Guidelines for Specifications of Biochars DRAFT VERSION

Type of Document:	Product Definition and Specification Guidelines
Status of Document:	Draft for Public Review
Revision Number:	0.6
Revision Date:	4 October 2011 For Public Posting
Original Date:	1 September 2011 Frankfurt Live Meeting
Document Reference Code:	IBI-STD-0

Leading Carbon Ltd.

October 2011

Disclaimer

The International Biochar Initiative (IBI) Guidelines for Specifications of Biochars have been prepared with the intent of providing the public with guidelines to categorize biochars according to relevant, reliable and measurable characteristics. In no way shall the IBI or its associates be responsible for the use or misuse of information and guidance provided in this document. This document prescribes tests and thresholds only to identify certain qualities and characteristics of biochars. No portion of this document is intended for use as a sustainability or production process guideline. Further documentation and guidance is necessary to identify appropriate sustainability practices and/or safe and effective production processes.

The benefits of a given biochar product can vary widely with the combination of crop, soil and climate factors. This guidance document makes no claims regarding the potential benefits of any given biochar in any particular application. Caution and careful investigation is warranted when selecting biochar for an application.

The IBI Guidelines for Specifications of Biochars is intended to be a living document. This document is subject to continuous updates and modifications as the science and body of knowledge surrounding biochar continues to evolve. Please ensure that you are using the most up-to-date version.

Foreword

The Guidelines for Specifications of Biochars have been developed by the International Biochar Initiative (IBI) in collaboration with a wide variety of industry and academic experts and through public input on an international level. The document was created to encourage further development of the biochar industry by providing standardized information regarding the characterization of biochar to assist in achieving more consistent levels of product quality. In addition to providing product definition and quality specification guidelines, this document has been developed to ensure that consumers have more consistent access to better information regarding the quality and physicochemical properties of biochar.

The Guidelines for Specifications of Biochars are designed to support an IBI certification program. Such a certification program has yet to be developed, but the implementation of a certification program will be informed by this document. Separately, the guidelines are also intended for use by various national and regional product standards bodies, national and regional biochar groups for their own local adaptation and use, and as a reference in regulatory situations, as may be appropriate.

IBI initiated the guideline creation as a transparent process open to public input. Document creation was focused among experts in the field, ensuring an efficient path from concept to final product, and addressing the needs of a broad range of biochar producers and users. As the

document was developed, public input from the larger international biochar community was also sought to provide a wider perspective on the use and functionality of this tool.

The design of the Guidelines for Specifications of Biochars follows current best practices and available science. As biochar science continues to improve, the document will be updated in an iterative process in order to remain current. Therefore these guidelines and this document will be periodically revised through further consultation with the international biochar community.

The Guidelines for the Specification of Biochars document development process is based on the following guiding principles:

- Maintain congruence with best practice guidance for standards development (such as ISO, ASTM, IEEE);
- Strictly adhere to process, ensuring efficient and effective collaboration;
- Engage the knowledgeable and diverse stakeholder group active in the biochar industry;
- Organize an independent review committee with broad stakeholder representation, (including project developers, environmental non-governmental organizations (ENGOs), researchers, and so on); and,
- Rely on existing infrastructure and capacity within IBI for leadership and administration of the initiative.

The experts charged with the development of the Guidelines for Specifications of Biochars took part in two phases of working group activities. At the end of each phase, new draft documents were posted, and comments were solicited. Throughout the process, public comments were incorporated in subsequent revisions of the draft. These consisted of Phase I, an initial review of document formatting and characterization criteria, and phase II, an in-depth discussion of characterization criteria and reporting levels selection. The working groups for each phase were organized as follows:

Phase 1: Initial review of document formatting and characterization criteria (December 2010 – March 2011)

Working Group #1: North America/South America/Africa

- Jim Amonette, United States
- Jason Aramburu, United States
- Louis de Lange, South Africa
- Mariam Ekebafe, Nigeria
- Johannes Lehmann, United States
- Kim Magrini, United States
- Hugh McLaughlin, Canada

- René Pigeon, Canada
- Joseph Pignatello, United States
- Miguel Rodriguez, Brazil
- Rogerio Traballi, Brazil
- Sunguo Wang, Canada

Working Group #2: Asia/Europe/ Australia/New Zealand

- Marta Camps, New Zealand
- Thomas Harttung, Denmark
- Michael Hayes, Ireland
- Stephen Joseph, Australia
- Rupam Kataki, India
- Guitong Li, China
- Franco Miglietta, Italy
- Amran Salleh, Malaysia
- Yoshiyuki Shinogi, Japan
- Balwant Singh, Australia
- Saran Sohi, United Kingdom
- Lukas Van Zwieten, Australia

Phase 2: Live, in-depth review of characterization criteria and reporting levels selection (July 2011)

- Marta Camps, New Zealand
- Stephen Joseph, Australia
- Johannes Lehmann, United States
- Cordner Peacocke, United Kingdom
- Michael Sesko, United States
- Saran Sohi, United Kingdom
- Edward Someus, Sweden

Table of Contents

1 Scope

Issued by the International Biochar Initiative (IBI) and based on international consultation, this document is intended to establish testing, measurement, reporting methods, and labeling guidelines for the physical and chemical properties of biochar. Biochar is a solid material obtained from the carbonization of biomass. Biochar can be used as a product or an ingredient within a blended product, with a range of applications as an agent for soil improvement, improved resource use efficiency, remediation and/or protection against particular environmental pollution, and as an avenue for greenhouse gas abatement.

These guidelines provide a standardized definition of biochar and biochar characteristics related to the use of biochar as a soil amendment. They will serve as the basis for IBI certification programs, and are intended for use and adaptation to local conditions and regulations by any nation or region. These guidelines support not only baseline safety considerations but also the evolving understanding of the positive functions of biochar in soil. This document does not prescribe appropriate uses for biochar products, nor provide guidelines on what biochar can or should be used for.

These guidelines for the specifications of biochar relate to the physical properties of biochar only, and do not prescribe production methods or feedstock types, nor do they provide limits or terms for defining the sustainability and/or greenhouse gas abatement potential of a biochar product, for a certification scheme or otherwise. Although the biochar production and use parameters, listed above, are critical attributes of biochar production and application, they will be addressed in further IBI documents, yet to be developed.

Different feedstocks, and hence differentiated testing requirements of biochar, are defined in this guidance document as means for the identification and classification of a range of biochars. This testing scheme is based upon increasing levels of physical and chemical property reporting and not necessarily on increasing levels of biochar performance.

The intended audiences for these guidelines for biochar specification include producers, users, regulators, researchers and marketers of biochar, as well as the many national and regional biochar affiliates of the IBI. However, the biochar producer is the entity most likely to apply the guidelines, as a label (of differentiation) to the output of their production process.

2 Effective Date

The effective date of the Guidelines for Specifications of Biochars is *[January 1, 2012].* The public posting and comment period is scheduled for autumn 2011.

3 Terms and Definitions

Ash: The solid mineral fraction of biomass or organic material that is not combustible. Ash may remain as a fixed solid after combustion of an organic substance, or it may be entrained as solid particulate matter in the exhaust gases from combustion.

Biochar: A solid material obtained from the carbonization of biomass.

Biochar Characteristics: For the purposes of these guidelines, biochar characteristics are those biochar physical properties that affect the following uses for biochar: 1) biochar that is added to soils with the intention to improve soil functions; and 2) biochar that is produced in order to reduce emissions from biomass (that would otherwise naturally degrade to greenhouse gases) by converting a portion of that biomass into a stable carbon fraction that has carbon sequestration value.

Biomass: The biodegradable fraction of products, waste and residues of biological origin from agriculture (including vegetal and animal substances), forestry, and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste (including municipal solid waste). (European Commission Agriculture and Rural Development 2010)

Carbonization: The process of converting feedstock into biochar through reductive thermal processing. The process involves a combination of time, heat and pressure exposure factors that can vary between processors, equipment and feedstocks.

Contaminant: An undesirable material in a biochar or biochar feedstock that compromises the quality or usefulness of the biochar. Contaminants include fossil fuels and fossil-fuel-derived chemical compounds, glass, and metal objects.

Diluent/Dilutant: Inorganic material that is deliberately or inadvertently comingled with biomass feedstock prior to processing. These materials will not carbonize in an equivalent fashion to the biomass. These materials include common constituents of natural soils, such as clays and gravel that may be gathered with biomass or intermixed through prior use of the feedstock biomass. Diluents/dilutants may be found in a diverse range of feedstocks, such as agricultural residues and municipal solid wastes.

Feedstock: The material undergoing the carbonization process to create biochar. Typically, feedstock material for biochar consists of organic material, but may also contain diluents.

Hazardous Materials or Wastes: Potential environmental pollutants that, when concentrated, can be a source of regulatory concern for any use or application that may influence human or environmental health and wellbeing (adapted from US Composting Council and US Department of Agriculture 2001).

Manufacturer/Producer: The party or parties who process the feedstock materials into biochar, acquire appropriate labeling, and test the biochar properties.

Municipal Waste/ Municipal Solid Waste (MSW): Domestic or small commercial non-hazardous wastes. MSW includes food wastes, yard wastes, containers and product packaging, and other miscellaneous inorganic wastes from residential, commercial, institutional and industrial sources. MSW may contain biodegradable components, recyclable material, inert waste, composite wastes, domestic hazardous waste and sludge. Other discarded material, including solid, semi-solid, liquid, or contained gaseous material resulting from community activities can also be found in MSW. MSW containing hazardous materials or wastes may not be included as eligible feedstocks under these guidelines. It is the manufacturer's responsibility to ensure that biochar feedstock materials are free of hazardous materials.

Organic Carbon: Biologically degradable carbon-containing compounds found in the organic fraction of biochar feedstocks. Biochar feedstock can contain such compounds as sugars, starches, proteins, fats, cellulose and lignocellulose, which are degradable by reductive thermal processing. Other organic carbon forms can include petroleum and petroleum byproducts such as plastics and contaminated oils, which are, for the purposes of this document, included within the definition of contaminants, but may also be thermally degraded. The organic carbon fraction does not include inorganic carbonate concretions such as calcium and magnesium carbonates. (adapted from US Composting Council and US Department of Agriculture 2001)

Organic Material: Biological material derived from, or produced by living or recently living organisms. This material can be "unprocessed" or "processed". Unprocessed material is living material, or recently living material, (biomass) that may have been mechanically resized (such as wood chips), but has not gone through an anthropogenic chemical modification. Processed material is recently living material that has been chemically modified by anthropogenic or biological processes (e.g., paper sludge, manure). This document recognizes that other definitions of "organic" exist such as those of organic chemistry; however, for the purposes of these guidelines the IBI has opted to define "organic" within these narrower bounds.

Processed Feedstock: Biomass that has gone through chemical processing (for example, chemical treatment such as occurs with wood preservatives and paper pulp sludges) or biological processing (for example, digestion, such as manures and sludge from waste effluent treatment) beyond simple mechanical processing to modify physical properties.

Residence Time: The time a feedstock is held within a consistent temperature range in a given carbonization process.

Soil Functions: Soil functions are defined by the proposal for a European Soil Framework Directive COM(2006)232, as follows: "(i) biomass production, including in agriculture and forestry; (ii) storing, filtering and transforming nutrients, substances and water; (iii) hosting the biodiversity pool, such as habitats, species and genes; (iv) acting as a platform for human activities; (v) source of raw materials; (vi) acting as carbon pool; and (vii) storing geological

and archeological heritage." The guidelines and this document will focus on functions of biochar in soils.

Unprocessed Feedstock: Biomass that has not gone through chemical processing (that is, chemical treatment, such as wood preservatives and sludges) or biological processing (that is, digestion, such as manures and sludges) processing, but may have gone through mechanical processing to change its physical properties, including particle size.

4 Biomass Feedstock Material and Biochar Production

4.1 General Feedstock Material Requirements

The materials used as feedstocks for biochar production have direct impacts on the nature and quality of the resulting biochar. Although the focus of this document is on the resulting biochar, some restrictions have been applied to feedstock contents and quality. To qualify as biochar under these guidelines, the feedstock may be any combination of biomass and diluents, and may not contain more than 2% by dry weight of contaminants, (following Brinton 2000). Suitable feedstocks include but are not limited to agriculture, food, and forestry residues, which may contain a minimal quantity of contaminants as part of the feedstock.

Note: Issues of feedstock sustainability are to be addressed in other IBI or related documents not included herein.

4.2 General Biochar Process and Material Recommendations

This guidance does not prescribe production and handling expectations for biochar, but instead provides recommendations for safe production processes. It is the responsibility of the biochar manufacturer to create biochar in a safe manner. The IBI recommends that best industry practices be followed throughout the manufacturing process.

Local requirements and regulations for the operation of biochar production facilities should be followed. Where applicable, biochar production must comply with local and international regulatory requirements and treaties that govern thermal processes, the production of volatile and particulate emissions, and the transport of goods. Relevant to local and international regulatory compliance, biochar producers should follow the two recommendations listed below:

- A biochar producer should provide a relevant material safety data sheet (MSDS) for the final output of its particular biochar production process. Brief outlines of MSDS document creation are available from numerous online sources, including MSDS Search, the Canadian Center for Occupational Health and Safety, and the US Department of Labor Occupational Health and Safety Administration.

- Biochar should be tested to address the potential for self-heating and flammability during storage and transportation. Documentation of the results of this testing should be appended to the MSDS.

While the IBI may not require these practices as part of its definition and certification of biochar since they do not relate directly to product quality, they are important considerations in good business practice and responsible industrial production. The majority of nations provide detailed guidelines, expectations and regulations governing the manufacturing sector and will have relevant information available to industrial operators.

5 Biochar Product Testing Categories

As is described in this section, biochar products shall be categorized based on the extent of testing and content analysis (relative to defined thresholds) completed for the given biochar material. The categorization structure is designed to:

- Provide a uniform presentation format by which a biochar user would be able to fairly compare and assess the reported properties of different biochars to determine if a particular biochar is suitable for a specific application.

- Incrementally increase the requirements of physical and chemical data reporting, so that a higher level of characterization and testing provides a more comprehensive understanding of the composition and properties of the material, as well as a better understanding of "fit for purpose".

Each testing level category was developed according to an assessment of the relevant parameters for biochar qualities, characteristics, and safety, balanced against cost and accessibility. This document, however, does not provide guidance on the interpretation of these parameters relative to the beneficial uses and applications of biochar. Rather, the intent of this categorization structure is to provide increasing detail on the relevant parameters of the biochar in order to support decision-making by users, according to their own requirements.

This guidance document defines three levels for testing of biochar, which are as follows:

Level 1 - Entry Level: Biochar meets entry level requirements if it has been tested for the most basic parameters required to assess utility. Level 1 applies only to biochar from unprocessed feedstock.[1]

[1] The exclusion of processed feedstocks from qualifying as Level 1 biochar reflects the need for further analysis to provide suitable assurance of the composition and properties of biochar made from processed feedstocks.

Level 2 - Moderate Level: Biochar that meets moderate level requirements has been tested for basic analysis and enhancement properties and meets some toxicity thresholds, in addition to the requirements of Level 1, regardless of whether it is of unprocessed or processed feedstock origin.

Level 3 - Advanced Level: Biochar that has been tested for advanced analysis and enhancement properties and meets some additional toxicity thresholds, in addition to meeting the requirements of Level 2.

Further details on each of the testing categories are provided in the following subsections. An illustration of the interrelationship between the testing level categories is provided in Figure 1, below.

Figure 1: Flow Chart of Biochar Testing and Declaration Levels

5.1 Level 1, Entry Level Testing and Declaration - Utility

Biochar that is characterised exclusively under Level 1 category tests must originate from unprocessed feedstocks. Biochar from processed feedstocks must be characterized by Level 2 or higher category tests.

Producers of biochar that has been tested to Level 1 must declare all basic biochar characteristics outlined below, meet carbon content ratio minimums, and pass vegetative and invertebrate vigour tests to meet the requirements of a Level 1 testing category. Basic biochar characteristics include the physical properties of particle size and moisture content, as well as chemical properties of element proportions (H, C and N), ash proportion and pH/liming ability. Biochars tested to Level 1 shall conform to all requirements presented in Table 1 below:

Table 1: Level 1 Characteristics and Criteria

Requirement	Criteria	Unit	Test Method
Basic Biochar Characterization			
Moisture Content	Declaration	% of total mass	ASTM D1762-84 (specify measurement date with respect to time from production)
Total Ash	50% (Maximum)	% of total mass	Apply loss on ignition (ASTM D1762-84) to ascertain total non-carbonate ash, then add back inorganic carbon as carbonate.
Organic Carbon	Declaration	% of total mass	C, H, N analysis by dry combustion (Dumas method), before (total C) and after (organic C) HCl addition; inorganic C is the difference between total and organic C.
Inorganic Carbon	Declaration	% of total mass	
$H:C_{org}$	0.7 (Maximum)	Molar ratio	
Total N	Declaration	% of total mass	Dry combustion (Dumas method) and gas chromatography, following same procedure as for C, H, N analysis above, without HCl addition.
pH	Declaration		Activated carbon pH, as outlined in Ahmedna et al. (2000), and Ahmedna et al (1997)
Liming (if pH is above 7)	Declaration	% CaCO3	Rayment & Higginson (1992)
Particle size distribution	Declaration	% or total mass in each class	Progressive dry sieving with 200µm, 2,000µm and 20,000µm sieves, as outlined in ASTM D5158-98 - Method for activated carbon
Vegetative and Invertebrate Vigour			
Earthworm Avoidance Test	Pass/Fail		OECD methodology (1984) as described by Van Zwieten et al. (2009)
Germination Inhibition Assay	Pass/Fail		OECD methodology (2004) 3 test species, as described by Van Zwieten et al. (2009)

5.2 Level 2, Moderate Testing and Declaration - Basic Analysis and Enhancement Properties

Biochars tested to Level 2 must meet basic soil toxicity assessment guidelines and thresholds as outlined in Table 2 below, report basic soil enhancement properties, and meet all Level 1 requirements to meet the requirements of a Level 2 testing category, regardless of whether the biochar is derived from a processed or unprocessed feedstock. Basic soil enhancement properties include N, P and K nutrient content, and electrical conductivity, while basic soil toxicity assessment guidelines follow commonly-identified soil toxicity and soil amendment chemical content reporting requirements (soil amendments include fertilizers and composts). All values must be reported in order to meet test Level 2 categorization. Where values exceed threshold levels, as outlined in Table 2, biochars will not achieve a Level 2 ranking.

Biochars tested to Level 2 shall conform to all requirements presented in Table 2 below:

Table 2: Level 2 Characteristics and Criteria

Requirement	Criteria	Unit	Criteria/Test Method
Basic Soil Toxicity			
	Maximum Allowed Threshold		
Arsenic	13	mg/kg	Bureau de normalisation du Québec (2005)
Cadmium	1.4	mg/kg	Amlinger, Faroino and Pollack, (2004)
Chromium	93	mg/kg	Amlinger, Faroino and Pollack, (2004)
Cobalt	34	mg/kg	Bureau de normalisation du Québec (2005)
Copper	143	mg/kg	Amlinger, Faroino and Pollack, (2004)
Lead	121	mg/kg	Amlinger, Faroino and Pollack, (2004)
Molybdenum	5	mg/kg	Bureau de normalisation du Québec (2005)
Mercury	1.0	mg/kg	Amlinger, Faroino and Pollack, (2004)
Nickel	47	mg/kg	Amlinger, Faroino and Pollack, (2004)
Selenium	2	mg/kg	Bureau de normalisation du Québec (2005)
Zinc	416	mg/kg	Amlinger, Faroino and Pollack, (2004)
Boron	Declaration	mg/kg	US Composting Council and US Department of Agriculture (2001)
Chlorine	Declaration	mg/kg	US Composting Council and US Department of Agriculture (2001)
Sodium	Declaration	mg/kg	US Composting Council and US Department of Agriculture (2001)
Basic Soil Enhancement Properties			
Total P & K[2]	Declaration	% content	Modified dry ashing followed by ICP (Enders and Lehmann 2011)
Mineral N (ammonium and nitrate)	Declaration	mg/kg	2M KCl extraction, followed by spectrophotometry (Rayment and Higginson 1992)
Available P	Declaration	mg/kg	2% formic acid followed by spectrophotometry

[2] Total K is sufficiently equivalent to available K for the purpose of this categorization

Requirement	Criteria	Unit	Criteria/Test Method
			(modified from Rajan et al 1992, Nutrient Cycl in Agroecosystems 32:291-302 and AOAC 2005, as used by Wang et al. 2011 Submitted to Plant and Soil)
Electrical Conductivity	Declaration	S/m	Method 3.A1 Rayment and Higginson 1992; EC of 1:5 soil/water content

1

5.3 Level 3, Advanced Testing and Declaration – Advanced Analysis and Enhancement Properties

Biochars tested to Level 3 must meet a series of advanced toxicity assessment requirements and report on a set of advanced soil enhancement properties, in addition to meeting all test Level 1 and test Level 2 requirements, regardless of whether the biochar is derived from a processed or unprocessed feedstock. Advanced soil toxicity reporting reflects the concentrations of volatile aromatic compounds, while advanced soil enhancement properties identify the porosity and surface area of biochars.

Biochars tested to Level 3 shall conform to all requirements presented in Table 3 below:

Table 3: Level 3 Characteristics and Criteria

Requirement	Criteria	Unit	Test Method
Advanced Soil Toxicity Reporting			
	Maximum Allowed Threshold		
Polychorinated Biphenyls	0.2	mg/kg TM or TEQ	Threshold criteria following Amlinger, Faroino and Pollack, (2004). Method following US Environmental Protection Agency (1996)
Polycyclic Aromatic Hydrocarbons (PAH)	6	mg EPA PAH/kg TM	
Furan	0.5	ng/kg I TEQ OMS	US Environmental Protection Agency (2007)
Dioxin	0.5	ng/kg I TEQ OMS	
Advanced Soil Enhancement Properties			
Porosity	Declaration	%	ASTM 1510-11a Iodine Adsorption Method
Surface Area	Declaration	m2/g	

6 Product Labeling and Instructions

Product labeling and information sharing will become an important part of any subsequently developed biochar certification program. In order to qualify for certification, biochar producers and manufacturers must share information about the feedstock and final biochar product. Communication of biochar qualities, test levels, and feedstock origins must be conducted in a uniform way to create an easily understood certification program that end-consumers will be able to support.

6.1 Labeling General Requirements

To meet the requirements of this guidance document, a label shall be attached, provided in a web-link, or otherwise included with all transactional documents, packaging, advertisement or other commercial documentation associated with the biochar. This label shall be legible and placed in a fashion that is visible and clear on the biochar packaging or documentation.

6.2 Product Information Requirements

Included with the label, the manufacturer of the biochar shall make available to the purchaser, information pertaining to:

- Feedstock material(s) including content (by weight) of diluents within the biochar fraction.
- Country of origin for biochar feedstock and production.
- All relevant information required by test level categories.

6.3 Special instruction

The manufacturer shall make available to the user instructions for suitable use, storage and transportation of the biochar in compliance with Hazardous Materials Identification System (HMIS) requirements, or other occupational health and safety requirements, as required by the prevailing jurisdiction. Specifically, this information should include guidance on the safe care, storage and handling of the biochar.

7 Conformity and Record Keeping

Adequate documentation and reporting are required by producers seeking to gain the IBI's confidence, or that of any national or regional certification program. The reporting of biochar feedstock contents and end-product quality are both necessary to provide assurance in end-product uniformity. Record keeping will be mandatory, in order to establish proof of adequate sampling, analysis, meeting of thresholds, and for proof of product test level category qualification over time.

7.1 Adequate Sample Testing

Biochar properties and characteristics according to the specification guidelines shall be assessed and reported as follows (whichever is most frequent):

- After every 600 metric tonnes (dry weight) of consistent feedstock through-put; or,
- Every 6 months; or,
- After a material change in feedstock;[3] or,
- After a material change in production parameters.[4]

Assessment, testing and categorization of biochar should occur before final storage or blending of product. Sampling of biochar shall be conducted by trained and accredited laboratory professionals following the appropriate procedures identified for each test within a category level. Biochar analysis shall follow strict quality control requirements according to standardized laboratory procedures. Documentation of biochar production and certification reporting and analyses should be kept for seven years.

7.2 Chain of Custody

Chain of custody and product traceability will require an assurance that adequate care and transparency is being exercised to enable trace-back of final end-products from end-users across the biochar market to manufacturers and feedstock suppliers. All levels in the biochar production and supply chain will be required to participate in record keeping, in order to maintain quality assurance.

[3] Material changes in feedstock reflect gross shifts in feedstock type from one source of biomass to a distinctly different source of biomass (e.g. corn stover switched to wood chips).
[4] Material changes in production processes reflect increases or decreases in process temperature (i.e. +/- 50˚C), or mean residence time (i.e. +/- 10 minutes in a continuous process).

8 References

Ahmedna, M., Johns, M.M., Clarke, S.J., Marshall, and W.E., Rao, R.M. (1997) Potential of agricultural by-product-based activated carbons for use in raw sugar decolourization. *Journal of the Science of Food and Agriculture.* 75, 117-124.

Ahmedna, M., Marshall, W.E., and Rao, R.M. (2000) *Production of granular activated carbons from select agricultural by-products and evaluation of their physical, chemical and adsorption properties.* Bioresource Technology 71: 113-123

Amlinger, F., Faroino, E., and Pollack, M. (2004) EU Heavy Metals and Organic Compounds from Waste Used as Organic Fertilizers Final Report ENV.A.2./ETU/2001/0024 REF.NR.: TEND/AML/2001/07/20

AOAC International (2005) AOAC Official Methods of Analysis. 18th Edition. Latimer, G. (Ed.) www.eoma.aoac.org (accessed September 2011)

ASTM International (2009) *ASTM D1510 - 11a Standard Test Method for Carbon Black—Iodine Adsorption Number* http://www.astm.org/Standards/D1510.htm (accessed September 2011)

ASTM International (2007) ASTM D1762-84 (2007) Standard Test Method for Chemical Analysis of Wood Charcoal http://www.astm.org/Standards/D1762.htm (accessed September 2011)

ASTM International (2005) ASTM D5158-98 (2005) Standard Test Method for Determination of Particle Size of Powdered Activated Carbon by Air Jet Sieving http://www.astm.org/Standards/D5158.htm (accessed September 2011)

Brinton, W.F. (2000) *Compost quality standards and guidelines.* Woods End Research Laboratory, prepared for New York State Association of Recyclers. http://compost.css.cornell.edu/Brinton.pdf (accessed September 2011)

Bureau de normalisation du Québec (2005) *National Standard of Canada, Organic Soil Conditioners – Compost.* CAN/BNQ 0413-200 (2005) ISBN: 2-551-22659-7 http://www-es.criq.qc.ca/pls/owa_es/bnqw_norme.detail_norme?p_lang=en&p_id_norm=8184&p_code_menu=NORME (accessed September 2011)

Enders and Lehmann (2011) Communications in Soil Science and Plant Analysis. *In Press.*

European Commission Agriculture and Rural Development (2010) Biomass Potential http://ec.europa.eu/agriculture/bioenergy/potential/index_en.htm (accessed September 2011)

European Commission COM(2006) *Directive Establishing a Framework for the Protection of Soil and Amending Directive* 2004/35/EC http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf (accessed September 2011)

International Biochar Initiative (2010) IBI Guidelines for the Development and Testing of Pyrolysis Plants to Produce Biochar http://www.biochar-

international.org/sites/default/files/IBI-Pyrolysis-Plant-Guidelines.pdf (accessed September 2011)

Rajan, S.S.S., Brown, M.W., Boyes, M.K., and Upsdell, M.P. (1992) *Extractable phosphorus to predict agronomic effectiveness of ground and unground phosphate rocks*. Nutrient Cycling in Agroecosystems. 32(3): 291-302 http://www.springerlink.com/content/j008x0248v237318/ (Accessed September 2011)

Rayment, G.E. and Higginson, F.R. (1992). *Australian Laboratory Handbook of Soil and Water Chemical Methods* (Reed International Books, Australia/ Inkata Press, Port Melbourne) And

Rayment, G.E., and Lyons, D.J. (2011) *Soil Chemical Methods – Australasia*. CSIRO Publishing, Collingwood, Victoria, Australia.

US Composting Council and US Department of Agriculture (2001) *Test methods for the examination of composting and compost. (TMECC)* Thompson W.H. (ed.) http://compostingcouncil.org/tmecc/

US Environmental Protection Agency (1996) *METHOD 8275A Semivolatile organic compounds (PAHs AND PCBs) in soils/sludges and solid wastes using thermal extraction/gas chromatography/mass spectrometry (TE/GC/MS)* http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/8275a.pdf (accessed September 2011)

US Environmental Protection Agency (2007) *EPA METHOD 8290A Polychlorinated Dibenzo-P-Dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) by high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS)* http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/8290a.pdf (accessed September 2011)

VanZwieten, L., Kimber, S., Morris, S., Chan, K.Y., Downie, A., Rust, J., Joseph, S., and Cowie, A. (2009) Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. *Plant and Soil* 327(1-2) 235-246

Wang, T., Camps Arbestain, M., Hedley, M., and Bishop, P. (2011) *Predicting phosphorus bioavailability from high-ash biochars*. *Currently under review.*

Appendix 1 – Labeling Example

The following is an example of adequate product labeling with the necessary product information as described in this guidance document:

Farmer Joe's Good-Grow Biochar-Compost Blend	
MATERIAL TYPE	Biochar Tested to Level 1
FEEDSTOCK TYPE	WOODY RESIDUES, SAW DUST, BARK
BIOCHAR PROPERTIES:	
Moisture	20%
Total Ash	10%
Organic Carbon	32%
Inorganic Carbon	18%
$H:C_{org}$	0.8
pH	6.5
Total N	14.4%
Particle Size Distribution	20% <200µm; 50% 200-2,000 µm; 15% 2,000-20,000 µm; 15% >20,000 µm[5]
Germination Assay	Pass
Earthworm Assay	Pass
PACKAGE INGREDIENTS, BY WEIGHT	50% - BIOCHAR 50% - COMPOSTED SOIL MIXTURE
COUNTRY OF ORIGIN	USA
Please see attached MSDS documentation for appropriate shipping, handling and storage procedures.	

These guidelines apply only to biochar, and thus require only the biochar portion of a blended product to be reported in the product information.

IBI will provide an updated label including certification date, registration number and IBI logo at the point of achieving certification and upon agreement on the terms of use.

[5] The goal with particle size distribution is to reach the mid-range of 200-20,000 micrometers (µm). The <200µm and >20,000µm categories are minimum and maximum standards.