Code of Practice for the Sustainable Production and Use of Biochar in Australia and New Zealand

Version 1.0 – November 22, 2021

ANZ BIOCHAR INDUSTRY GROUP

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Document Status

The Code of Practice is based on science at the date of publication. It is a live document that will be regularly updated to ensure currency.

Submissions to improve and update the Code of Practice are invited from producers, users and other stakeholders. These submissions should be sent to ANZBIG at execdirect@anzbig.org. All written submissions will be reviewed by the ANZBIG Code of Practice Working Group.

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1. Objective of the Code of Practice

This Code of Practice sets out industry best practice for the sustainable production and use of biochar. Biochar is currently used for many different applications, including soil conditioning and improvement, compost and fertiliser additives, animal feed supplement and as a material for industrial applications. The list of potential uses continues to expand.

As the number of applications for biochar increases, so too does the number of manufacturers. This leads to new challenges in ensuring the quality and sustainability of biochar. It is important to ensure biochar is being produced from a sustainably sourced and supplied feedstock, is not contaminated and is safe for its intended end-use application. The production should not infringe environment, health and safety laws and regulations.

It is critical to consider the quality and properties of biochar for different applications. For example, biochar used in animal feed must be high quality and uncontaminated due to the potential risk of impurities entering the human food chain by secondary consumption. Conversely, in some industrial applications such as asphalt or concrete additives, biochar with a certain degree of contamination may be acceptable. Lower quality biochar still has many applications and is an important means of utilising lower quality biomass resources that may otherwise end up as landfill.

One of the main attributes of biochar is its unique ability to sequester carbon. However, if its production involves high levels of greenhouse gas emissions, other noxious emissions or unsustainable feedstock sources, it should not be considered a sustainable product. The overall production of biochar should, if possible, be a carbon negative (climate positive) process and completed with minimal emissions, meaning the process is clean and more carbon is sequestered by the biochar than is released by its production and use.

This Code of Practice provides guidelines suitable for Australia and New Zealand for the sustainable production of biochar and its end use applications. The Code builds upon information provided in the International Biochar Initiative (IBI) Biochar Standard and the European Biochar Certificate (EBC) Guidelines for a Sustainable Production of Biochar.

It does not replace the legal requirements of the operating jurisdiction but provides guidance on the production and utilisation of biochar products.

2. Definitions

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 relatively stable, carbon rich material produced by heating sustainably obtained biomass under controlled low oxygen conditions using a clean technology. Biochar can be used for any purpose that does not involve its rapid breakdown to carbon dioxide. (Adapted from EBC, 2019). Biochar will have an organic carbon content greater than 30% and a molar H/C ratio below 0.7.

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)

Impurity: A potentially 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).

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)

Feedstock: The material undergoing the thermochemical process to create biochar. Feedstock for biochar consists of biological material but may also contain diluents. (IBI, 2015).

Homogenous / heterogeneous feedstock: Homogeneous feedstock consists of feedstocks of the same type, for example, woody biomass, grass biomass, or poultry litter. Heterogeneous feedstock is a mixture of different feedstock types.

Processed / unprocessed feedstock: Unprocessed feedstock consists of recently harvested, uncontaminated feedstock, for example, woody biomass or grass biomass. Processed feedstock consists of feedstock that has undergone some form of processing and/or may be contaminated, such as poultry litter, biosolids or processed wood.

Sustainable feedstock: For unprocessed feedstock, feedstock is sustainable if it has been sustainably sourced, that is, the harvesting of the feedstock must not be undertaken at an unsustainable rate nor significantly impact the environment or people. Processed feedstocks can be sustainable if it is diverting waste from landfill or similar.

3. Feedstock Requirements

3.1 General biomass feedstock requirements

The following are recommended requirements for biochar feedstock:

- Reactive impurities such as plastic, rubber, some metals, electronic scrap etc. are regarded as undesirable impurities and must be removed to the greatest extent possible. The presence of reactive tramp material triggers the need for biochar product analysis to ensure that final concentrations of any impurities are below the thresholds presented in Table 3.
- Inert tramp material such as stones, mild steel, stainless steel etc. must be removed from the feedstock, however they are not considered an "impurity" unless present to the extent that they materially alter the bulk biochar physical and chemical characteristics.
- Reactive coatings and timber treatments (such as laminates, glues, paints, varnishes, anti-fungal, CCA, etc) should be avoided by identifying and removing treated or coated materials from the feedstock whenever possible. The presence of reactive coatings and timber treatments triggers the need for biochar product analysis to ensure that final concentrations of any impurities are below the thresholds presented in Table 3.
- Materials such as CCA treated timber and PVC/chlorinated and other halogenated plastics and materials must generally not be allowed to enter the pyrolysis reactor as their thermal degradation may cause the formation of dangerous gaseous products and their subsequent release into the environment poses a risk to human health and safety. The only exceptions are where these materials are used for industrial grade biochar and suitable emission control systems are in place consistent with relevant regulations
- The transport of feedstock over long distances exclusively for biochar production should be avoided. A simple carbon assessment should be conducted to ensure that the transportation of the feedstock does not negate the carbon sequestration potential of the biochar.
- Complete records of feedstocks must be kept. Records should include, but not be limited to: date acquired, feedstock source location, description of feedstock, transport method and distance, and preliminary assessment of potential impurities.

3.2 Biochar produced from unprocessed biomass feedstock

In addition to the above general feedstock requirements, the following is recommended for unprocessed biomass feedstock:

- Source of feedstock must be sustainable. For example, wood feedstock must be sourced from legally harvested wood that is not being harvested at a rate at which the harvest site cannot sustainably maintain and must not be affecting local ecology. For further information, see the Forest Stewardship Council (FSC) National Forest Stewardship Standard of Australia.

* Feedstock should not be contaminated by any other materials.

3.3 Biochar produced from processed biomass feedstock

Biochar produced from processed biomass feedstock must follow the general feedstock requirements as well as the following:

* Feedstock must be tested for acceptable levels of impurities (see Table 3). With the exception of lead (e.g. lead paint) and arsenic (e.g. CCA treatments) most inorganic impurities present in feedstock will not be volatile at pyrolysis temperatures, so the concentration of these impurities in the biochar will be greater than in the feedstock.

4. Production

Biochar production processes should be designed and operated to international best practice standards. They must adhere to all applicable health, safety and environmental requirements in the place of operation. For example:

- **Only biochar from unprocessed feedstock can be used for animal feed.**
- **During production substances or impurities emitted to air, land or water must not exceed local standards, regulations or licence requirements.**

Table 1 identifies common biochar types and their typical ash and carbon content. Carbon contents of biochar vary significantly depending on the feedstock and process temperatures.

This Code only covers production using pyrolysis which is the dominant production method. Other technologies such as microwave are not yet commercially available.

Table 1: List of some common biochars and typical carbon and ash content. Contents are % dry weight.

Biomass type and production temperature	**%C**	**%Ash**
Pine chips 400 °C	74.1	3.7
Switchgrass 400 °C	73.7	2.9
Eucalyptus wood 400 °C	70.4	5.6
Wheat straw 550 °C	69.5	20.5
Switchgrass 550 °C	81.7	5.3
Pine chips 550 °C	76.8	4.9
Rice husk 550 °C	38.7	48.4
Miscanthus straw 550 °C	67.8	11.6
Eucalyptus wood 550 °C	75.6	5.3
Poultry litter 550 °C	36.7	42.8
Digestate biochar 700 °C	50.6	32.7
Wheat straw 700 °C	69.0	21.3
Rice husk 700 °C	42.5	11.8
Miscanthus straw 700 °C	72.4	11.6
Mixed softwood 700 °C	86.6	6.1
Coffee husk 450 °C	61.3	16.1

4.1 Pyrolysis

The following are required for best practice pyrolysis reactors:

- Fossil fuels must not be used for heating during pyrolysis, except for preheating the pyrolysis reactor. Fuels not derived from fossil fuels should be considered as an alternative for preheating. Once the reactor is preheated, no additional heating should be necessary, as the process releases energy.

- Pyrolysis gases must not be allowed to escape to the atmosphere- they should be recovered or burned.
- Flue gas emissions from the burning of the pyrolysis gas or syngas must be within regulatory emission thresholds.
- Wherever possible, heat produced by pyrolysis should be utilised. For example, heat produced could be used to dry the biomass before pyrolysis or for heat applications and electricity generation.
- If using a processed feedstock that may lead to the generation of dioxins and/or furans, the temperature of the gas at the combustion chamber of the thermal oxidiser must be raised to at least 850°C after the last injection of combustion air, in a controlled and homogeneous fashion even under the most unfavourable conditions, for at least two seconds in the presence of at least 6% v/v oxygen on a dry basis to ensure complete destruction of any dioxins or furans formed.
- If using a processed feedstock that contains halogenated organic compounds, or the feedstock contains polychlorinated biphenyls (PCBs), polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), Polychlorophenols or Polycholobenzenes, the gas temperature at the combustion chamber must be at least 1100 °C.

4.2 Production records

Biochar production must be documented and labelled in series with a unique identification number. The biomass feedstock and production conditions for each series of biochar must be traceable. Separate production records must be kept for each series, with samples kept from each series for testing.

The following requirements define a biochar series:

- The highest treatment temperature during pyrolysis must not fluctuate by more than 20% in ˚C. Production can be interrupted provided the production parameters are the same once it is restarted.
- Each series is comprised of only one homogeneous feedstock. This may consist of more than one type of biomass.
- The composition of the pyrolysed biomass must not fluctuate outside of the specified biochar grade for one type of feedstock (see Section 5. Use).
- Each series must not exceed a production period of more than one year, including any interruption of the production.
- Complete production records must be kept to provide detailed descriptions and dates of any production problems or halts. A suitable recall procedure utilising the production and sales records, and unique identifiable numbers per record, must be available.

5. Using Biochar

5.1 Biochar grades

Biochar produced under this Code is categorised into grades based on carbon content and impurity levels as follows:

Biochar Feed Grade (BFG)

1. Biochar Feed Grade High Carbon (BFG-HC)
2. Biochar Feed Grade Medium Carbon (BFG-MC)
3. Biochar Feed Grade Low Carbon (BFG-LC)

Generally suitable for agricultural use including animal feed. Generally, can be safely used for all other applications. No or minimal impurities as per Table 3.

Biochar Standard Grade (BSG)

1. Biochar Standard Grade High Carbon (BSG-HC)
2. Biochar Standard Grade Medium Carbon (BSG-MC)
3. Biochar Standard Grade Low Carbon (BSG-LC)

Generally suitable for most agricultural use excluding animal feed. Generally, can be safely used for other applications.

Biochar Industrial Grade A (BIGA)

1. Biochar Industrial Grade High Carbon (BIGA-HC)
2. Biochar Industrial Grade Medium Carbon (BIGA-MC)
3. Biochar Industrial Grade Low Carbon (BIGA-LC)

Suitable for some industrial uses. Generally, not suitable for agriculture accept when applied in low concentrations and / or application rates.

Biochar Industrial Grade (BIGB)

1. Biochar Industrial Grade High Carbon (BIGB-HC)
2. Biochar Industrial Grade Medium Carbon (BIGB-MC)
3. Biochar Industrial Grade Low Carbon (BIGB-LC)

Suitable for specified industrial uses where impurities do not present as an environmental or health hazard.

The carbon content and impurity levels are specified in Tables 2 and 3 respectively.

Table 2- Carbon content of each grade of biochar. Carbon content is expressed as % of total mass on a dry basis

Biochar grade	High Carbon	Medium Carbon	Low Carbon
Carbon content	>70%	>50-70%	<50%

Table 3- Maximum concentration of impurities in each grade of biochar (dry matter). Feed Grade are generally based on the EBC standard for biochar suitable for animal feed, and Standard and Industrial concentrations are derived from the IBI standard for biochar impurities, NEPM health investigation levels and other Australian and New Zealand standards.

Impurity	Units	Biochar Grade			
		Feed	**Standard**	**Industrial A**	**Industrial B**
Lead	mg/kg	<0.2	<20	<300	Use specific
Cadmium	mg/kg	<0.5	<1	<20	Use specific
Mercury	mg/kg	<0.02	<0.2	<10	Use specific
Arsenic	mg/kg	<2	<13	<100	Use specific
Copper	mg/kg	<70	<200	<6000	Use specific
Nickel	mg/kg	<25	<60	<400	Use specific
Selenium	mg/kg	<1	<3	<200	Use specific
Zinc	mg/kg	<200	<600	<7400	Use specific
Chromium	mg/kg	<70 (<1 for CrVI)	<90 (<1 for CrVI)	<100	Use specific
Polycyclic aromatic hydrocarbons (PAHs)	mg/kg	<4	<5	<300	Use specific
Benzo(a) Pyrene	ng/kg	<25	NS	NS	NS
Dioxin/furans	ng/kg	See below	<17	<17	Use specific
Fluorine (soluble salts as fluoride)	mg/kg	<40	NS	NS	NS
PCBs	mg/kg	See below	<0.2	<1	Use specific

Notes

DM = Dry Matter, commonly at 88% DM (12% moisture).

Australian soils are commonly deficient in certain trace metals (eg Zinc and Copper) and some crops require replacement balance (eg wheat). This should be considered by biochar users on a case-by-case basis.

Note that Cu in animal feeds in WA must be <15 mg/kg.

Declaration values should also be made for chlorine in all chars, and for Bo, Mn, Nitrite and Melamine in Feed chars.

For biochars derived from municipal biosolids, a range of additional tests should be undertaken in consultation with regulators (eg organochlorines/POPs, PFAS, Pthalates, and otehr emerging contaminants). For biochars sourced from feedstocks treated with pesticides and herbicides, additional tests should be considered.

All standard and feed grade chars should pass a germination inhibition test.

The following limits apply for dioxins, furans, dioxin-like PCB (WHO-PCB) and non-dioxin-like PCB (DIN-PCB) in Feed, Standard, Industrial A biochar: for PCDD/PCDF, a trigger value of 0.5 ng TE kg^{-1} at 88% dry matter and a limit of 0.75 ng TE kg^{-1} at 88% dry matter apply. For dl-PCB, a trigger value of 0.35 ng TE kg^{-1} at 88% dry matter applies. For PCDD/PCDF + dl-PCB the threshold is 1.25 ng TE kg^{-1} at 88% TS. For the sum 6 of DIN PCB, a limit value of 10 µg TE kg^{-1} at 88% dry matter applies (limits derived from the EBC guidelines for feed grade biochar). Feed Grade biochar must also contain less than 40 mg/kg (88% TS) of soluble fluorine salts (as fluoride). Although fluorine salts are usually volatile in pyrolysis conditions, this test is still suggested for animal feed (limit derived from the EBC guidelines for feed grade biochar).

All biochar grades apart from Industrial B must have impurities at levels lower than Australian NEPM health investigation levels. Feed and Standard grade biochar must have impurities at lower levels than mandatory reporting requirements under the Australian Code of Practice for Fertiliser Description and Labelling (May, 2018).

Leachate testing may be required for Industrial Grade biochar, in particular Industrial B depending on the application.

Additional testing on the bioavailability of impurities can be used to further demonstrate the suitability of biochar for particular applications within each ANZBIG Grade where total values exceed the total concentrations of parameters in Table 3. See further details below.

5.2 Fit-for-Purpose Considerations and Potential Additional Tests

All biochars have different characteristics and abilities and may perform differently in different situations. For these reasons biochar users and their consultants are advised to check that:

1. The Grade of biochar and its characteristics are fit for their intended purpose/situation.
2. The biochar application rates and frequency are suitable for their situation (not too little or too much).
3. The biochar’s characteristics are cosnidered alongside other inputs.

5.3 What happens if a biochar exceeds recommended levels?

Many biochars can adsorb and reduce the mobility and bioavailability of heavy metals and PAHs and other toxic components. If total concentrations of analytes listed in Table 3 are recorded above the recommended levels then additional tests should be undertaken to ensure they are fit for intended purpose under a suitable risk-based approach. These additional tests can include:

- **Leaching tests**: Specific leaching tests should be undertaken by a NATA accredited laboratory. TCLP (Toxicity Characteristic Leaching Procedure) and ASLP (Australian Standard Leaching Procedure) are considered highly conservative as they were designed for assessing leaching behaviour in chemically harsh receiving environments such as landfills. They are commonly used as ‘worst-case’ assessment by regulators. EDTA extractable metals leaching tests can also be undertaken to further assess bioavailability in more representative conditions (EDTA is a chelating agent commonly used to bind minerals and metals). Other options are also available which can be considered on a fit-for-purpose basis. Leachate testing may also be required for Industrial Grade biochar, depending on the application. Consultation with relevant regulators in the place(s) of production and intended sale/use is recommended in all cases.

- **Soil/plant-based tests**: These tests determine the bioavailability of heavy metals and organic toxins at recommended application by taking into account the characteristics of the soil/plants in which biochar is to be applied in, and can also be carried out to determine if the biochar is fit for purpose. Australian soils are commonly deficient in certain trace metals (e.g. zinc and copper) and some crops require replacement balance (e.g. wheat). This should be considered by biochar users on a case-by-case basis.
- **Germination tests**: Biochars can also contain a range of organic molecules that can either assist or potentially inhibit seed germination. International guidelines (including IBI) recommend that germination tests be carried out to determine if there is an inhibitory effect and at what rate the inhibition occurs. The response of a plant to a given biochar is rate dependent. Too little biochar and there may be no or a negative response; too much biochar and the plant's growth may be inhibited.
- **Worm avoidance tests**: It is recommended to carry out a worm avoidance test and also plant trials to provide the consumer with evidence-based advice on recommended application rates for given soils and crops.

Further supporting guidance on additional recommended tests is being developed by ANZBIG to assist biochar producers and users, and will be referenced in subsequent versions of the Code.

5.4 Animal Feeds

Present EU Regulations on Feed Additives and some Australian states have very specific requirements for potential contaminant contents in animal feeds (including heavy metals and other toxic organic chemicals) specified for different types of animals, and these requirements must be met as the highest priority for Feed Grade biochar.

For example, some animals need higher Zn, Se and Cu supplementation than others. Biochar users and their consultants are advised to follow the biochar supplier's recommended dosage, factoring in the biochar's component levels (e.g. Zn, Se, Cu, Fe, etc.) along with all other daily inputs for animals, and check these against their individual jurisdiction's limits.

5.5 Sampling and Testing

Biochar producers must collect samples for testing when there is a change in the feedstock, a change in the production process, or the biochar has not been tested for one year. The sampling method suggested by the EBC is provided in Appendix 3.

Samples must be sent to a NATA accredited laboratory for testing.

Compulsory tests for certification are:

- Carbon content (within limits of specified grade)
- Impurities specified in Table 3 (within limits of specified grade)
- Molar ratio of hydrogen to organic carbon (less than 0.7)
- Moisture content as % of total mass, dry basis
- Ash content as a % of total mass, dry basis
- Density in g/cm^3
- pH

Moisture content, ash content, density and pH do not have specific limits but must be declared.

Additional voluntary tests may include:

- Molar ratio of oxygen to organic carbon
- Liming
- Electrical conductivity
- Available and total phosphorous
- Total nitrogen and nitrogen available as nitrate and ammonium
- Potassium
- Silica
- Calcium
- Magnesium
- Chloride
- Iron
- Sulphate-S
- Additional metal analysis suite (e.g. Sb, Be, Bo, Co, Mn, Mo, Sn, V)
- Particle size distribution
- Volatile and semi-volatile organic compounds (VOC)
- Total and external surface area
- Germination and worm avoidance tests
- PAH
- Other relevant parameters specific to feedstocks (e.g. PFAS)

6. Handling and Packaging

6.1 Safety

The following safety precautions must be followed for the production and use of biochar:

- Any fire or explosion risks must be identified and completely mitigated.
- Biochar manufacturers must provide a relevant materials safety data sheet (MSDS) for the final output of its biochar production process.
- Quenching of biochar in water immediately after pyrolysis is highly recommended, as this removes hazards associated with dust formation (dust explosions, respiratory and eye irritation) and self-heating and flammability. If quenching is not conducted, adequate safety measures (personal protective equipment from dust and testing for self-heating and flammability) must be followed.
- A site safety analysis must be conducted.
- All equipment must be maintained so that it is fully operational and functioning properly during production. Maintenance records for all potentially hazardous equipment (pyrolysers, vehicles, etc.) are required.
- Staff operating the production site must be well trained on the equipment and site hazards by previously trained staff or the equipment manufacturer to ensure proper handling of equipment.

6.2 Packaging

The following information must be stated on the packaging of biochar produced in accordance with this Code of Practice:

- Name or registered trademark and full street address of the manufacturer, packer or distributer.
- Volume of contents in litres.
- If the product contains fine particles that could cause respiratory problems or could contain pathogenic microorganisms, a health warning label and hazardous information label for customers on the handling of the products on the package for bagged product or the information sheet/invoice in the case of bulk products shall be provided.
- Grade of biochar and where produced.
- Type of feedstock and processing (pyrolysis and/or gasification).
- Carbon content.

Biochar must be packaged and stored appropriately to ensure no contamination can occur. It is important to consider gaseous pollutants such as engine exhaust gases that could be adsorbed by the biochar.

7. Quality Assurance and Verification

7.1 Biochar Certification

If manufacturers produce biochar in accordance with this Code, they may apply for ANZBIG Biochar Certification. The following guidelines must be followed to maintain certification:

- All biochar and biochar-based products should have the ANZBIG Biochar Certificate with the corresponding grade visible on all documentation and labels.
- Batches and grades of biochar should not be mixed without documentation. The identification number and product name of each batch must be clearly visible.
- Each processing step of biochar and biochar-based products must be documented. This includes the quantity and quality of all processed biochar and the amount of biochar in the final product. The control of the flow of goods must always be tracked and documented.
- Any claims of carbon sequestration from the biochar produced must be evidence based and in keeping with the EBC Guidelines for the Certification of Biochar Based Carbon Sinks (Version 2.1 from 1st February 2021.

7.2 Labelling and Advertising with ANZBIG Biochar Certification

ANZBIG will provide suitable labels to biochar producers once they have achieved certification. Labels cannot be used without ANZBIG Certification. If the producer's ANZBIG Certification is suspended or terminated, the producer must immediately discontinue labelling products with the ANZBIG certification label, and withdraw any products currently labelled with ANZBIG certification.

Key References

Environmental Protection Authority Victoria 2009, Soil hazard categorisation and management, https://www.epa.vic.gov.au/about-epa/publications/iwrg621

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International Biochar Initiative 2015, Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil, https://biochar-international.org/wp-content/uploads/2019/01/IBI_Biochar_Standards_V2.1_Final1.pdf

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Appendices

Appendix 1: PAH, PCDD/F and PCB Compounds to be Tested

PAHs, PCDD/Fs, and PCBs are each suites of related chemical compounds (congeners), sometimes numbering in the hundreds. The US EPA maintains a list of 126 Priority Pollutants as part of the (US) Clean Water Act that have been determined to have detrimental human and environmental health impacts; these compounds must be reported under requirements of the Clean Water Act. Contained therein are the primary PAHs and PCBs of concern. For PCDD/Fs, the World Health Organization (WHO) maintains a list of the primary PCDD/Fs of concern as well as the toxic equivalency factor (TEF) of each PCDD/F (Van den Berg et al, 2005).

For the purposes of biochar testing for PAHs, PCDD/Fs, & PCBs, testing labs shall test for the following priority compounds as determined by the US EPA & WHO.

The 16 PAH priority compounds to be tested are:

PAH		CAS number
1	Acenaphthene	83-32-9
2	Acenaphthylene	208-96-8
3	Anthracene	120-12-7
4	Benz(a)anthracene	56-55-3
5	Benzo(a)pyrene	50-32-8
6	Benzo(b)fluoranthene	205-99-2
7	Benzo(k)fluoranthene	207-08-9
8	Benzo(ghi)perylene	191-24-2
9	Chrysene	218-01-9
10	Dibenz(a,h)anthracene	53-70-3
11	Fluoranthene	206-44-0
12	Fluorene	86-73-7
13	Indeno(1,2,3-cd)pyrene	193-39-5
14	Naphthalene	91-20-3
15	Phenanthrene	85-01-8
16	Pyrene	129-00-0

The 7 PCB priority compounds to be tested are:

PCB		CAS number
1	Aroclor 1016	12674-11-2
2	Aroclor 1221	11104-28-2
3	Aroclor 1232	11141-16-5
4	Aroclor 1242	53469-21-9
5	Aroclor 1248	12672-29-6
6	Aroclor 1254	11097-69-1
7	Aroclor 1260	11096-82-5

The 17 PCDD/PCDF cogeners to be tested are:

PCDD/F		Acronym
1	2,3,7,8-Tetrachlorodibenzo-p-dioxin	TCDD
2	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	PeCDD
3	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	HxCDD
4	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	HxCDD
5	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	HxCDD
6	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	HpCDD
7	1,2,3,4,5,6,7,8-Octachlorodibenzo-p-dioxin	OCDD
8	2,3,7,8-Tetrachlorodibenzofuran	TCDF
9	1,2,3,7,8-Pentachlorodibenzofuran	PeCDF
10	2,3,4,7,8-Pentachlorodibenzofuran	PeCDF
11	1,2,3,4,7,8-Hexachlorodibenzofuran	HxCDF
12	1,2,3,6,7,8-Hexachlorodibenzofuran	HxCDF
13	1,2,3,7,8,9-Hexachlorodibenzofuran	HxCDF
14	2,3,4,6,7,8-Hexachlorodibenzofuran	HxCDF
15	1,2,3,4,6,7,8-Heptachlorodibenzofuran	HpCDF
16	1,2,3,4,7,8,9-Heptachlorodibenzofuran	HpCDF
17	1,2,3,4,5,6,7,8-Octachlorodibenzofuran	OCDF

References:

US Environmental Protection Agency (2013) Clean Water Act Priority Pollutants http://water.epa.gov/scitech/methods/cwa/pollutants.cfm (accessed November 2013).

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Appendix 2: The Use of H:Corg to Indicate C Stability

(From IBI Standardized Product Definition and Product Testing Guidelines for Biochar That Is Used in Soil (IBI Biochar Standards), Version 2.1)

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

Figure A2.1 below shows relationships between processing temperature and H:Corg molar ratio for a number of thermochemically altered materials, as compared to unprocessed biomass.

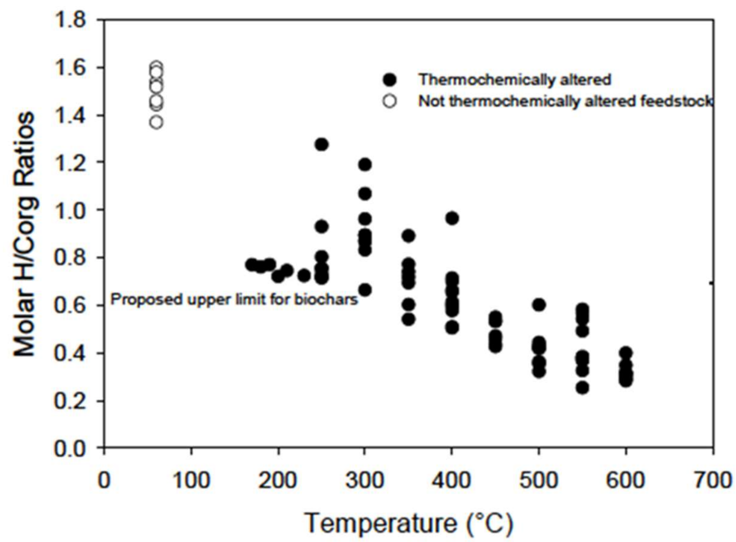

Figure A2.1. Relationship between molar H:Corg ratios and temperature of thermochemically altered organic matter in comparison to untreated biomass. The dashed line is the upper limit of 0.7. Data points below the 0.7 line are thermochemically altered materials that are considered to be thermochemically "converted" (data from Sevilla and Fuertes, 2009; Calvelo Pereira et al, 2011; Enders et al., 2012).

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Appendix 3: Method for Sampling, Sampling Handling and Preparation Prior to Analysis

(Taken from EBC Guidelines)

The biochar samples must be taken as per the procedure described here. The accredited controlling inspector is entitled to take samples and sent to the accredited laboratory. To obtain a biochar sample as representative as possible (in terms of accuracy and precision) of a total lot (batch), it must be taken in a proper way. For this, the following general guidelines must be followed:

- A biochar lot (batch) subject to sampling must consist of at least the amount of one day of production.
- Before sampling, the whole lot must be thoroughly mixed 3 times by turning and piling it upside-down by means of physical replacement with a front loader or comparable technical device.
- 15 subsamples of 1.5 litre each have than to be arbitrarily gathered from different spots of the homogenized biochar lot (ISO (2006) or Bunge & Bunge (1999)).
- For small scale production of less than 200 litres per day the subsample size may be reduced to 0.5 litres.
- The 15 subsamples must be united and milled or crushed if the particle size is above 3 mm.
- The new subsample has than to be homogenized thoroughly by turning and piling it 3 times upside-down.
- A further 15 sub-subsamples of 150 mL each must be arbitrarily taken from different spots of the gathered subsample lot.
- The 15 sub-subsamples (totalling 2.25 L) must be united and well mixed.
- The sample of 2.25 L must be sent to an accredited laboratory.

As illustrated in Bucheli et al. (2014), such a sampling procedure may still not be sufficient to obtain truly representative samples, but assures a degree of accuracy (bias) and reproducibility (variance) affordable to compare analytical results with guide values set in this certificate.

Alternatively, an automated incremental cross-stream sample of 100 g could be taken every 30 min for at least 24 hours. Such an automated incremental cross-stream sample could replace the above-described sampling method.

Random Sampling

At each control visit, the controller takes a random sample of the biomass feedstock and the resulting biochar, seals both sample bags and let the producer send them to the certified laboratory.

Retention Sample

In addition to the EBC-analysis sample and random sample, the producers are obliged to take daily an incremental cross-stream sample of at minimum 100g. The time of the daily sample must be marked in the production protocol. The daily cross-stream samples must be collected in a monthly sample bag or case. After one month the sample bag must be sealed and dated. The next 30 cross-stream samples will be collected in a new monthly bag or case. The incremental cross-stream sample can be taken manually or implemented. The incremental cross-stream sampling guaranties a most representative sampling of the product.

References:

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