400
Mean	2343	868.2	1323	549	1091	1570	2478	2071
Median	752	60.3	488	230	600	517	1465	1285
Minimum	600	60.0	400	200	500	200	400	400
Maximum	11800	4700.0	3560	1390	3680	6150	7290	10300
No. of samples	10	10	10	10	10	10	10	10
90^{th} percentile	5212	3017.0	3119	1057	2663	4521	6228	2956
LOD	30	3	20	10	30	10	20	20

Table 7.4 Primary data for domestic coal: 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)
Coal 01	<3.0	<3.00	<5	1.21	<8
Coal 02	<4.0	<4.0	<7	<2.00	<10
Coal 03	<4.0	<10.00	<9	<2.00	<10
Coal 04	<4.0	<4.00	<7	<2.00	<10
Coal 05	<3.0	6.51	<7	<2.00	<10
Coal 06	<3.0	<3.00	<7	<2.00	<10
Coal 07	<4.0	<10.00	<8	<2.00	<10
Coal 08	<4.0	<4.00	<9	<2.00	<10
Coal 09	<3.0	3.47	<6	<2.00	<9
Coal 10	44.3	4.06	169	33.00	103
Mean	7.6	5.20	23	5.02	19
Median	4.0	4.00	7	2.00	10
Minimum	3.0	3.00	5	1.21	8
Maximum	44.3	10.00	169	33.00	103
No. of samples	10	10	10	10	10
90^{th} percentile	8.0	10.00	25	5.10	19
LOD	1	1	2	0.5	3

Table 7.5 Primary data for domestic coal: calorific value and proximate analysis (composition)

Sample ID	Calorific value (gross)	Calorific value (net)	Total moisture	Ash	Volatile matter	Fixed carbon
	kJ/kg	kJ/kg	%	%	%	%
Coal 01	28496	27306	8.7	5.5	34.3	51.5
Coal 02	30079	29127	6.5	6.4	17.2	69.9
Coal 03	30528	29614	8.9	5.1	11.1	74.9
Coal 04	30528	29614	5.1	3.5	7.7	83.7
Coal 05	33904	33070	3.7	2.6	7.2	86.5
Coal 06	28313	27131	10.2	5.4	30.9	53.5
Coal 07	29443	28132	12.1	1.0	35.7	51.2
Coal 08	29058	28082	12.0	4.7	10.4	72.9
Coal 09	32928	32133	3.5	5.0	5.9	85.6
Coal 10	28050	26856	10.3	5.9	32.0	51.8
Mean	30133	29107	8.1	4.5	19.2	68.2
Median	29761	28630	8.8	5.1	14.2	71.4
Minimum	28050	26856	3.5	1.0	5.9	51.2
Maximum	33904	33070	12.1	6.4	35.7	86.5
No. of samples	10	10	10	10	10	10
90th percentile	33026	32227	12.0	6.0	34.4	85.7
LOD	100	100	0.1	0.1	1.1	n/a

Table 7.6 Primary data for domestic coal: ultimate analysis

Sample ID	Bromine	Carbon	Chlorine	Fluorine	Hydrogen	Nitrogen	Oxygen	Sulphur
	mg/kg	%	%	mg/kg	%	%	%	%
Coal 01	<100	69.31	0.02	22.8	4.43	2.13	9.6	0.31
Coal 02	<100	75.36	0.04	24.8	3.37	1.49	5.3	1.52
Coal 03	<100	76.01	0.17	46.4	2.95	1.41	3.8	1.67
Coal 04	<100	83.60	0.01	47.3	3.01	1.29	2.7	0.78
Coal 05	<100	86.84	0.02	22.2	3.15	1.33	1.5	0.86
Coal 06	<100	69.45	0.01	42.5	4.15	2.06	8.4	0.29
Coal 07	<100	71.77	0.02	<10.0	4.66	1.59	8.5	0.38
Coal 08	<100	74.59	0.13	48.8	2.86	1.19	3.0	1.52
Coal 09	<100	84.10	0.02	72.3	2.94	1.17	2.3	1.01
Coal 10	<100	64.58	0.01	<10.0	3.94	1.53	13.4	0.33
Mean	100	75.56	0.05	34.7	3.55	1.52	5.9	0.87
Median	100	74.98	0.02	33.7	3.26	1.45	4.6	0.82
Minimum	100	64.58	0.01	10.0	2.86	1.17	1.5	0.29
Maximum	100	86.84	0.17	72.3	4.66	2.13	13.4	1.67
No. of samples	10	10	10	10	10	10	10	10
90^{th} percentile	100	84.37	0.13	51.2	4.45	2.07	10.0	1.54
LOD	100	0.41	0.01	10	0.06	0.1	Calculated	0.02

Table 4.7 Primary data for steam coal: physical properties

Sample ID	Dry solids @ 30°C	PSD 2–20 mm	PSD 20–50 mm	PSD >50 mm	Loose bulk density
	%	%	%	%	kg/m^3
Coal 11	86.3	20.3	<0.1	<0.1	682
Coal 12	92.1	6.5	<0.1	<0.1	740
Coal 13	98.9	<0.1	8.6	<0.1	853
Coal 14	98.1	<0.1	13.5	<0.1	847
Coal 15	97.5	<0.1	18.3	<0.1	851
Coal 16	96.6	<0.1	18.0	<0.1	797
Coal 17	96.0	38.4	<0.1	<0.1	–
Mean	95.1	9.4	8.4	0.1	795
Median	96.6	0.1	8.6	0.1	822
Minimum	86.3	0.1	0.1	0.1	682
Maximum	98.9	38.4	18.3	0.1	853
No. of samples	7	7	7	7	6
LOD	0.5	n/a	n/a	n/a	n/a

Notes: – Particle size reduced, loose bulk density test not conducted
n/a = not applicable

Table 7.8 Primary data for steam coal: metals (mg/kg DW)

(a)

Sample ID	Al	Sb	As	Ba	Be	Bo	Cd	Ca	Cr	Cr VI	Co	Cu	Fe	Pb	Li
Coal 11	3810	<1	14.90	53.9	0.596	14.6	0.489	1320	4.86	<0.6	7.31	42.10	8850	19.80	15.70
Coal 12	5450	<1	24.10	52.3	0.832	14.6	0.760	2120	8.84	<0.6	7.67	46.70	13000	26.60	17.20
Coal 13	3500	<1	6.37	58.4	1.090	45.4	<0.200	2350	8.23	<0.6	4.51	17.90	7490	8.50	5.70
Coal 14	3200	<1	2.58	166.0	0.290	43.6	<0.200	7620	3.74	<0.6	1.29	5.05	3230	4.82	2.42
Coal 15	4780	<1	5.86	47.4	1.090	33.9	<0.200	8750	10.50	<0.6	7.83	40.50	5990	36.10	11.80
Coal 16	2480	<1	7.79	52.9	0.524	26.9	0.363	1090	8.70	<0.6	2.61	8.54	6190	3.49	2.48
Coal 17	338	<1	3.60	2.8	0.499	31.2	<0.200	498	1.62	<0.6	5.25	14.40	2730	62.00	<1.00
Mean	3365	1	9.31	62.0	0.703	30.0	0.3446	3393	6.64	0.6	5.21	25.03	6783	23.04	8.04
Median	3500	1	6.37	52.9	0.596	31.2	0.200	2120	8.23	0.6	5.25	17.90	6190	19.80	5.70
Minimum	338	1	2.58	2.8	0.290	14.6	0.200	498	1.62	0.6	1.29	5.05	2730	3.49	1.00
Maximum	5450	1	24.10	166.0	1.090	45.4	0.760	8750	10.50	0.6	7.83	46.70	13000	62.00	17.20
No. of samples	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
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
Coal 11	803	40.1	<0.2	3.20	19.1	18.7	955	1.60	<1	2420	27.2	<1	<1.00	24.5	19.9	28.3
Coal 12	1170	58.7	<0.2	3.51	26.9	51.8	1190	<1.00	<1	1770	32.0	<1	<1.00	44.9	38.7	32.9
Coal 13	580	43.4	<0.2	2.27	11.5	65.2	778	3.69	<1	217	36.5	<1	<1.00	59.9	15.9	19.8
Coal 14	1450	70.0	<0.2	<1.00	5.1	280.0	736	<1.00	<1	708	134.0	<1	<1.00	34.1	6.4	15.3
Coal 15	3310	242.0	<0.2	<1.00	20.6	123.0	718	1.87	<1	235	32.2	<1	<1.00	45.8	39.6	43.5
Coal 16	650	55.4	<0.2	2.51	10.6	58.1	479	3.87	<1	291	27.5	<1	<1.00	47.3	15.9	23.4
Coal 17	104	21.4	<0.2	<1.00	20.8	32.6	112	1.39	<1	50.4	4.7	<1	7.51	26.0	10.6	12.8
Mean	1152	75.9	0.2	2.07	16.4	89.9	710	2.06	1	813	42.0	1	1.93	40.4	21.0	25.1
Median	803	55.4	0.2	2.27	19.1	58.1	736	1.60	1	291	32.0	1	1.00	44.9	15.9	23.4
Minimum	104	21.4	0.2	1.00	5.1	18.7	112	1.00	1	50.4	4.7	1	1.00	24.5	6.4	12.8
Maximum	3310	242.0	0.2	3.51	26.9	280.0	1190	3.87	1	2420	134.0	1	7.51	59.9	39.6	43.5
No. of samples	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
LOD	20	2	0.2	1	0.6	10	50	1	1	10	1	1	1	3	0.1	2

Table 7.9 Primary data for steam coal: 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**
Coal 11	878	386.0	1710	919	381	415	300	<300
Coal 12	1120	388.0	1530	1470	795	775	961	<300
Coal 13	933	423.0	746	1180	1140	1490	2010	<400
Coal 14	260	93.0	<400	401	<400	<400	176	<400
Coal 15	2320	150.0	2660	2840	2680	2200	3460	741
Coal 16	204	87.4	956	761	406	422	282	<100
Coal 17	2020	159.0	2590	2940	2250	2330	3750	576
Mean	1105	240.9	1513	1502	1150	1147	1563	402
Median	933	159.0	1530	1180	795	775	961	400
Minimum	204	87.4	400	401	381	400	176	100
Maximum	2320	423.0	2660	2940	2680	2330	3750	741
No. of samples	7	7	7	7	7	7	7	7
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
Coal 11	899	72.4	1040	2650	<500	67500	9650	1420
Coal 12	1460	170	1530	2690	<500	69100	11100	2100
Coal 13	1330	292	1180	2070	595	23000	11200	1770
Coal 14	<600	<60	1070	796	<600	3050	2240	650
Coal 15	4140	493	3520	6270	785	3540	21100	5510
Coal 16	842	<60	2010	555	<600	1180	2450	2720
Coal 17	2700	582	3100	6140	923	1620	21700	5300
Mean	1710	247	1921	3024	643	24141	11349	2781
Median	1330	170	1530	2650	600	3540	11100	2100
Minimum	600	60	1040	555	500	1180	2240	650
Maximum	4140	582	3520	6270	923	69100	21700	5510
No. of samples	7	7	7	7	7	7	7	7
LOD	30	3	20	10	30	10	20	20

Table 7.10 Primary data for steam coal: 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)
Coal 11	877.00	1050.00	1740.00	544.00	3300.0
Coal 12	270.00	177.00	691.00	192.00	672.0
Coal 13	4.94	37.70	7.54	3.68	37.9
Coal 14	2.28	10.40	4.03	1.67	13.6
Coal 15	<5.00	1.44	<10.00	<3.00	<20.0
Coal 16	<5.00	1.58	<10.00	<3.00	<20.0
Coal 17	<2.00	<2.00	<5.00	<1.00	<7.0
Mean	166.60	182.87	352.51	106.91	581.5
Median	5.00	10.40	10.00	3.00	20.0
Minimum	2.00	1.44	4.03	1.00	7.0
Maximum	877.00	1050.00	1740.00	544.00	3300.0
No. of samples	7	7	7	7	7
LOD	1	1	2	0.5	3

Table 7.11 Primary data for steam coal: calorific value and proximate analysis (composition)

Sample ID	Calorific value (gross)	Calorific value (net)	Total moisture	Ash	Volatile matter	Fixed carbon
	kJ/kg	kJ/kg	%	%	%	%
Coal 11	25630	24432	12.6	12.1	29.8	45.5
Coal 12	25470	21308	14.7	19.5	24.7	41.1
Coal 13	27949	26909	2.9	15.1	32.1	49.9
Coal 14	27049	25964	4.8	13.6	34.4	47.2
Coal 15	27546	26444	6.3	11.7	32.1	49.9
Coal 16	27103	25937	6.8	7.4	39.2	46.6
Coal 17	29710	28503	9.8	5.8	29.7	54.7
Mean	27208	25642	8.3	12.2	31.7	47.8
Median	27103	25964	6.8	12.1	32.1	47.2
Minimum	25470	21308	2.9	5.8	24.7	41.1
Maximum	29710	28503	14.7	19.5	39.2	54.7
No. of samples	7	7	7	7	7	7
LOD	100	100	0.1	0.1	1.1	n/a

Table 7.12 Primary data for steam coal: ultimate analysis

Sample ID	Bromine	Carbon	Chlorine	Fluorine	Hydrogen	Nitrogen	Oxygen	Sulphur
	mg/kg	%	%	mg/kg	%	%	%	%
Coal 11	376.9	61.16	0.55	39.3	4.01	1.45	6.3	1.88
Coal 12	176.7	54.29	0.29	68.9	3.43	1.15	4.5	2.15
Coal 13	<100.0	67.14	0.13	47.0	4.32	1.35	7.5	1.53
Coal 14	<100.0	65.90	0.02	54.6	4.41	2.07	8.9	0.27
Coal 15	<100.0	66.21	0.04	30.1	4.39	1.50	8.7	1.21
Coal 16	<100.0	65.46	0.02	14.1	4.80	1.47	13.2	0.82
Coal 17	<100.0	68.21	0.01	17.8	4.31	1.98	9.1	0.80
Mean	150.5	64.05	0.15	38.8	4.24	1.57	8.3	1.24
Median	100.0	65.90	0.04	39.3	4.32	1.47	8.7	1.21
Minimum	100.0	54.29	0.01	14.1	3.43	1.15	4.5	0.27
Maximum	376.9	68.21	0.55	68.9	4.80	2.07	13.2	2.15
No. of samples	7	7	7	7	7	7	7	7
LOD	100	0.41	0.01	10	0.06	0.1	n/a	0.02

Table 5.13 Primary data for coking coal: physical properties

Sample ID	Dry solids @ 30°C	PSD 2–20 mm	PSD 20–50 mm	PSD >50 mm	Loose bulk density
	%	%	%	%	kg/m^3
Coal 18	96.8	34.3	<0.1	<0.1	792
Coal 19	93.4	24.3	<0.1	<0.1	588
Coal 20	100.0	15.0	<0.1	<0.1	626
Mean	96.7	24.5	0.1	0.1	669
Median	96.8	24.3	0.1	0.1	626
Minimum	93.4	15.0	0.1	0.1	588
Maximum	100.0	34.3	0.1	0.1	792
No. of samples	3	3	3	3	3
LOD	0.5	n/a	n/a	n/a	n/a

Table 7.14 Primary data for coking coal: metals (mg/kg DW)

(a)

Sample ID	Al	Sb	As	Ba	Be	Bo	Cd	Ca	Cr	Cr VI	Co	Cu	Fe	Pb	Li
Coal 18	1560	<1	4.88	62.6	0.778	12.50	<0.2	990	1.49	<0.6	3.41	12.7	1700	5.76	3.51
Coal 19	1480	<1	9.84	17.7	0.484	7.12	<0.2	583	2.00	<0.6	4.50	18.0	2050	4.90	2.84
Coal 20	2650	<1	2.23	75.9	0.542	<1.00	<0.2	1180	3.13	<0.6	2.38	17.2	810	6.11	5.72
Mean	1897	1	5.65	52.1	0.601	6.87	0.2	918	2.21	0.6	3.43	16.0	1520	5.59	4.02
Median	1560	1	4.88	62.6	0.542	7.12	0.2	990	2.00	0.6	3.41	17.2	1700	5.76	3.51
Minimum	1480	1	2.23	17.7	0.484	1.00	0.2	583	1.49	0.6	2.38	12.7	810	4.90	2.84
Maximum	2650	1	9.84	75.9	0.778	12.50	0.2	1180	3.13	0.6	4.50	18	2050	6.11	5.72
No. of samples	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
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
Coal 18	335	28.0	<0.2	<1.00	5.49	24.2	644	2.33	<1	85.1	70.6	<1	<1	24.6	8.25	24.4
Coal 19	151	7.8	<0.2	1.31	6.54	48.9	382	2.54	<1	103.0	32.4	<1	<1	16.6	7.36	12.8
Coal 20	305	19.5	<0.2	1.51	4.07	257.0	397	1.31	<1	183.0	69.2	<1	<1	22.3	14.00	13.9
Mean	264	18.4	0.2	1.27	5.37	110.0	474	2.06	1	123.7	57.4	1	1	21.2	9.87	17.0
Median	305	19.5	0.2	1.31	5.49	48.9	397	2.33	1	103.0	69.2	1	1	22.3	8.25	13.9
Minimum	151	7.8	0.2	1.00	4.07	24.2	382	1.31	1	85.1	32.4	1	1	16.6	7.36	12.8
Maximum	335	28.0	0.2	1.51	6.54	257.0	644	2.54	1	183.0	70.6	1	1	24.6	14.00	24.4
No. of samples	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
LOD	20	2	0.2	1	0.6	10	50	1	1	10	1	1	1	3	0.1	2

Table 7.15 Primary data for coking coal: 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**
Coal 18	1250	144.0	<400	<400	<400	<400	295	<400
Coal 19	119	60.9	<400	<400	585	<400	388	<400
Coal 20	162	136.0	<700	<700	<700	<700	328	<700
Mean	510	113.6	500	500	562	500	337	500
Median	162	136.0	400	400	585	400	328	400
Minimum	119	60.9	400	400	400	400	295	400
Maximum	1250	144.0	700	700	700	700	388	700
No. of samples	3	3	3	3	3	3	3	3
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
Coal 18	720	65.7	674	1320	<500	2330	3780	644
Coal 19	886	70.3	454	839	<600	2520	3280	461
Coal 20	<1000	111	<700	592	<1000	2260	2070	<700
Mean	869	82	609	917	700	2370	3043	602
Median	886	70.3	674	839	600	2330	3280	644
Minimum	720	65.7	454	592	500	2260	2070	461
Maximum	1000	111	700	1320	1000	2520	3780	700
No. of samples	3	3	3	3	3	3	3	3
LOD	30	3	20	10	30	10	20	20

Table 7.16 Primary data for coking coal: 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)**
Coal 18	<5	<5	<10	<2	<10
Coal 19	<1	<1	<3	<0.7	<4
Coal 20	<5	<5	<10	<2	<10
Mean	4	4	8	2	8
Median	5	5	10	2	10
Minimum	1	1	3	0.7	4
Maximum	5	5	10	2	10
No. of samples	3	3	3	3	3
LOD	1	1	2	0.5	3

Table 7.17 Primary data for coking coal: calorific value and proximate analysis (composition)

Sample ID	Calorific value (gross)	Calorific value (net)	Total moisture	Ash	Volatile matter	Fixed carbon
	kJ/kg	kJ/kg	%	%	%	%
Coal 18	31454	30289	5.1	6.9	32.0	56.0
Coal 19	30277	29250	7.5	8.8	18.6	65.1
Coal 20	29010	27923	9.6	9.0	21.4	60.0
Mean	30247	29154	7.4	8.2	24.0	60.4
Median	30277	29250	7.5	8.8	21.4	60.0
Minimum	29010	27923	5.1	6.9	18.6	56.0
Maximum	31454	30289	9.6	9.0	32.0	65.1
No. of samples	3	3	3	3	3	3
LOD	100	100	0.1	0.1	1.1	Calculated

Table 7.18 Primary data for coking coal: ultimate analysis

Sample ID	Bromine	Carbon	Chlorine	Fluorine	Hydrogen	Nitrogen	Oxygen	Sulphur
	mg/kg	%	%	mg/kg	%	%	%	%
Coal 18	<100	75.47	0.22	18.8	4.70	1.44	5.3	0.83
Coal 19	<100	74.22	0.13	35.8	3.90	1.23	3.4	0.84
Coal 20	<100	71.30	0.05	18.8	3.95	1.43	4.1	0.56
Mean	100	73.66	0.13	24.5	4.18	1.37	4.3	0.74
Median	100	74.22	0.13	18.8	3.95	1.43	4.1	0.83
Minimum	100	71.30	0.05	18.8	3.90	1.23	3.4	0.56
Maximum	100	75.47	0.22	35.8	4.70	1.44	5.3	0.84
No. of samples	3	3	3	3	3	3	3	3
LOD	100	0.41	0.01	10	0.06	0.1	n/a	0.02

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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
CV	calorific value
DCM	dichloromethane
DW	dry weight
Fe	Iron
GCMS	gas chromatography–mass spectrometry
Hg	Mercury
HR	high resolution
ICP-OES	inductively coupled plasma optical emission spectrometry
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
NH_3 as N	Ammoniacal nitrogen
NH_4	Ammonium
Ni	Nickel
NLS	National Laboratory Service [Environment Agency]
NO_2	Nitrogen dioxide
P	Phosphorus
PAH	polycyclic aromatic hydrocarbon
Pb	Lead
PSD	particle size distribution
PTEs	Potentially Toxic Elements
SAL	Scientific Analysis Laboratories Limited
Sb	Antimony
Se	Selenium
Sn	Tin
Sr	Strontium
TC	total carbon
TC	total carbon
Ti	Titanium
Tl	Thallium
TN	total nitrogen
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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