Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil

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NOTE TO USERS:
The International Biochar Initiative may update this manual as necessary. Please make sure you are using the latest version available at http://www.biochar-international.org/characterizationstandard.

DISCLAIMER

The International Biochar Initiative (IBI) *Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil* (hereinafter referred to as the *IBI Biochar Standards*) have been prepared with the intent of providing stakeholders and commercial entities with standards to identify certain qualities and characteristics of biochar materials according to relevant, reliable, and measurable characteristics. Manufacturers who follow these *IBI Biochar Standards* do so voluntarily. In no way shall the IBI or its associates be responsible for the use or misuse of information and guidance provided in this document. Anyone making use of this document assumes all liability arising from such use.

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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.

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Foreword

The *IBI Biochar Standards* provide a standardized definition of biochar and biochar characteristics related to the use of biochar as a soil amendment. They 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 *IBI Biochar Standards* were created to encourage further development of the biochar industry by providing standardized information regarding the characterization of biochar materials to assist in achieving more consistent levels of product quality. In addition to providing product definition and qualitative specification standards, this document has been developed to assist biochar manufacturers in providing consumers with consistent access to credible information regarding qualitative and physicochemical properties of biochar.

The *IBI Biochar Standards* are designed to support an IBI certification program. Separately, the *IBI Biochar Standards* are also intended for use by various national and regional product standards bodies, and national and regional biochar groups for their own local adaptation and use, and as a reference in regulatory situations, as may be appropriate.

The *IBI Biochar Standards* were developed as a means of providing information and market certainty about the attributes of biochars for use in soil applications. Ultimately, the use and promotion of these *IBI Biochar Standards* will build consumer and regulatory confidence about biochar, through the provision of consistent and reliable information regarding biochar properties. Biochar can be made from a variety of feedstocks, using a variety of different production processes, and can possess many different attributes. The consistent reporting of biochar properties will ensure that pertinent information about biochars for use in soil applications is systematically communicated, regardless of feedstock type, production process, or final properties.

IBI developed the *IBI Biochar Standards* in a transparent process open to public participation, review, and input. Throughout the development process IBI relied upon the drafting, review, and guidance of experts in the field, ensuring an efficient path from concept to final product, and addressing the needs of a broad range of commercial biochar manufacturers and end users. As the document was developed, public input from the larger international biochar community was continuously sought to provide a wider perspective on the use and functionality of this tool.

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

The *IBI Biochar Standards* document development process is based on the following guiding principles:

- Maintain congruence with best practice guidance for standards development such as International Standards Organization (ISO), ASTM International (ASTM), and Institute of Electrical and Electronics Engineers (IEEE);
- Strictly adhere to process, ensuring efficient and effective collaboration;

- Engage the knowledgeable and diverse stakeholder groups active in the biochar industry;
- Organize independent working groups with broad stakeholder representation, and,
- Rely on IBI infrastructure and capacity for leadership and administration of the initiative.

The complete record of process documentation, including the list of working group members, can be found on the IBI website at: http://www.biochar-international.org/characterizationstandard.

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1 Scope

Issued by the International Biochar Initiative (IBI) and based on international consultation, this *IBI Biochar Standards* document is intended to establish a common definition for biochar, testing and measurement methods for selected physicochemical properties of biochar, and labeling standards for biochar materials.

Biochar is a solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment. Biochar can be used as a product itself or as 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 (GHG) mitigation.

These *IBI Biochar Standards* 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 an IBI certification program, and are intended for use and adaptation to local conditions and regulations by any nation or region. These *IBI Biochar Standards* 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 materials, nor provide guidance on what biochar can or should be used for.

These *IBI Biochar Standards* relate to the physicochemical properties of biochar only, and do not prescribe production methods or specific feedstocks, nor do they provide limits or terms for defining the sustainability and/or GHG mitigation potential of a biochar material, for a certification program or otherwise.

Different feedstock types, and hence differentiated testing requirements of biochar, are defined in this guidance document as means for the identification and classification of a range of biochar materials. The testing categories are based upon increasing levels of physicochemical property reporting and not necessarily on increasing levels of biochar performance or quality. The intended audiences for these *IBI Biochar Standards* include commercial biochar manufacturers, users, regulators, researchers and marketers, as well as the many national and regional biochar affiliates of the IBI. However, the commercial biochar manufacturer is the entity most likely to apply the *IBI Biochar Standards*, as a label (of differentiation) on its biochar material or product.

2 Terms and Definitions

A complete list of terms and definitions is found, along with a list of acronyms, in Appendix 6. A clear understanding of the defined terms is essential to the proper use of these *IBI Biochar Standards*. Defined terms are indicated with a double underline in the text on the first instance of the use of that term.

3 Biomass Feedstock Material and Biochar Production

3.1 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 biochar material, some restrictions have been applied to feedstock contents and quality. To qualify as biochar feedstock under these standards, the feedstock may be any combination of biomass and diluents, but may not contain more than 2% by dry weight of contaminants (following Brinton 2000). Any diluents that constitute 10% or more by dry weight of the feedstock material must be reported as a feedstock component on the product label.

Feedstocks are differentiated into two types: unprocessed feedstocks and processed feedstocks, with different requirements for sampling and analysis of potential toxic substances.

Suitable feedstocks include but are not limited to agriculture, food, and forestry residues, which may contain a minimal quantity of contaminants (see above) as part of the feedstock. Any feedstock that may have been grown on contaminated soils shall be considered to be a processed feedstock and must meet the toxicant assessment testing frequency requirements for processed feedstocks given in Section 6, *Testing Protocols*.

Municipal Solid Waste (MSW) containing hazardous materials or wastes may not be included as eligible feedstock under these standards. It is the manufacturer's responsibility to ensure that biochar feedstock materials are free of hazardous materials.

Note: Issues of feedstock sustainability are not addressed in this document.

3.2 General Biochar Production and Material Handling Recommendations

These *IBI Biochar Standards* do not prescribe production and handling parameters for biochar, but do include recommendations for safe production processes. It is the responsibility of the biochar manufacturer to create biochar in a safe manner. The IBI recommends that current best industry practices be followed throughout the manufacturing and handling 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 manufacturers should follow the two recommendations listed below:

- A biochar manufacturer 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 practices and responsible industrial production. The majority of nations provide detailed standards, expectations, and regulations governing the manufacturing sector and will have relevant information available to industrial operators.

4 Biochar Material Test Categories and Characteristics

As described in this section, biochar characteristics shall be assessed according to a defined set of test categories intended to provide increasing levels of physicochemical property reporting. A required set of tests to measure basic biochar characteristics that impact soil functions is supplemented with an optional test category for advanced analysis and soil enhancement properties. Toxicant assessment testing is required for all biochars. Increasing levels of physicochemical property testing and reporting do not correspond to increasing levels of biochar performance or quality; rather, 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 biochar materials;
- provide a set of required tests for basic biochar utility and an optional set of additional tests for measuring advanced analysis and soil enhancement properties; and
- require toxicant reporting appropriate to the potential risks associated with both unprocessed and processed feedstocks. Increased testing frequency is required to attain quality assurance for processed feedstocks, which carry a higher potential risk of contamination.

Each test category was developed according to an assessment of the relevant parameters for biochar properties and safety, balanced against cost and accessibility.

These *IBI Biochar Standards* identify three categories of tests for biochar materials:

Test Category A – Basic Utility Properties: ***Required for all biochars***. This set of tests measures the most basic properties required to assess the utility of a biochar material for use in soil.

Test Category B – Toxicant Reporting: ***Required for all biochars***. Biochars made from processed feedstocks must be tested more frequently than biochars made from unprocessed feedstocks, as defined in Section 6, *Testing Protocols*.

Test Category C – Advanced Analysis and Soil Enhancement Properties: Optional for all biochars. Biochar may be tested for advanced analysis and enhancement properties in addition to meeting test requirements for Test Categories A and B. All tests in Test Category C are optional. Manufacturers may report on none, one, some or all of the properties.

Further details on each of the test categories are provided in the following subsections.

4.1 Test Category A – Basic Utility Properties

All biochar must be tested for basic utility properties and meet the criteria specified under Test Category A, as shown in Table 1 below. Basic biochar characteristics include the physical properties of particle size and moisture, as well as the chemical properties of elemental proportions [Hydrogen (H), Carbon (C), and Nitrogen (N)], ash proportion, Electrical Conductivity (EC) and pH/liming ability. Organic carbon (C_{org}) content is used to assign the biochar material to one of three Classes depending on the percentage of C_{org} in the material and representing the range of C_{org} contents typical of biochar materials. Carbon stability is indicated by the molar ratio of hydrogen to organic carbon. Lower values of this ratio are correlated with greater carbon stability. See Appendix 5, *The Use of H:C_{org} to Indicate C Stability*, for more information on this analysis.

Table 1: Test Category A Characteristics and Criteria

Test Category A: Basic Biochar Utility Properties - Required for All Biochars			
Requirement	**Criteria[1]**	**Unit**	**Test Method**
Moisture	Declaration	% of total mass, dry basis	ASTM D1762-84 (specify measurement date with respect to time from production)
Organic Carbon	Class 1: ≥60% Class 2: ≥30% and<60% Class 3: ≥10% and <30%	% of total mass, dry basis	Total C and H analysis by dry combustion-IR detection. Inorganic C analysis by determination of CO2-C content with 1N HCl, as outlined in ASTM D4373-02. Organic C calculated as Total C – Inorganic C. See Appendix 5 for $H:C_{org}$ discussion.
$H:C_{org}$	0.7 (Maximum)	Molar ratio	
Total Ash	Declaration	% of total mass, dry basis	ASTM D1762-84
Total Nitrogen	Declaration	% of total mass, dry basis	Dry combustion-IR detection following the same procedure for total C and H above.
pH	Declaration	pH	pH analysis procedures as outlined in section 04.11 of US Composting Council and US Department of Agriculture (2001), following dilution and sample equilibration methods from Rajkovich et al. (2011) See Appendix 2.
Electrical Conductivity	Declaration	dS/m	EC analysis procedures as outlined in section 04.10 of US Composting Council and US Department of Agriculture (2001), following dilution and sample equilibration methods from Rajkovich et al. (2011) See Appendix 2.
Liming (if pH is above 7)	Declaration	% CaCO3	Rayment & Higginson (1992)
Particle size distribution	Declaration	% <420µm;	Progressive dry sieving with 4760µm, 2380µm and 420µm sieves, as outlined in ASTM D2862-10 Method for activated carbon.
		% 420-2,380 µm;	
		% 2,380-4,760 µm;	
		% >4,760 µm;	

[1] All values will be reported to one decimal place significant digit (0.1), unless otherwise indicated within the criteria for any reporting requirement. (e.g., if the analysis is 0.73, it can be reported as 0.7)

4.2 Test Category B – Toxicant Reporting

In addition to Test Category A thresholds and declarations, all biochar materials must meet the soil toxicity assessment thresholds as outlined in Table 2 below. Toxicants may be divided into two categories – those that may be present in the feedstocks used (metals and polychlorinated biphenyls) and those that may be produced by the thermochemical process used to make biochar (polycyclic aromatic hydrocarbons and dioxins).

Biochar made from processed feedstocks may carry additional risks from the potential presence of toxicants in the feedstock and must meet the toxicant assessment testing frequency requirements of Section 6.

Biochar toxicity assessment reporting follows commonly identified soil toxicity and chemical content reporting requirements for soil amendments, composts and fertilizers. The threshold values in Table 2 are given as a range of values based on standards for soil amendments or fertilizers from a number of countries.[2] The Maximum Allowed Thresholds (MAT) indicate toxicant levels above which the material would not be considered acceptable. In order to meet the requirements of these *IBI Biochar Standards*, reported toxicant levels must be below the MAT that has been established in the area of jurisdiction where biochar is produced and/or intended for use. If the area of jurisdiction where the biochar will be used has no threshold at all for a particular toxicant, the biochar must be below the highest maximum value established below for each specific toxicant. See Appendix 3, *Toxicant Assessment and Determination of Thresholds*, for more information.

Table 2: Test Category B Characteristics and Criteria

Test Category B: Biochar Toxicant Reporting - Required for All Feedstocks			
Requirement	**Range of Maximum Allowed Thresholds**		**Test Method**
Germination Inhibition Assay	Pass/Fail		OECD methodology (1984) using three test species, as described by Van Zwieten et al. (2010), see Appendix 2
Polycyclic Aromatic Hydrocarbons (PAHs)	6 – 20	mg /kg dry wt	Method following US Environmental Protection Agency (1996)
Dioxin/Furan (PCDD/Fs)	9	ng/kg I-TEQ	Method following US Environmental Protection Agency (2007)
Polychlorinated Biphenyls (PCBs)	0.2 – 0.5	mg/kg dry wt	Method following US Environmental Protection Agency (1996)

[2] The following jurisdictions were used to construct the range of values: Australia, Canada, EU, UK, USA. These entities were chosen as standards because they all have a long history of regulations addressing these toxicants in soils and other substrates.

Table 2 (continued): Test Category B Characteristics and Criteria

Requirement	Range of Maximum Allowed Thresholds		Test Method
Arsenic	12 – 100	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Cadmium	1.4 – 39	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Chromium	64 – 1200	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Cobalt	40 – 150	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Copper	63 – 1500	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Lead	70 – 500	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Mercury	1 – 17	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Molybdenum	5 – 20	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Nickel	47 – 600	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Selenium	1 – 36	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Zinc	200 – 7000	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Boron	Declaration	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Chlorine	Declaration	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)
Sodium	Declaration	mg/kg dry wt	US Composting Council and US Department of Agriculture (2001)

4.3 Test Category C – Advanced Analysis and Soil Enhancement Properties

Test Category C is optional for all biochar materials. Manufacturers may report on none, one, some, or all of the properties contained in the Test Category C set of advanced analysis and soil enhancement properties, using the prescribed test methods. Biochar advanced analysis characteristics include the volatile matter content and surface area of biochars. Biochar soil enhancement properties identify plant nutrients contained in the biochar.

Biochars tested under Test Category C may report on any or all of the properties presented in Table 3 below:

Table 3: Test Category C Characteristics and Criteria

Test Category C: Biochar Advanced Analysis and Soil Enhancement Properties - Optional for All Biochars			
Requirement	**Criteria**	**Unit**	**Test Method**
Mineral N (ammonium and nitrate)	Declaration	mg/kg	2M KCl extraction, followed by spectrophotometry (Rayment and Higginson 1992)
Total Phosphorus & Potassium (P&K)*	Declaration	% of total mass, dry basis	Modified dry ashing followed by ICP (Enders and Lehmann 2012)
Available P	Declaration	mg/kg	2% formic acid followed by spectrophotometry as described by Wang et al (2012) after Rajan et al (1992) and AOAC (2005)
Volatile Matter	Declaration	% of total mass, dry basis	ASTM D1762-84
Total Surface Area	Declaration	m^2/g	ASTM D 6556-10 Standard Test Method for Carbon Black – Total and External Surface Area by Nitrogen Adsorption. See Appendix 2.
External Surface Area	Declaration	m^2/g	
* Total K is sufficiently equivalent to available K for the purpose of this characterization			

5 Product Labeling and Documentation

Product labeling and documentation will be an important part of any biochar certification program. In order to qualify for certification, biochar manufacturers must share information about the feedstock and final biochar material. Biochar test results and feedstock origins must be uniformly labeled to communicate information that is important to end consumers and regulators.

5.1 Labeling Instructions

To meet the requirements of these *IBI Biochar Standards*, a label containing all of the required test results shall be attached, or provided in a web link, or otherwise included with all transactional documents, packaging, or other commercial documentation associated with the biochar material. Furthermore, basic product information including the brand name, net weight, and name and address of the manufacturer shall be included on the label. The label shall be legible and placed in a fashion that is visible and clear on the biochar packaging or documentation. See Appendix 1 for a sample label.

5.2 Product Information Requirements

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

- feedstock material composition and type, whether Processed or Unprocessed, including the identification of any diluents making up 10 percent or more of the total feedstock content;
- country of origin for the biochar feedstock;
- country where the biochar was produced; and
- country where the biochar will be sold for use.

5.3 Conformity and Record Keeping

Adequate documentation and reporting will be required by manufacturers seeking to gain certification. The reporting of biochar feedstock and mandatory and optional test results are all necessary in order to provide assurance of end-product properties. Record keeping will be mandatory in order to establish proof of adequate sampling, testing, and results. Documentation of biochar feedstock (see Appendix 4 for guidelines on identifying feedstocks) and type (unprocessed or processed), production parameters (processing temperature and residence time), and test results should be kept for seven years. Individual biochar manufacturers may wish to consult with a local attorney to determine whether recordkeeping for longer than seven years is appropriate, in light of state, regional, or provincial laws regarding product liability claims.

5.4 Chain of Custody

Chain of custody and biochar traceability provide necessary assurances that adequate care and transparency has been exercised to enable trace-back of final biochar from feedstock providers to biochar manufacturers through to end-users. All entities in the biochar production and supply chain will be required to participate in record keeping to maintain quality assurance.

6 Testing Protocols

Biochar manufacturers must follow the testing protocols described in this section, beginning with the selection of accredited laboratories using trained personnel to conduct the tests. Material changes in feedstocks and/or processing parameters will determine the timing of tests. In the case of Test Category B, the frequency of required testing will depend on the feedstocks used (see section 6.3).

6.1 Laboratory Standards

Laboratory analysis of biochar shall be conducted by trained and accredited laboratory professionals following the appropriate procedures identified for each test. Please refer to Appendix 2 for further guidance on sampling procedures and sample processing and handling prior to analysis. Testing shall follow strict quality control requirements according to standardized laboratory procedures. Laboratory professionals are expected to be trained in the relevant field of analytical chemistry and operate in professional laboratories that have received general laboratory accreditation. Such accreditation should be provided by a relevant governing body or an international standards body like the ISO. The intent of such laboratory standards is to make certain that contributing laboratories will provide reliable and replicable results that will ensure that an appropriate standard of quality is met.

6.2 Timing and Frequency of Testing

Biochar testing and reporting of all Category A, B, and C Tests according to the *IBI Biochar Standards* shall be performed:

- annually; or
- after a material change in feedstock; or,
- after a material change in thermochemical production parameters;

whichever is more frequent.

Material changes in feedstock reflect shifts in feedstock type from one source of biomass to a distinctly different source of biomass. See Appendix 4 for more information on how to determine feedstock types that constitute a "material change" in type. In mixed feedstocks, whether processed or unprocessed, a 10% or greater shift in total feedstock composition shall constitute a material change in feedstock.

Material changes in production processes reflect increases or decreases in process temperature or residence time. A material change in thermochemical production parameters has occurred if process temperature (also known as Heat Treatment Temperature) changes by +/- 50°C, or if the thermochemical processing time (residence time) changes by more than 10%.

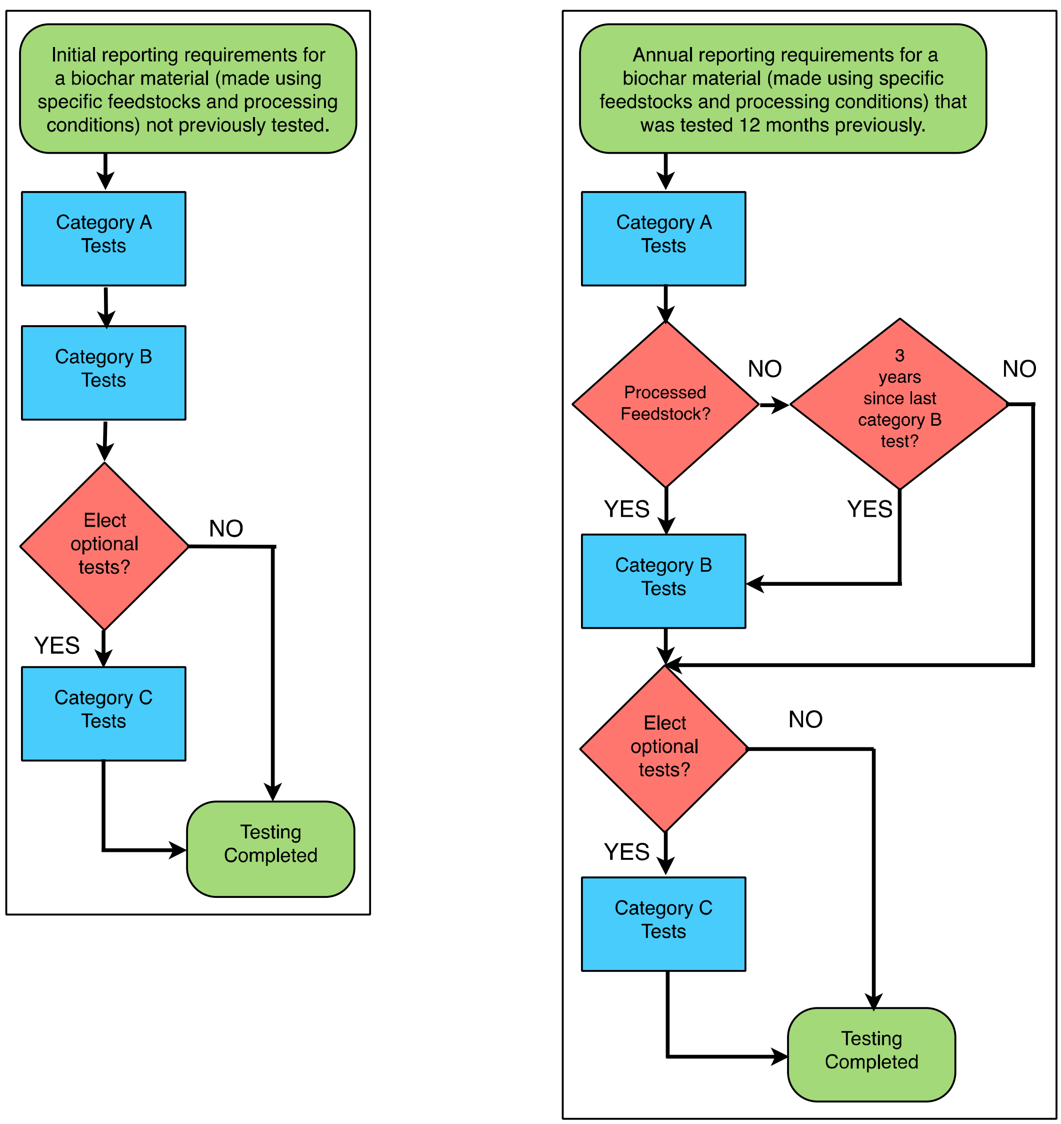
Testing of biochar materials should occur after thermochemical processing is complete and before final shipment. If the material is intended to be mixed with another material, testing of the biochar material must occur before mixing or blending with any other product.

6.3 Category B Test Requirements for Unprocessed Feedstocks

Category B Toxicant Assessment Tests shall follow the test frequency and reporting requirements given above, with the following exception for unprocessed feedstocks:

If the initial Category B test results for biochar made from an unprocessed feedstock are all within the Maximum Allowed Thresholds established by these *IBI Biochar Standards*, then the Category B tests may be repeated every three years rather than annually, as long as the thermochemical production parameters and the feedstock composition all remain the same. Figure 1, below, is a set of two process flow charts that compares the initial testing requirements for all feedstock materials with the annual testing requirements, showing how the exception for unprocessed feedstocks is incorporated.

Figure 1: Process flow charts showing testing protocols for initial testing and annual testing of biochar materials.



7 Revisions to the *IBI Biochar Standards*

IBI will make periodic revisions to the *IBI Biochar Standards* based on further development in the fields of biochar science and technology, regulatory changes, and feedback from the public, particularly users of the *IBI Biochar Standards*. Revisions occur in two forms—policy revisions and technical program revisions—and are effective the date of publication on IBI's website.

7.1 Policy revisions

Policy revisions occur when there is a substantive change to the policies, rules, and/or scope of the *IBI Biochar Standards* that may change the eligibility or acceptability of a biochar material. A policy revision creates a new version of the *IBI Biochar Standards* (e.g., Version 1.0 undergoes a policy revision to become Version 2.0). Examples of policy revisions include: changes to feedstock parameters such as the threshold for contaminants; the addition of new toxicants under Test Category B; changes in testing timing and frequency for biochars derived from processed feedstocks; or changes to the "material change" threshold for mixed feedstocks.

When policy revisions are warranted, IBI may convene an expert panel or reach out to experts involved in the development of the *IBI Biochar Standards*. The experts may be asked to provide insight and guidance on the identified policy issues prior to a revised draft of the *IBI Biochar Standards* being circulated for a 30-day public comment period. IBI will incorporate feedback gathered during the public comment period before publishing the final revised version.

7.2 Technical program revisions

Technical program revisions occur when technical or editorial changes are deemed necessary. Technical program revisions create a new sub-version of the *IBI Biochar Standards* (e.g., Version 1.0 undergoes a technical program revision to become Version 1.1). Examples of technical program revisions include: changes to recommended test methods in Test Categories A, B or C; changes to sampling procedures for biochar analysis; or changes to the Maximum Allowed Thresholds for Test Category B toxicants based on revised guidance from regulatory bodies.

As with policy revisions, IBI may seek guidance from experts when considering technical program revisions. However, a public comment period is not required and IBI will publish the revised sub-version of *IBI Biochar Standards* once the identified issues have been resolved.

8 References

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Appendix 1 – Sample Biochar Label

Figure A1.1 below is an example of adequate product labeling with the necessary product information as specified in section 5.1 of these *IBI Biochar Standards.* Manufacturers who wish to report on the properties of biochar contained in a blended product must also report the percentage of biochar as an ingredient in that product and make it clear that the information reported on the biochar label applies to the biochar portion only.

Figure A1.1 Sample Label for a Biochar Product

Brand Name →	**GOOD GROW BIOCHAR**	
	MATERIAL TYPE	Biochar made from declared feedstock
	COUNTRY OF ORIGIN	Australia
	COUNTRY OF USE	Australia
	FEEDSTOCK COUNTRY OF ORIGIN	Australia
	FEEDSTOCK TYPE	Processed Feedstock
Ingredients →	FEEDSTOCK COMPOSITION DECLARATION	poultry manure - 83%, wood chip bedding - 17%
Test Category A →	**BIOCHAR BASIC UTILITY PROPERTIES**	
	Moisture (at time of analysis)	20% - DECLARATION
	Organic Carbon	42% - CLASS 2 BIOCHAR
	$H:C_{org}$	0.6 - PASS
	Total Ash	40% - DECLARATION
	Total N	5.4% - DECLARATION
	pH	7.5 - DECLARATION
	Electrical Conductivity	7.3 dS/m - DECLARATION
	Liming	23% $CaCO_3$
	Particle Size Distribution	5% <420μm;
		35% 420-2,380 μm;
		45% 2,380-4,760 μm;
		15% >4,760 μm
Test Category B →	**TOXICANT ASSESSMENT**	
	Germination Inhibition Assay	PASS
	Polycyclic Aromatic Hydrocarbons (PAHs)	6 mg /kg - PASS

	Dioxin/Furan (PCDD/Fs)	0.02 ng/kg I-TEQ - PASS
	Polychlorinated Biphenyls (PCBs)	0.2 mg/kg - PASS
	Arsenic	10 mg/kg - PASS
	Cadmium	1.2 mg/kg - PASS
	Chromium	60 mg/kg - PASS
	Cobalt	14 mg/kg - PASS
	Copper	143 mg/kg - PASS
	Lead	125 mg/kg - PASS
	Mercury	0.5 mg/kg - PASS
	Molybdenum	5 mg/kg - PASS
	Nickel	25 mg/kg - PASS
	Selenium	10 mg/kg - PASS
	Zinc	320 mg/kg - PASS
	Boron	20 mg/kg- DECLARATION
	Chlorine	90 mg/kg- DECLARATION
	Sodium	140 mg/kg- DECLARATION
Test Category C →	**BIOCHAR ADVANCED ANALYSIS AND SOIL ENHANCEMENT PROPERTIES**	
	Mineral N (ammonium and nitrate)	21 mg/kg - DECLARATION
	Total P&K	3.1% P, 4.4%K - DECLARATION
	Available P	16 mg/kg - DECLARATION
	Volatile Matter	6.8% - DECLARATION
	Total Surface Area	790 m2/g- DECLARATION
	External Surface Area	160 m2/g- DECLARATION
Net Weight →	**Net Weight – 25 lbs (11.33kg)**	
Name and → Address of Manufacturer	Good Grow Biochar Company	
	123 County Route 1	
	Centerville, Any State, USA	
	Please see attached MSDS documentation for appropriate shipping, handling, and storage procedures.	

Appendix 2 – Recommended General Sample Analysis Procedures and Protocols for Specific Tests

Biochar sampling

Strict adherence to standardized biochar sampling procedures is critical to ensure reliable, representative, and replicable test results. Following accepted compost analysis practices, the Test Methods for the Examination of Composting and Composts (TMECC) (US Composting Council and US Department of Agriculture (2001)) has been identified as an effective general sampling procedure to comply with the *IBI Biochar Standards*. The TMECC documents provide detailed descriptions of sampling procedures for piles of unsorted, potentially heterogeneous material, which result in homogeneous, representative samples to be used in subsequent chemical analysis (Section 02.01 Field Sampling of Compost Materials in US Composting Council and US Department of Agriculture (2001)). Adhering to TMECC sampling guidance will ensure consistency in analytical approach, since subsequent physicochemical analyses within the *IBI Biochar Standards* document recommend the use of TMECC methodologies.

Sample handling and processing

Since sample handling and processing is analysis methodology-dependent, appropriate procedures should be selected based upon the chemical tests that will be conducted. Sample processing can vary depending upon the physicochemical analyses to be conducted; sample preparation methods followed should be specifically intended for the selected physicochemical tests to be conducted. For example, sample preparation methods can include grinding and sieving or oven-drying for analysis, to provide the dry weight measure indicated in Table 3 of the biochar test categories. General sample preparation procedures can be found in TMECC Section 02.02 Laboratory Sample Preparation in US Composting Council and US Department of Agriculture (2001). Caution should be exercised, however, since the methodologies recommended therein are designed for compost, and not for biochar. Comments within the TMECC document (US Composting Council and US Department of Agriculture (2001)) indicate that sample heating can occur while grinding, which can result in a change in sample qualities and characteristics. To avoid this, it is recommended that samples to be ground and sieved to a smaller size range (e.g. 2mm) be hand-ground in a mortar and pestle, to reduce the risk of heating, sparking, or ignition (following sample grinding methods for pH and EC assessment noted in Rajkovich et al, 2011).

Combined approach to analyzing pH and EC

Generic pH and EC analysis procedures have been drawn from the TMECC methodologies (US Composting Council and US Department of Agriculture (2001)). These procedures for the use of control and reference pH samples and electrode probes have been adapted for use with biochar, as follows: where the TMECC methodology recommends a 1:5 (v:v or w:w)[3] solution of compost:deionized water, a 1:20 (w:v)[4] solution of biochar:deionized water should be used for biochar pH and EC analysis, following Rajkovich et al (2011). Similarly, additional time should be allotted for solution equilibration after the combination of deionized water and biochar. Following Rajkovich et al (2011), 1.5 hours should be provided for the shaking and equilibration of biochar-deionized-water solutions prior to pH and EC analysis. Upon completion of the shaking and equilibration phase, pH and EC analysis may be conducted on the same samples, rather than making separate replicates for pH and EC. To complete the pH and EC analysis follow methodologies 04.10 and 04.11 of the TMECC methodology (US Composting Council and US Department of Agriculture (2001)).

Germination Inhibition Assay

The purpose of the analysis is to determine whether adding biochar to soil has an effect on seed germination. It is assumed that a negative effect indicates the presence of undesirable compounds in the biochar material. The Germination Inhibition Assay analysis follows procedures outlined by Van Zwieten et al (2010). The recommended approach for biochar analysis is to follow Van Zwieten et al's method, as it is drawn from the initial 1984 OECD methodology, and to report seedling germination as it relates to the potential failure to germinate in biochar-soil. Lettuce (*Lactuca sativa L.*) is the most widely recommended species to use in germination assessments, due to its sensitivity. Other species that can be used are found within the OECD (1984) methodology. Results should be reported as a "fail" to reflect a failure of seedling germination and growth in biochar-blended soils, thus rejecting the null-hypothesis that there is no difference between biochar-soil blends and unamended soils within the test. Results can be reported as a "pass" where there is no difference of germination and seedling growth success between biochar-soil blends and (control or unamended) soil, or where biochar-soil blends are preferred; both conditions are considered to pass these tests.

Analysis of Surface Area

The analysis of surface area will follow the methodologies presented in ASTM D6556-10: Standard Test Method for Carbon Black – Total and External Surface Area by Nitrogen Adsorption. Although carbon blacks can be made at much higher temperatures than biochar,

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[3] v:v – volume:volume denotes a ratio based on equivalent units of volume measurement in a dilution or blend (e.g. a 1:5 v:v biochar:water blend indicates the need to blend 1 ml of biochar with 5 ml of water)
w:w – weight:weight denotes a ratio based on equivalent units of weight measurement in a dilution or blend (e.g. a 1:5 w:w biochar:soil blend indicates the need to blend 1 g of biochar with 5 g of soil)

[4] w:v – weight:volume denotes a blend or dilution ratio expressed as grams of solid per milliliter of liquid. (e.g. a 1:20 w:v biochar:water blend indicates the need to blend 1 mg of biochar with 20 ml of water)

the following Brunauer, Emmett and Teller (BET) procedure will be effective for analyzing biochar surface area, with the following additional steps:

1. The relevant measure is the B.E.T. nitrogen surface area ("BET NSA").
2. The Vacuum Degassing method should be used (section 8.5) in preference to the Flow Degassing (8.4).
3. Section 8.5.3 Degassing temperature should not exceed 250°C to avoid further thermochemical alteration of the sample, as some biochars are made at temperatures as low as 300°C. The times necessary to degas may greatly exceed the ½ hour mentioned in this section of the analysis; up to 48 hours can be used to conduct the analysis, however this time must be reported along with the results. The actual time needed will depend on the instrument tolerance level, which is dictated by the manufacturer.
4. As indicated in section 9.6, a minimum of five evenly-spaced data points can be presented between 0.05 and 0.5 p/p0. Two additional data points, at 0.05 and 0.075 p/p0 should also be presented in the results.
5. The mass of sample on which the measurement is based should be determined after the surface area measurement has been completed.
6. The instrument should be calibrated periodically with a reference standard supplied by the manufacturer to make sure it is in good working order according the manufacturer's specifications.

Final units for surface area analysis should be reported in square meters per gram (m^2/g).

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Appendix 3 – Toxicant Assessment and Determination of Thresholds

The following table indicates the maximum allowed toxicant thresholds for some jurisdictions, including the European Union (EU), the United Kingdom (UK), Australia, Canada, and the United States (US) that were used to help develop reporting levels for the *IBI Biochar Standards*. These entities were chosen as resources for toxicant standards due to their history of regulations addressing these toxicants in soils and other substrates, and their development of similar soil quality standards (e.g. land-application of biosolids, wood ash, and/or compost). Toxicant ranges for reporting to the IBI are **not** indicated within this appendix, and are instead indicated within Table 2 as part of Test Category B. The below table is intended to provide a better understanding of how IBI developed the Maximum Allowed Threshold ranges indicated in Table 2 through a survey of international regulations.

Table A3.1 – International toxicant regulation resources used for determining IBI range of Maximum Allowed Thresholds (MAT)

Toxicant	International Regulatory Maximum Toxicant Thresholds	
Polycyclic Aromatic Hydrocarbons (PAHs)	6(A), 20(B)	mg/kg (dry wt)
Dioxin/Furan (PCDD/Fs)	9 (F)	ng/kg I-TEQ (dry wt)
Polychlorinated Biphenyls (PCBs)	0.2(A), 0.5(C)	mg/kg (dry wt)
Arsenic	100(B), 41(D), 13(E)	mg/kg (dry wt)
Cadmium	1.4(A), 20(B), 39(D), 3(E)	mg/kg (dry wt)
Chromium	93(A), 100(B), 1200 (D), 210(E)	mg/kg (dry wt)
Cobalt	100(B), 34(E)	mg/kg (dry wt)
Copper	143(A), 1000(B), 1500(D), 400(E)	mg/kg (dry wt)
Lead	121(A), 300(B), 300(D), 150(E)	mg/kg (dry wt)
Mercury	1(A), Methyl mercury 10(B), Inorganic mercury 15(B), 17(D), 0.8(E)	mg/kg (dry wt)
Molybdenum	5(C), 75(D)[5], 5(E)	mg/kg (dry wt)
Nickel	47(A), 600(B), 420(D), 62(E)	mg/kg (dry wt)

[5] For molybdenum, EPA only provides a concentration limit for "All Biosolids". All other EPA limits listed in Table A3.1 are derived from "Environmental Quality and Pollutant Concentration Biosolids".

Table A3.1 (continued) – International toxicant regulation resources used for determining IBI range of Maximum Allowed Thresholds (MAT)

Toxicant	International Regulatory Maximum Toxicant Thresholds	
Selenium	36(D), 2(E)	mg/kg (dry wt)
Zinc	416(A), 7000 (B), 2800(D), 700(E)	mg/kg (dry wt)

(A) Amlinger F., Favoino E. and Pollack M., (2004) Heavy metals and organic compounds from wastes used as organic fertilisers. Final Report July 2004. REF. Nr. TEND/AML/2001/07/20 ENV.A.2./ETU/2001/0024 http://www.bvsde.paho.org/bvsacd/cd43/used.pdf See Table S1 *Averaged limit values of EU countries* (Austria, Belgium, Germany, Denmark, Spain, France, Finland, Greece, Italy, Ireland, Luxembourg, Netherlands, Portugal, Sweden, and United Kingdom) for specific toxicant information. *NB*: Individual nations within the EU will have different regulatory expectations than the average values reported herein; appropriate regulatory values should be followed, rather than regional averages. (accessed March 2013)

(B) Australia National Environment Protection NEPC 1999. Assessment of Site Contamination Measure Schedule B(1) Guideline on the Investigation Levels for Soil and Groundwater. www.ephc.gov.au/contam See Schedule B1 Table 5-A *Health Investigation Levels column A* for specific toxicant information. (accessed March 2013)

(C) Canadian Council of Ministers of the Environment (CCME) 2001; 2006 Soil Quality Guidelines for the Protection of Environmental and Human Health (first published 1999, updated 2001, 2002, 2003, 2004, 2005, 2006 & 2007). http://st-ts.ccme.ca See *Agricultural concentration limits* for soil PCB limit. (accessed March 2013)

(D) United States Environmental Protection Agency (US EPA) 1994. A Plain English Guide to the EPA Part 503 Biosolids Rule US EPA 40 CFT Part 503 US EPA, Office of Wastewater Management, Washington DC. EPA/832/R-93/003. http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm See Table 2-1 *Pollutant Concentration Limits for EQ and PC Biosolids* for specific toxicant information. (accessed March 2013)

(E) Bureau de Normalisation du Quebec 2005. National Standard of Canada. Organic Soil Conditioners – Composts http://www-es.criq.qc.ca/pls/owa_es/bnqw_norme.detail_norme?p_lang=en&p_id_norm=8184&p_code_menu=NORME See *Maximum Acceptable Trace Element Content in Compost* for Type AA Compost. (accessed April 2013)

(F) Alberta Environment 2002 Standards and Guidelines for the Use of Wood Ash as a Liming Material for Agricultural Soils. Science and Standards Branch, Edmonton, Alberta. ISBN: 0-7785-2281-4 (online edition). The Alberta Guideline sets the threshold value for PCDD/F in wood ash at 27 ng/kg based on an assumed cumulative application of 45 tonnes/hectare over 100 years. Biochar may be applied in larger total amounts. Under the assumption that the maximum cumulative application of biochar over a 100-year period is 135 tonnes/hectare[6], a linear extrapolation yields a threshold value for PCDD/F concentration of 9 ng/kg, I-TEQ. For further information please review the IBI White Paper *Implications and Risks of Potential Dioxin Presence in Biochar* available under Supporting Documents on the *IBI Biochar Standards* website http://www.biochar-international.org/characterizationstandard.

[6] Glaser, B., Lehmann, J., and Zech, W. (2002) Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal - a review. *Biology and Fertility of Soils* 35(4):219-230.

Appendix 4 – Determining a "Material Change" in Feedstock

This Appendix addresses the need to identify feedstock types for purposes of determining a "material change" in feedstock types under Section 6.2 – *Timing and Frequency of Testing*. Section 6.2 requires that biochar properties and characteristics according to the specification guidelines shall be assessed and reported after every "material change" in feedstock.

Unprocessed Feedstocks

Table A4.1 is a list of distinct unprocessed feedstock types based on biomass composition that are used to make biochar. Changes between these feedstock types will constitute a "material change" in feedstock.

Any change in feedstock from one listed type in Table A4.1 to another shall constitute a "material change" in feedstock.

Feedstocks not listed in this table may be used to make biochar if they meet the other feedstock requirements outlined in these guidelines. However, any change between a feedstock listed in Table A4.1 and a feedstock not listed will constitute a "material change" in feedstock and require a new round of testing.

If an unprocessed feedstock not listed in Table A4.1 is changed to another unprocessed feedstock not listed in Table A4.1, then a "material change" in feedstock shall be based on the species of plant material used for the feedstock, so that a change in species constitutes a "material change" in feedstock.

Table A4.1 – Unprocessed Feedstock Types

Unprocessed Feedstock Types for determining "material change" in feedstock
Rice hulls & straw
Non-maize cereal straws & switchgrass
Maize cobs & stover
Sugar cane bagasse & trash
Softwoods (conifers)
Hardwoods (angiosperms)
Bamboo
Miscanthus

Mixed Feedstocks

When a mix of unprocessed feedstocks is used, a change of 10% or more in the total feedstock composition shall constitute a "material change" in feedstock. The magnitude of the change in the feedstock shall be calculated by adding up the decreases in percentages for each individual feedstock type composing the mixed feedstock. The following is an illustrative example:

Rosie's Biochar is typically made of:

- 35% spruce wood chips,
- 25% aspen wood chips,
- 15% wheat straw,
- 15% assorted leaves, and
- 10% corn stover.

This past year, due to a change in spruce availability, her feedstock changed to:

- 25% spruce wood chips,
- 35% aspen wood chips,
- 15% wheat straw,
- 15% assorted leaves, and
- 10% corn stover.

Because a 10% total change in feedstock has occurred, Rosie must re-test her biochar.

If Rosie's biochar had instead changed from her typical blend in the following way, she would still need to re-test her biochar because a 10% total change in feedstock has also occurred:

- 38% spruce wood chips,
- 20% aspen wood chips,
- 20% wheat straw,
- 17% assorted leaves, and
- 5% corn stover.

Processed Feedstocks

Table A4.2 is a list of feedstocks sourced from processed biomass. Any change from one processed feedstock to another will constitute a "material change" in feedstock, e.g.:

1. a change from sheep manure to pig manure;
2. a change from sludge/waste provided by Facility A to that provided by Facility B; or
3. a significant change in the process parameters (e.g., a change in process chemistry for paper sludge, or a change from dairy cow manure to dairy cow manure digestate from an anaerobic digester).

Processed feedstocks not listed in this table may be used to make biochar if they meet the other feedstock requirements outlined in these standards.

When a mix of different processed feedstocks is used, or where the processed feedstock consists of a mix of components, a change of 10% or more in the total feedstock composition shall constitute a “material change” in feedstock. Please see the above example of Rosie’s biochar using unprocessed feedstocks for a better understanding of how to assess total feedstock composition changes of at least 10%.

Table A4.2 – Processed Feedstock Types

Processed Feedstock Types for determining "material change" in feedstock
Cattle manure
Pig manure
Chicken manure
Sheep manure
Horse manure
Paper mill sludge
Sewage sludge
Distillers grain
Anaerobic digester sludge
Biomass fraction of MSW
Food industry waste

Appendix 5 – The Use of $H:C_{org}$ to Indicate C Stability

The molar $H:C_{org}$ ratio is recommended to distinguish biochar from other thermochemically altered organic matter for several reasons:

1. H:C ratios change substantially with thermochemical treatment (Keiluweit et al., 2010);
2. O:C ratios have been shown to correlate well with stability of biochars (Spokas, 2010);
3. H:C and O:C ratios are closely related (for low-ash biochars <50% ash and <80% volatiles (ash-free basis));
4. H is determined directly in most laboratories, whereas O is calculated by subtraction.

The modification of using the organic C values rather than total C for this ratio is motivated by the presence of inorganic carbonates in some high-ash biochars. These inorganic carbonates do not form aromatic groups distinctive of biochar materials.

The molar $H:C_{org}$ ratio is a material property that is correlated with the degree of thermochemical alteration that produces fused aromatic ring structures in the material. The presence of these structures is an intrinsic measure of the stability of the material.

The upper $H:C_{org}$ limit of 0.7 is used to distinguish biochars from biomass that has not been thermochemically altered and from other materials that have been only somewhat thermochemically altered. We use the term "thermochemically converted" to refer to thermochemically altered materials that have an $H:C_{org}$ below 0.7. These materials have a greater proportion of fused aromatic ring structures. Other thermochemically processed materials that have an $H:C_{org}$ value greater than 0.7 may be thermochemically "altered" but they are not considered to be thermochemically "converted".

Figure A5.1 below shows relationships between processing temperature and $H:C_{org}$ molar ratio for a number of thermochemically altered materials, as compared to unprocessed biomass.

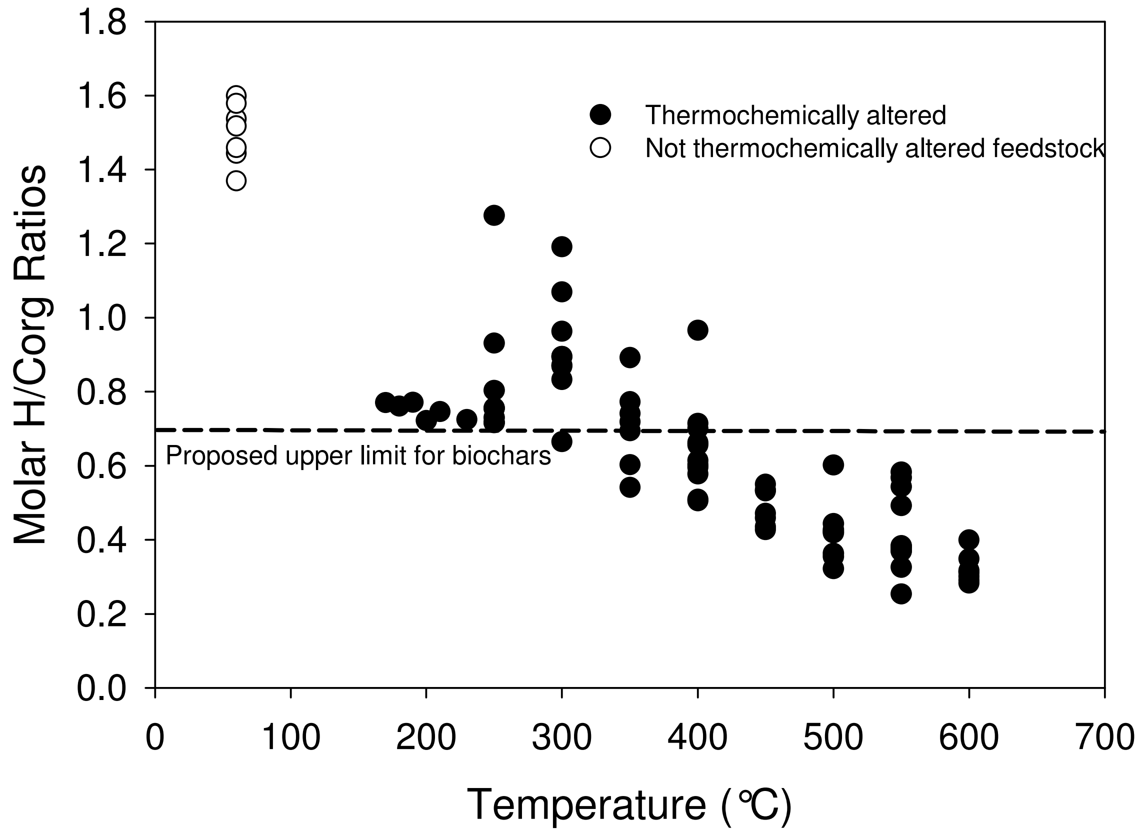

Figure A5.1: Relationship between molar $H:C_{org}$ ratios and temperature of thermochemically altered organic matter in comparison to untreated biomass. Dashed line is the upper limit of 0.7. Data points below the 0.7 line are thermochemically altered materials that are considered to be thermochemically "converted" (data from Sevilla and Fuertes, 2009ab; Calvelo Pereira et al, 2011; Enders et al., 2012).

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Appendix 6 – Glossary

List of Acronyms and Abbreviations

AOAC – Association of Analytical Communities

ASTM – ASTM International (formerly known as the American Society for Testing and Materials)

BNQ – Bureau de Normalisation du Quebec (a member of the National Standards System of Canada involved in developing product and process standards for Canadians)

C – Carbon

$CaCO_3$ – Calcium Carbonate

C_{org} – Organic Carbon

CCME – Canadian Council of Ministers of the Environment

CSIRO – Commonwealth Scientific and Industrial Research Organisation, Australia

dS – decisiemens

dS/m – decisiemens per meter

dry wt – dry weight

EC – Electrical Conductivity

EPA – Environmental Protection Agency, United States

EU – European Union

F – Polychlorinated Dibenzofuran (Furan)

g – gram

GHG – greenhouse gas

H – Hydrogen

HCl – hydrochloric acid

HMIS – Hazardous Materials Identification System

IBI – International Biochar Initiative

ICP – Inductively Coupled Plasma

IEEE – Institute of Electrical and Electronics Engineers

ISO – International Organization for Standardization

I-TEQ – International Toxicity Equivalent

K – Potassium

KCl – potassium chloride

kg – kilogram

m – meter

mg – milligram

M – molar

MAT – Maximum Allowed Threshold

MSDS – Material Safety Data Sheet

MSW – Municipal Solid Waste

N – Nitrogen

NEPC – National Environment Protection Council, Australia

ng – nanogram

OECD – Organisation for Economic Co-operation and Development

OMS – Office of Mobile Sources, division of US EPA

P – Phosphorus

PAH – Polycyclic Aromatic Hydrocarbon

PCB – Polychlorinated Biphenyl

PCDD – Polychlorinated Dibenzodioxin (Dioxin)

PCDD/F – Dioxins/Furans

POPs – Persistent Organic Pollutants

S – Siemens

S/m – Siemens per meter

SA – Surface Area

TMECC – Test Methods for the Examining of Composting and Compost (from US Composting Council and USDA)

USDA – United States Department of Agriculture

USGS – United States Geological Service

µg – microgram

Definition of Terms

Note: Terms and definitions have been adapted from the references given. Terms and definitions created specifically for this document are referenced as "IBI".

Ash: The inorganic matter, or mineral residue of total solids, that remains when a sample is combusted in the presence of excess air. (Adapted from US Composting Council and US Department of Agriculture, 2001)

Biochar: A solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment. (IBI, 2012)

Biochar Characteristics: For the purposes of these standards, biochar characteristics are those physical or chemical properties of biochar 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 GHG, by converting a portion of that biomass into a stable carbon fraction that has carbon sequestration value. (IBI, 2012)

Biological Material: Material derived from, or produced by, living or recently living organisms. This material can be "unprocessed" or "processed". Unprocessed biological material is living material, or recently living material from the plant kingdom (or other non-animal taxa such as fungi or algae) that may have been mechanically resized (such as wood chips), but has not been processed in an animal's body or gone through an anthropogenic chemical modification. Processed biological material is recently living material that has been chemically modified by anthropogenic or biological processes (e.g., paper sludge, manure). All animal products, including bones, offal, food-waste containing animal products, and animal manures are considered to be processed biological material. (IBI, 2012)

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). (Adapted from European Commission Agriculture and Rural Development, 2010)

Contaminant: An undesirable material in a biochar material or biochar feedstock that compromises the quality or usefulness of the biochar or through its presence or concentration causes an adverse effect on the natural environment or impairs human use of the environment (adapted from Canadian Council of Ministers of the Environment, 2005). Contaminants include fossil fuels and fossil-fuel-derived chemical compounds, glass, and metal objects. (IBI, 2012)

Diluent/Dilutant: Inorganic material that is deliberately mixed or inadvertently comingled with biomass feedstock prior to processing. These materials will not carbonize in an equivalent fashion to the biomass. These materials include soils and 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, manures, and municipal solid wastes. (IBI, 2012)

Dioxin: The term "dioxin" is commonly used to refer to a family of chemicals that share chemical structures and characteristics. These compounds include polychlorinated dibenzo dioxins (PCDDs) and polychlorinated dibenzo furans (PCDFs), which are unwanted by-products of industrial and natural processes, usually involving combustion. Dioxins are listed as Persistent Organic Pollutants by the Stockholm Convention. (IBI, 2012)

Feedstock: The material undergoing the thermochemical process to create biochar. Feedstock material for biochar consists of biological material, but may also contain diluents. (IBI, 2012)

Fossil-Fuel-Derived Chemical Compounds: This category of contaminant includes any compound of a synthetic nature, created from hydrocarbons, including, but not limited to plastics, solvents, paints, resins, and tars. Because of the blending of wastes and use of synthetic materials to bind and label other materials (e.g. plastic flagging tape in forestry residues), fossil-fuel-derived chemical compounds have become commonplace in multiple waste streams, and are often difficult to separate from feedstocks prior to processing. These contaminants can contain highly toxic chemicals like polychlorinated biphenyls (PCBs) that may act as bioaccumulators and affect the resulting quality of biochar. (IBI, 2012)

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)

Heat Treatment Temperature: The temperature at which a feedstock material is processed during thermochemical conversion in a biochar production process. (IBI, 2012)

Manufacturer: The party or parties who process feedstock materials into biochar, test the biochar properties, and acquire appropriate labeling. (IBI, 2012)

Municipal Waste/Municipal Solid Waste (MSW): solid non-hazardous refuse that originates from residential, industrial, commercial, institutional, demolition, land clearing, or construction sources (adapted from Canadian Council of Ministers of the Environment 2005). Municipal solid waste includes durable goods, non-durable goods, containers and packaging, food wastes and yard trimmings, and miscellaneous inorganic wastes. (Adapted from US Environmental Protection Agency, 1995)

Organic Carbon: Biologically degradable carbon-containing compounds found in the organic fraction of biochar feedstocks. Biochar feedstocks can contain such compounds as sugars, starches, proteins, fats, cellulose, and lignocellulose, which are thermochemically degradable. Other organic carbon forms can include petroleum and petroleum by-products such as plastics and contaminated oils, which are, for the purposes of this document, included within the definition of contaminants, but may also be thermochemically 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)

Persistent Organic Pollutants (POPs): POPs are organic chemical substances, that is, they are carbon-based. They possess a particular combination of physical and chemical properties such that, once released into the environment, remain intact for exceptionally long periods of time (many years); become widely distributed throughout the environment as a result of natural processes involving soil, water and, most notably, air; accumulate in the fatty tissue of living organisms including humans, and are found at higher concentrations at higher levels in the food chain; and are toxic to both humans and wildlife. (Adapted from Stockholm Convention, 2012)

Polychlorinated biphenyls (PCBs): PCBs are a group of organic compounds used in the manufacture of plastics, as lubricants, and dielectric fluids in transformers, in protective coating for wood, metal and concrete, and in adhesives and wire coating. PCBs have been banned in most countries and are no longer manufactured, but sources remain in the environment in the form of products and waste. The Stockholm Convention lists PCBs as POPs. (IBI, 2012)

Polycyclic aromatic hydrocarbons (PAHs): PAHs refer to a family of compounds built from two or more benzene rings. Sources of PAHs include fossil fuels and incomplete combustion of organic matter, in auto engines, incinerators, forest fires, charcoal grilling, or other biomass burning. PAHs are usually found as a mixture containing two or more of these compounds, such as soot. Out of hundreds of different PAH compounds, only a few are considered to be highly toxic and of regulatory concern. (Adapted from USGS, 2012)

Processed Feedstock: Biomass that has gone through chemical processing (for example, paper pulp sludge) or biological processing (for example, digestion, such as manures and sludge from waste effluent treatment) beyond simple mechanical processing to modify physical properties. Because animals may bioaccumulate toxicants in their tissues, all animal parts and products are considered to be Processed Feedstocks for purposes of these guidelines. Any biomass material that may have been grown on soils contaminated with heavy metals or other toxicants will also be considered a Processed Feedstock for purposes of these guidelines. (IBI, 2012)

Residence Time: The time a feedstock is held within a consistent temperature range in a given thermochemical process. (IBI, 2012)

Soil Functions: Soil functions include: "(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." (Adapted from European Commission COM, 2006)

Toxicants: Chemical or physical agents that, depending on dose, can produce adverse effects in biological organisms (adapted from Trush 2008). These chemicals may be essential for some plants and animals at low levels, or in a specific oxidation state, but can be toxic at higher concentrations or in a different oxidation state. Toxicants may be naturally present in soils or artificially produced by human activity. (Adapted from US EPA, 1999)

Unprocessed Feedstock: Biomass from the plant kingdom (or other non-animal taxa such as fungi and algae), grown in a clean, uncontaminated environment, that may have gone through mechanical processing to change its physical properties (e.g., particle size), but has not gone through chemical processing or treatment, or biological processing (e.g., digestion). (IBI, 2012)

Volatile Matter: Those products, exclusive of moisture, given off by a material as a gas or vapor, determined by definite prescribed methods that may vary according to the nature of the material. (Adapted from Milne et al, 1990)

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