Guidelines for a safe Biochar Industry

Draft for Discussion

Foreword

The intentions of this document are to:

- Provide a voluntary set of guidelines that can be adopted by Producers and Retailers of biochar (possibly as "IBI approved biochar")
- To allow purchasers of biochar to ensure it is derived from sustainable resources and is basically safe to use
- Provide some suggestions on the types of analysis that can conducted on biochar to allow basic characterisation
- Provide results from some basic biochar properties that describe the processing conditions, feedstock and biochar characteristics

This document is **not** intended to:

- Be published in a scientific journal
- Provide a detailed assessment or comparison of analytical methods- (we are preparing a separate document/ publication)
- Be a definitive document that is inflexible\

This draft document will be discussed at the Boulder Biochar meeting, following which it may get distributed to the IBI scientific Committee for further comment and/ or adoption.

1. Purpose

The IBI and Australia New Zealand Biochar Researcher network recognise that there are currently no guidelines for manufacturers, retailers or purchasers of biochar to describe the material. These guidelines are currently designed as a voluntary set of parameters that may used to provide a basic set of characteristics of biochar and we propose voluntary guidelines for sustainable production. The purpose is to ensure the material being used for application to soil is safe for human and environmental health, and is likely to provide agronomic benefits for farmers through improvements to a wide range of soil chemical, physical and biological properties. These guidelines also suggest a framework for classification of biochars based on a range of physico-chemical properties. The IBI and Australia New Zealand Biochar Researcher network suggest that if these tests are undertaken then consumers will have a basis for comparison and assessment of the suitability for their particular application.

2. Introduction

Biochar is the carbon-rich solid product resulting from the heating of biomass in an oxygen-limited environment. Due to its highly aromatic structure, biochar is chemically and biologically more stable compared with the organic matter from which it was made. It has been proposed as a technology with play a useful role in building soil health and mitigating climate change. Properties of biochar vary widely, depending on the biomass source used and the conditions of production of biochar (Lehmann and Joseph, 2009). Therefore it is important that consumers know the quality of the biochar that they are applying, to ensure that it is safe to use, and appropriate for their application. Biochar can be produced from a wide range of biomass materials; from forest residues and post-consumer wastes to purpose-grown crops. To ensure that there are no adverse environmental effects from production of biochar, the feedstock should be obtained from sustainable sources (discussed below) and the processing facility should meet minimum requirements for emissions control.

3. Sustainable biochar production

3.1 Source of Material and Process Conditions

It is recommended that the manufacturer of biochar adhere to these recommendations and guidelines. A number of these guidelines have been adopted from the Roundtable on Sustainable Biofuels (2008).

Recommendations

1. Biochar production shall follow all applicable laws of the country in which it occurs, and shall endeavour to follow all international treaties relevant to thermal processes to which the relevant country is a party.
2. Biochar production shall comply with local regulatory requirements that govern utilisation of the source material.
3. Biochar production must utilise feedstock from sustainable resources.
4. Biochar production and utilisation shall contribute to climate change mitigation by reducing GHG emissions (compared to fossil fuels) and converting labile carbon into more stable forms of carbon. To ensure that the biochar production process results in a net greenhouse gas benefit, the syngas should be captured and at the minimum flared but optimally used as a source of energy to offset fossil fuels. The plant itself should comply with local emission and OHS standards.
5. Biochar production shall not violate human rights or labour rights, and shall ensure decent work and the well-being of workers.
6. Biochar production shall contribute to the social and economic development of local, rural and indigenous peoples and communities.
7. Biochar production should promote food security through improved agronomic performance when applied to soil.
8. Biochar production and application shall avoid negative impacts on biodiversity, ecosystems, and areas of High Conservation Value.
9. Biochar utilisation will seek to improve soil health.

10. Biochar production shall optimize surface and groundwater resource use, including minimizing contamination or depletion of these resources, and shall not violate existing formal and customary water rights.
11. Air pollution from biochar production and processing shall be minimized along the supply chain.
12. Biochar production shall not violate land rights.

Table 1: Guidelines and information to be supplied with biochar

	Does not comply	Complies
1) Biochar is produced according to the relevant laws of the Country in which it is processed		
2) Feedstock is from a renewable source		
3) Syn gas is utilised for bioenergy production or be flared		
4) Biochar production complies with local regulatory requirements that govern utilisation of source material		
	List	
5) Country of manufacture		
6) Country where feedstock materials sourced		
7) Distance feedstock travelled prior to processing		
8) Provide details on source materials, both major and minor components, and percentage of each in feedstock.		
9) Detail the use of syn gas (flaring, bioenergy production etc)		

*note: Biochar must comply with first 4 items

3.2 Potential benefits of biochar when sustainability criteria are met

Table 2 provides a list of the potential benefits of sustainably produced biochar. This table is provided to encourage consideration of the various processes associated with biochar manufacture, distribution, and use.

Table 2: Potential benefits of biochar (and energy) manufacture and application

Biochar (and the energy by-products) manufacture and application can:-	**Which can present as benefits…**
i) Reduce atmospheric Carbon dioxide levels	If generated, processed and applied sustainably and efficiently
ii) Provide essential ecosystem services as a collateral outcome	If sourced as sustainable yields from appropriate land use
iii) Provide sustainable economic opportunities for regional and rural industries	Through value added to residues, by-products or land use activities
iv) Benefit soil quality, remediate degraded soil and enhance agricultural productivity	If biochar suited to the specific site conditions is utilised at an appropriate rate
v) Provide local, catchment and global water cycle and management outcomes	If conducted sensitively and with due regard to the prevailing water cycle issues

vi) Deliver net biodiversity outcomes in the soil and above ground	Where biochar overcomes limitations to biodiversity caused by soil contamination or land degradation
vii) Provide an opportunity for beneficial recycling of certain urban and industrial waste materials	Where the production processes have a "community licence to operate" and are conducted with minimal impact in relation to value achieved

4. Characterisation of biochar

Characterisation aims to document the basic features of a biochar and to ensure that it is safe to apply as a soil amendment. It is also appropriate to quantify the key properties that may give rise to the beneficial qualities of biochar. Some standard soil tests are appropriate but biochar has some unique properties that mean that analytical methods developed for soil may not be appropriate for biochar. Here we propose a minimum data set of properties that should be determined, and suggest appropriate analytical methods which may be used.

4.1 Process conditions

Biomass feedstock material and biochar manufacturing conditions determine the properties of biochar. The feedstock material (as discussed in 3.1), and the aspects listed in Table 3, should be reported.

Table 3 Process conditions

1) Rate of heating of the feedstock	
2) Processing of feedstock (eg, grind size, addition of other reagents)	
3) The final temperature of the charring process and the time held at this temperature	
4) The pressure of the reactor (Amonette and Joseph 2009)	
5) Post-biochar processing (eg chemical or steam activation of the surface, crushing, prilling, combination with other organics such as compost of manure)	

4.2 Properties of the Biochar

It is recommended that the following properties of the material, measured according to the recommended test (or equivalent), be reported. Furthermore, it is recommended that biochar should meet the minimum criteria outlined in the table below. Each batch of biochar should be tested, or if treatment and feedstock remain identical, testing performed on a 6-monthly basis.

Table 4: Physico-chemical properties of biochar

Required analysis	Recommended method	Minimum criteria	Notes
Total C content	Dumas combustion with removal of	20%*[1]	

	carbonate C.		
Total N content	Dumas combustion	na	
Molar H/C ratio	Australian Standards 1038	<0.6*[2]	Ultimate analysis
Ash content	Australian Standards 1038 (details required)	na	Proximate analysis or similar.
pH	Method 4B2 of Rayment and Higginson (1992) using 0.01 M CaCl2 (1:5)	na	
EC	Method R&H 3A1 (Rayment and Higginson 1992)	na	Indicates soluble cations and anions
Acid neutralising capacity	Method 19A1 (Rayment and Higginson 1992) testing carbonate equivalent	na	Expressed as a percentage of $CaCO_3$
Total P	Acid Extractable Elements and Metals by microwave and ICP USEPA 3050B and USEPA 6010	na	
Total K	Acid Extractable Elements and Metals by microwave and ICP USEPA 3050B and USEPA 6010	na	
Available P	Colwell, Olsen or Mehlich etc	na	Colwell method generally performs well in both acidic and alkaline conditions, the hydroxyls and carbonate in the NaHCO3 decreases the activity of Ca and Al, and therefore resulting in release of P. Other methods may also be appropriate.
Mineral N	Method 7C2 (Rayment and Higginson 1992) using KCl extraction	na	
Surface Area	Iodine Method; ASTM 1510-09	na	Compares the relative surface area of biochar (Mianowski et al., 2007)
Heavy metal concentration	Acid Extractable Elements and Metals by ICP USEPA 3050B and USEPA		Concentrations relevant to soil additives, eg, Compost guidelines (see below)

	6010		
Bulk density			

*1 For composite materials (for example with added mineral matter) the 20% refers to the carbon content of biochar used in the composite material
*2 It is recognised that there is a wide variation in molar H/C ratio. Aromaticity and longevity in soil is generally associated with lower molar H/C ratios. See Krull et al., (2009).\

Table 5. Threshold values of contaminants in biochar

CONTAMINANT ACCEPTANCE CONCENTRATION THRESHOLDS **NSW EPA230800d (EPA Compost Guidelines Public Consultation (2009)**		
Contaminant	Grade A (mg/kg)	Grade B (mg/kg)
	Note: Contaminant Acceptance Concentrations are <u>not</u> mean values	
Arsenic	20	20
Cadmium	3	5
Chromium (total)	100	250
Copper	100	375
Lead	150	150
Mercury	1	4
Nickel	60	125
Selenium	5	8
Zinc	200	700

It is anticipated biochar should meet Grade A standards for application above 10t/ha. Grade B standard of heavy metal contamination may be adequate for lower application rates, or for non-food soil amendment.

To determine the suitability of a biochar material for improving soil health and agronomic performance, a minimum set of ecotoxicological assessments need to be undertaken. These tests will not guarantee the biochar has a positive influence on crop performance, however, they will assess any potential harm a poorly-produced biochar may impart in soil.

Table 6: Ecotoxicological assessment of biochar

Required analysis	**Recommended method**	**Minimum criteria to be termed biochar (or notes)**
Earthworm avoidance	Toxicity testing conducted using the Organisation for Economic Co-operation and Development (OECD) earthworm avoidance method (OECD, 1984) as described	Biometrical analysis against controls should show no biometrically significant earthworm avoidance to the biochar treatment.

	in Van Zwieten et al., 2004. *Biochar is applied into OECD standard soil at a rate of 1% w/w, with 10 replicates.*	
Germination inhibition assay	Germination inhibition is tested against three test species using OECD standard soil (OECD 2004). Method description in Van Zwieten et al., 2009.	Biometrical analysis against controls should show no biometrically significant decrease in plant germination.

4.2 Safety

Biochars can contain constituents that can be toxic to both humans and animals, if present at high concentration. Those of special concern are (i) crystalline silica that can be produced in rice husk biochar when made at high temperatures (>450 ºC), (ii) organic compounds, such as polyaromatic hydrocarbons, that can be produced under certain process conditions, and possibly dioxins, derived from certain waste sources and (iii) heavy metals if biochar is derived from contaminated biomass materials (Table 1).

Most Countries have recommended test procedures and standards related to the maximum content of these constituents when applied to soils.

Table 5: Analysis of human or environmental risks in biochar

Toxic constituent	**Test and Compliance**
Crystalline Silica (applies to rice husk biochar)	XRD (should be less than recommended by local standard). If no standard then consult most recent research
Toxic Organic Compounds including PAH and Dioxins	Relevant local standards
Heavy metals	Discussed in Table 5

5.0 Classification

A basic framework for biochar classification has been proposed here building on a model developed by Joseph et al (2009). It is not possible to currently predict the long-term effects of biochar in soil, however, there are a few basic biochar characteristics that may be useful for classification.

Using the test results obtained in these guidelines, the following classification system is now suggested.

Table 6: Simple Biochar Classification[*1]

1	**2**	**3**

A	Biomass Composition	
0-50% plant material, 50% other material eg manure	50-90% plant material	90-100% plant material
B	**Production[*2]**	
Engineered pyrolysis with temperature and residence time controls	Pyrolysis without controls	Carbonisation or gasification procedures
C	**Surface area**	
10-50sq.m./gm	50-200sq.m./gm	>200 sq.m./gm
D	**Carbon (%)**	
20-40	40-60	>60
E	**Molar H/C ratio**	
<0.2	0.2-0.4	0.4-0.6
F	**Liming value (%$CaCO_3$)**	
0-5	5-20	>20
G	**Total N%**	
0-0.5	0.5-1.5	>1.5
H	**Total P%**	
0-0.25	0.25-1.5	>1.5
I	**Total K%**	
0-0.5	0.5-1.5	>1.5
J	**Mineral N (mg/kg)**	
0-2	2-20	>20
K	**Available P (mg/kg)**	
0-100	100-1000	>1000
L	**EC (Ds/m)**	
0-1	1-2.5	>2.5
M	**Earthworm avoidance/attraction**	
Earthworms avoid	Nil effect	Earthworm attracted
N	**Germination inhibition**	
Seed germination inhibited	Nil effect	Germination enhanced

*1 At this stage, rankings from 1-3 do not indicate beneficial or non beneficial. Each row (from A-N) is independent.
*2 These categories are broad and a more detailed description may be required.

From this table, it may be possible to classify biochars according to a broad range of parameters.

For example a greenwaste biochar from BEST Energies:
made exclusively from plant material in an engineered slow pyrolysis process, with high C, low molar H/C ratio, high surface area, low liming value, low total and available N and P, low K and low EC, and nil effect on earthworms and seedling germination would be classified as

A3, B1, C3, D2, E2, F1, G1, H1, I1, J1, K1, L1, M3, N2.

6.0 References

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