Biochar Quality Mandate

(BQM) v. 1.0

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Contents

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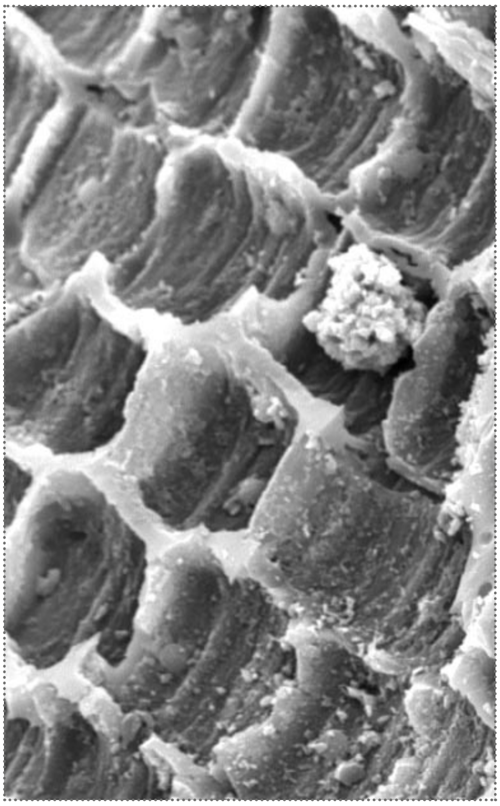
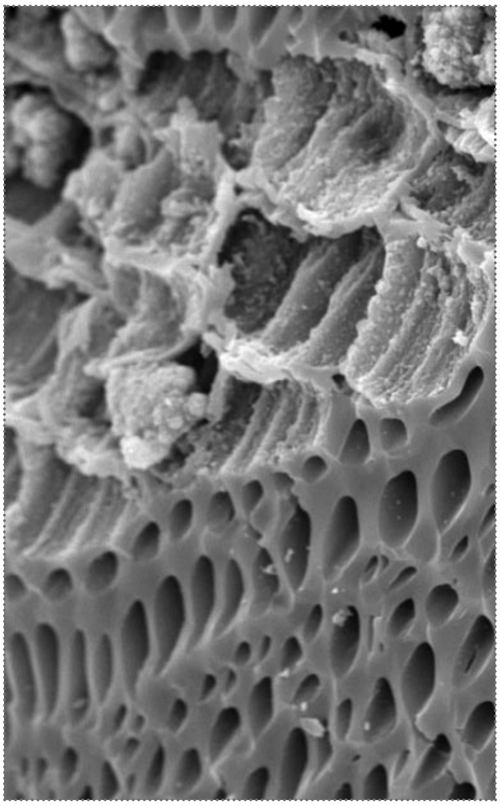




Foreword

Biochar is defined as ‘a solid material obtained from the thermochemical conversion of sustainably sourced biomass in an oxygen-limited environment using clean processes and which is used for any purpose that does not involve its rapid mineralisation to CO2’.

Examples of the existing and potential uses of biochar include application as a: soil amendment, constituent of fertilisers, soil remediation technology, water filter and animal feed supplement. Version 1.0 of the Biochar Quality Mandate (BQM) focuses only on the use of biochar as an addition to soil.

Biochar has the potential to be used widely across the UK - by itself or as a constituent of other products. Whatever the proximate use, the end-use of biochar is as a carbon storage technology on timescales (100’s of years) that are relevant to carbon abatement. The goal of the BQM is to remove impediments to the widespread use of biochar by categsorising and providing, where possible, methodologies for quantifying the risks associated with the production and use of biochar. The BQM provides the criteria by which a safe to use, good quality biochar product can be evaluated with reference to the UK context.

Biochar can be made from waste materials as well as from virgin biomass. Uncertainty as to whether producing biochar from a waste material can be classified as a waste recovery operation, and how to go about achieving end-of-waste status, are barriers to further biochar usage. Although ultimately this is a matter for the regulators, the BQM aims to provide guidance on such issues. Biochar (containing) products are at a very early stage of development and their regulatory and testing requirements are liable to change, even in the short term, hence it will be necessary for the BQM - and other regulatory guidance or standards which emerge to regulate biochar - to be updated as and when appropriate.

Image courtesy of Ondrej Masek, UKBRC.

What is the Biochar Quality Mandate?

Preparation of the Biochar Quality Mandate was supported by the Esmeé Fairbairn Foundation, with a contribution from the UK Engineering and Physical Sciences Research Council (EPSRC). Expert advice and inputs have been provided by the Environment Agency (England), Waste & Resources Action Programme (WRAP), Scottish Environmental Protection Agency (SEPA), Rothamsted Research, the James Hutton Institute, Newcastle University, the UK Biochar Research Centre at the University of Edinburgh and the British Biochar Foundation. The Biochar Quality Mandate (BQM) was initially based on the format of a Quality Protocol document, with the hope that it might be converted into a quality protocol. A quality protocol has two purposes: to assist in identifying the point at which a waste has been fully recovered, ceases to be a waste and becomes a product; and to give assurance that once recovered the product conforms to adequate standards and may therefore be used with confidence.[1] As of 2013, the Environment Agency is not intending to produce further Quality Protocols as a result of policy changes.

The Biochar Quality Mandate (BQM) aims to fulfil the two goals of a quality protocol as stated above. However, the BQM differs from a Quality Protocol in a number of ways: firstly, it applies to non-waste as well as waste biomass feedstocks; secondly, it does not carry the same authority to set out criteria by which regulators agree to assess products; and thirdly, it is not based upon a large body of case-law or regulatory experience with the product class in question. Even so, it is hoped that this document will be used by producers, end users and environmental regulators of biochar.

1. This wording is adapted from the Quality Protocols for Compost, Gypsum and Aggregates.

How has the Biochar Quality Mandate been prepared?

The BQM has been written by a core team of: Dr Simon Shackley, Rodrigo Ibarrola, Jim Hammond (all of University of Edinburgh at the time of writing) and Darren Hopkins (British Biochar Foundation - BBF). Additional input on Section 5 has been provided by Dr Tony Yates (BBF Board Member). The legal 'owner' of the BQM is the BBF Biochar Community Interest Company Ltd., which retains the copyright and reserves the right to withdraw or amend the BQM upon receipt of authoritative evidence and advice which indicates that it is appropriate to do so.

The first draft of the BQM was submitted to the Steering Group in February 2013 and discussed by the SG meeting in March 2013, following which a large number of changes were made and considered by the SG in June 2013. The membership of the BRAF SG is presented in Table 1.

The draft was published for public consultation on a range of websites and comments were invited from organisations or individuals. The core writing team responded to all comments received, either accepting the suggestion or providing an explanation where the proposed change was not accepted. The BQM was discussed at the meeting of the British Biochar Foundation in June 2013, during which comments, queries and questions were raised and noted by members of the writing team present. Additional comments have been received over the period June 2013 to June 2014.

Development of the BQM has been greatly assisted by the availability of two other documents which provide (in some ways) similar guidance on biochar standards and quality: the International Biochar Initiative's (IBI) *Guidelines for biochar that is used in soils*[2] and the European Biochar Certificate (EBC, Ithaka Institute, Switzerland)[3]. Both of these documents have been drawn upon in development of the BQM. In some cases, we have adopted the same thresholds as in other guidance. What makes the BQM distinctive from the IBI guidance and EBC, however, is that it focuses upon the specific regulatory requirements of UK developers, producers, users and authorities.

Disclaimer

Whilst every care has been taken in developing and checking the Biochar Quality Mandate (BQM), the British Biochar Foundation, the University of Edinburgh, and the individual authors and contributors do not accept any liability whatsoever for any loss or damage caused, arising directly or indirectly, in connection with reliance on its contents.

1. http://www.biochar-international.org/characterizationstandard
2. http://www.european-biochar.org/en

SG MEMBER	ORGANIZATION	EXPERTISE
Dr. Simon Shackley	UK Biochar Research Centre	Environmental management and biochar systems
Rodrigo Ibarrola	UK Biochar Research Centre	Waste management and biochar systems
Jim Hammond	UK Biochar Research Centre	Life cycle analysis and biochar systems
Darren Hopkins	British Biochar Foundation	Waste management and biochar policy
Professor David Manning (Chairman of SG)	Newcastle University	Soil science
Dr. Rupert Hough	James Hutton Institute (JHI)	Risk modelling and exposure assessment
Dr. Nicola Dunn	National Farmers Union (NFU)	Environment policy
Mathew Davis	Environment Agency (EA)	Soil protection
Mark Collinson	Waste and Resources Action Programme (WRAP)	Energy from waste
Fiona Donaldson	Scottish Environment Protection Agency (SEPA)	Waste
Professor Steve McGrath	Rothamsted Research	Sustainable soil function
Dr. Saran Sohi	UK Biochar Research Centre	Biochar and soil science
Duncan McLaren	McLaren Environmental: Research and Consulting	Environmental research and advocacy
Dr. Margaret Graham	University of Edinburgh	Environmental geochemistry
Dr. OndrejMasek	UK Biochar Research Centre (UKBRC)	Biochar production technologies

Table 1: Steering group members

1. Introduction

1.1 What is a Quality Mandate?

Note: definitions of terms that appear in *coloured italics* when they are first used in the BQM are given in Appendix A.

1.1.1 The Biochar Quality Mandate (BQM) provides a methodology for evaluating the environmental and occupational health and safety risks of biochar as a soil amendment. The BQM is owned and managed by the British Biochar Foundation (BBF), a Community Interest Company Limited by Guarantee. It was developed by the University of Edinburgh, the BBF and a panel of UK experts (listed in Table 1).

1.1.2 The BQM can be used by regulators and biochar project developers to help develop a robust, risk-based position on the regulation of biochar for soil application in the UK.

1.1.3 The BQM sets out the criteria for a substance to be termed 'quality biochar' either as a high or standard grade. Where a char does not meet the requirements of a quality biochar, it may still be suitable for an alternative application such as a fuel; however, the BQM does not specify the regulatory requirements of non-biochar products.

1.1.4 If the BQM criteria are met, the biochar may be sold with confidence for use in *designated market sectors*.

1.1.5 The BQM marque may be used where third party verification by a UKAS-registered certification body has been undertaken and a dossier deposited with the BBF.

1.1.6 At the time of writing, any biochar made from a waste material is considered waste, unless an application for end of waste has been approved by the responsible authority; and wastes may not be spread onto land unless they possess an exemption or permit (license) for this purpose.

1.1.7 Producers of biochar are not obliged to comply with the BQM. If they do not, the biochar produced cannot be sold as a BQM-compliant product.

1.1.8 The BQM does not affect the obligation of producers to hold an environmental exemption or permit if required under existing regulation and to comply with its conditions when receiving, storing and processing waste, nor does it affect the obligation to comply with all other relevant legal requirements to protect human health and prevent pollution of the environment (including soil, water and air and ecosystem functions).

1.1.9 We recognise that there may be codes of practice or standards which apply in the European Economic Area States other than the UK setting out requirements for the production and use of quality mandated biochar. Biochar protocols, standards and codes which already exist in the EEA may be applicable in the UK where:

1. a relevant standard or code of practice exists for a quality biochar of a national standards body or equivalent body of any EEA State; or
2. any relevant international standard for biochar is recognised for use in any EEA State; or
3. any relevant technical regulation exists with mandatory or *de facto* mandatory application for marketing or use in any EEA State;
4. provided that these give levels of protection of human health and the environment equivalent to those required by the BQM.

1.2 The Purpose of the Biochar Quality Mandate

1.2.1 The Biochar Quality Mandate has five main purposes:

- to provide a product definition of what is a safe and quality biochar to be used in designated market sectors in the UK;
- to provide guidance on the *end-of waste criteria* which apply to biochars made from *"waste" biomass feedstocks*;
- to provide confidence to producers that they can create and sell a product which is likely to meet UK regulatory guidelines;
- to provide users with confidence that the biochar they purchase conforms to an approved quality mandate;
- to protect human health and safety and prevent pollution of the environment.

1.2.2 The BQM has been written for two main audiences:

- Regulatory Authorities, who have to deal with permitting applications for biochar production and use;
- Producers and Users of biochar, who may have to apply to regulatory authorities for permission to produce or use biochar and can follow the guidance in this document in making a regulatory submission to the relevant authority. The BQM also describes good practice for the storage, handling, application and use of biochar (see Section 7).

2. Product Definitions

2.1 Definition of Biochar

2.1.1 Biochar is a solid material obtained from the thermochemical conversion of sustainably sourced biomass in an oxygen-limited environment, using clean production processes and which is used for any purpose that does not involve its rapid mineralisation to CO_2.

2.1.2 Version 1.0 of the BQM applies only to biochar that is used for the safe and long-term storage of carbon by permanent addition to land and soil.

2.1.3 A proponent of a Quality Biochar must demonstrate that the material has the following properties:

- Firstly, it must be safe for application to land and soil. By safe is meant that the biochar does not contain potentially dangerous levels of toxicants such as *potentially toxic elements* (PTEs) and *organic molecules* (such as dioxins / furans, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), benzene, ethyl-benzene, toluene, xylene (BETX), etc.).

- Secondly, the biochar has to contain at least 10% stable organic carbon by mass on a dry matter basis. By stable is meant that proportion of organic carbon which is estimated to remain in the soil after 100 years under UK conditions. (Guidance on methods for calculating long-term stability of carbon is provided in Appendix H).

- Thirdly, Life Cycle Assessment (LCA) (from 'seed to seed') has to return a favourable net carbon (equivalent) balance.

- Biochar must conserve a minimum of 30% of the organic carbon present in the feedstock in a stable form.

2.1.4 A differentiation is made in this mandate between two different biochar grades, **"high grade"** and **"standard grade".**

2.1.5 A biochar will be differentiated as "high grade" or "standard grade" according to the maximum permissible limits (MPLs) of toxicants present in a biochar. The MPLs, the tests to determine them, and other basic biochar properties that have to be measured for quality assurance are specified in Section 6.

2.1.6 Although a quality biochar may reasonably be expected to improve soil quality this will not be directly assessed by the Biochar Quality Mandate Version 1.0 as the precise mechanisms by which biochar affects soil properties are complex and remain a subject of research. Evidence for agricultural and ecological benefit will have to be presented to regulatory authorities when a biochar producer makes an end-of-waste application for waste-derived biochar; otherwise it will be left to the seller of a biochar to assure the buyer of the performance related benefits in soil. Advice on assessing biochar benefit to soils is provided in Appendix G.

2.1.7 Any material not complying with the quality criteria set out in this mandate will fail to be defined as BQM-biochar. Such material will not be appropriate for application to soils which are used for agricultural, horticultural or other food-related purposes (unless evidence can be provided to the contrary), but might be suitable to be used for other purposes (e.g. as fuel through the end-of-waste route for fuels).

2.2 Feedstocks

2.2.1 Only biomass feedstocks are considered for producing biochar.

2.2.2 The feedstock used to produce the biochar must be reported. Mixed feedstocks are acceptable and should be reported on a percentage dry mass basis.

2.2.3 Some feedstocks may contain materials other than the intended feedstock, such as plastics, stones, metals or glass. These *contaminants* in the feedstock must be less than 0.25% on a dry mass basis. A suggested method for determining the contamination level is provided in Annex E of PAS 100:2011.

2.2.4 Any *dilutants* or *mineral additions* that constitute 10% or more by dry weight of the feedstock material must be reported as a feedstock component.

2.2.5 Feedstocks may be divided into *waste and non-waste* categories. This has regulatory implications as *waste management controls* are applied to wastes.

2.2.6 Non-waste feedstocks produce biochars which are not considered to be wastes provided that the biochar is not intended to be discarded or otherwise disposed of. Specific controls do not exist in the UK for the use of non-waste biochar, but all relevant environmental legislation must be complied with (such as the Environmental Protection Act and the Water Framework Directive).

2.2.7 Waste feedstocks produce biochars which are classed as wastes, and are subject to waste management controls unless the biochar is 'recovered' by achieving an end of waste status. This is dealt with in greater detail in Section 4.

2.2.8 It is the responsibility of the producer to establish if the biomass feedstock(s) intended to be used in the biochar production process is a waste or a non-waste according to national guidelines.

2.2.9 Some waste materials are lower risk than others, and requirements for making an end of waste case will be more easily achieved. For example: untreated waste wood is less likely to contain toxicants than preservative- or paint-treated waste wood, and, all else being equal, it will be easier to achieve an end of waste status[4].

2.2.10 Imported feedstocks (wastes or non-wastes) may be used provided that full sustainability reporting requirements are met, as outlined in Section 3.

4. The distinction is similar to the distinction drawn by the Environment Agency's *Position Statement on The Environmental Regulation of Wood* between clean and treated waste wood. Treated waste wood is subject to stricter regulatory controls on its use and end-of-waste status.

3. Sustainability of Biomass Feedstocks

3.1 Sustainability Schemes

3.1.1 In addition to feedstock requirements which impact upon the material properties of the biochar itself, it is necessary to produce biochar in an environmentally sustainable way. The sustainability of feedstocks must therefore be considered under the BQM.

3.1.2 There are three sustainability schemes which the BQM has drawn upon:

- The EU Renewable Energy Directive[5] (RED) stipulates that for liquid biofuels, a 35% reduction in life cycle greenhouse gas emissions compared to the liquid fossil fuel that it substitutes for (petroleum, diesel, etc.) must be achieved for the biofuel to contribute to meeting the EU's RED targets. The UK government has applied the requirement to biofuel suppliers who wish to receive compensation payments for supply of biofuels under the Renewables Obligation (RO).

- The UK Government proposes to assure sustainability of solid biomass feedstock supply as set out in the consultation document "Biomass Electricity & Combined Heat & Power plants – ensuringility and affordability"[6].

- The UK Government already requires that all governmental sourcing of wood and wood products must be undertaken according to the standards set out by CPET[7], which aims to harmonise UK wood imports with the requirements under the EU Timber Regulation 2010[8]. The UK Government also proposed to use the CPET standard for assessing the sustainability of all biomass supplies, whether produced domestically or imported.

3.1.3 In August 2013, the European Commission proposed a new EU Directive which applies similar sustainability criteria to solid biomass as those in the RED Directive for bioenergy facilities over 1 MW electrical or thermal capacity. If this Directive is passed, it will introduce requirements similar to those proposed for the UK to all 28 Member States. When the Directive has been passed, the BQM will be revised to take account of its requirements.

5. Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, 2009.
6. Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/66519/6339-consultation-on-biomass-electricity--combined-hea.pdf
7. UK Government's Central point of expertise for timber procurement by the public sector', http://www.cpet.org.uk
8. Regulation (EU) No 995/2010 Of The European Parliament And Of The Council. Laying Down The Obligations Of Operators Who Place Timber And Timber Products On The Market, 2010.

3.2 Sustainable Biomass Provision BQM Requirements

3.2.1 The BQM Sustainable Biomass Provision Scheme consists of three parts:

- i Monitoring the source of the biomass (including chain of custody);
- ii Evidence that the biomass source was legally and sustainably managed;
- iii Greenhouse gas (GHG) life cycle assessment ('seed to seed') to ensure a minimum GHG saving is met compared to alternative use of the biomass.

3.2.2 Biochar producers will need to provide sufficient evidence that these conditions are met, using existing guidance and reporting schemes as necessary. Examples of potential schemes that can be evaluated for suitability are provided in Appendix C.

Following the CPET guidelines, two types of evidence to meet the requirements will be accepted[9]:

- recognised certification schemes (listed in Appendix C); or
- documentary evidence which is credible and will be judged on a case-by-case basis by the project developer and verified by the third party certifier.

3.2.3 It is permissible to mix evidence types, for example to provide certification evidence for the source and sustainability of the biomass but provide documentary evidence for the life cycle emissions minimum saving.

3.2.4 Biochar systems will be exempt from sustainability reporting and complying with the requirements in 3.2.1 if they consume below **4 oven dry tonnes (odt) per day of feedstock** or 1,350 odt per year. This exemption is based on recommendations in the EU Commission's proposed Directive on solid and gaseous biofuels and the UK Government's "Biomass Electricity & Combined Heat & Power plants – ensuring sustainability and affordability" consultation document. The draft Directive and consultation state that facilities below 1MW thermal or electrical capacity should be exempt from sustainability reporting. The equivalent feedstock consumption for biochar production has been calculated at 4 odt per day, as electrical or thermal capacity is not an appropriate way to measure the scale of biochar producing systems[10].

3.2.5 In line with the UK Government's consultation, waste feedstocks are exempt from the sustainability reporting requirements outlined in 3.2.1, except for the first requirement "Monitoring the source of the biomass", for which chain of custody documents will have to be provided. Any *imported* waste feedstock should, however, comply with all the requirements in 3.2.1.

9. CPET Provide useful guidelines on these: http://www.cpet.org.uk/uk-government-timber-procurement-policy/timber-guidance
10. For the details behind this calculation see the document "Biochar Risk Assessment Framework: mitigating the risk of unsustainable provision of biomass for biochar and bioenergy production", UKBRC 2012, available at http://www.biochar.ac.uk/

3.2.6 In the large majority of cases, feedstock sustainability issues are only relevant to the main product or by-products, not to the associated wastes since it is very unlikely that demand for a recovered waste (as opposed to the product or by-products) would ever drive feedstock extraction. There is, however, a small risk that unsustainable non-waste feedstocks be declared “wastes” to avoid sustainability requirements. Producers of biochar from waste should justify their exclusion from sustainability reporting by providing summary information on the waste feedstock, including the Waste to Product Ratio (WPR) in quantity, energy and economic terms.

3.2.7 The BBF will undertake a yearly check of a sample of waste feedstocks with respect to sustainability issues and if the risk referred to in 3.2.7. appears to be evident, this section of the BQM will be modified to include sustainability reporting of wastes.

3.3 Monitoring the source of biomass

3.3.1 In order to improve data on biomass use, RED recommends that Member States keep records of the origin of primary biomass used in electricity, heating and cooling installations of 1 MW or above, in order to improve statistics on biomass use and to monitor the effects of biomass use on the areas of origin. This can be done by applying the “traceability” concept to biomass sustainability schemes.

3.3.2 The term traceability describes the practice of tracing production, use or location of a certain material. For final products this can cover the origin of material and (parts of) the production history. Traceability covers not only the basic requirements that products can be traced back and forth throughout the supply chain from origin to the point of final delivery but also the possibility of specifying what their properties are, e.g. what they are made from and how they have been processed.

3.3.3 The BQM does not recommend one methodology or evaluation method over another to trace the biomass used, but rather leaves it to the producer to prepare a convincing case based upon its own understanding of the information requirements to secure sustainable feedstocks.

3.3.4 More information on how to trace back biomass feedstocks can be found in the recognised certification schemes listed in Appendix C.

3.4 Evidence that the biomass source was legally and sustainably managed

3.4.1 In the context of sustainable development, it is justifiable to use biomass sources if an environmentally and socially responsible production of the biomass is ensured. In order to achieve this, the BQM suggests that any sustainable biomass provision scheme should follow six principles which not only aim at the prevention of ecological damage but also maintain adequate working conditions and the protection of the health of workers.

3.4.2 Principle One: Biomass shall not be produced on land with high biodiversity value or high carbon stocks and not from soil containing high levels of peat where that cultivation threatens existing carbon stocks. This principle is in line with the requirements of Article 17.3 of the RED. Additionally, utilization of biomass obtained from areas with locally, nationally or internationally recognised environmental designations (see Section 7.1) should be avoided unless the biomass extraction is a part of a recognised environmental management plan.

3.4.3 Principle Two: Biomass shall be produced in an environmentally responsible way by following good agricultural or forestry practices that should ensure the protection of soil, water and air through mechanisms that measure and mitigate any potential negative environmental impact of biomass production activities.

3.4.4 Principle Three: Safe conditions shall be guaranteed for workers in accordance with the requirements of the Health and Safety at Work Act 1974 and other relevant legislation. This is likely to be achieved through training and education, adoption of standard operating procedures, and proper use of risk assessments that clearly identify and specify actions to reduce risk and responses to incidents that may arise.

3.4.5 Principle Four: Biomass production shall not violate human labour rights or land rights.

3.4.6 Principle Five: Biomass production shall take place in compliance with all applicable regional and national laws and shall follow relevant international treaties.

3.4.7 Principle Six: Good management practices shall be implemented by good record keeping and internal assessment, evidence of compliance with sustainability schemes with applicable regional or national laws and a good track record of site history and management.

3.5 Greenhouse Gas Life Cycle Assessment

3.5.1 Greenhouse Gas Life Cycle AssessmentLife cycle assessment (LCA) should assess the full life cycle of biochar systems, including production and transportation of the feedstocks, and follow appropriate guidelines such as the ISO 14040 series and PAS 2050.

3.5.2 *Direct land use change* (LUC) emission measurement is included in the LCA methodology of the EU Renewable Energy Directive[12]. However, at present, the *indirect land use change* emissions (ILUC) arising from biomass production are not included in the EU RED. The UK Committee on Climate Change strongly recommends that ILUC is included in the LCA methodology in future. The European Commission has released a proposal on how to include ILUC factors when considering liquid biofuels[13], but this proposal is still under scrutiny and has yet to be enacted. The BQM will be modified once agreement has been reached at the EU level on inclusion of appropriate ILUC factors.

3.5.3 The BQM strongly recommends consideration of both LUC and ILUC emissions when calculating GHG life cycle assessments for biochar systems. Since, as yet, there is no standard on ILUC factors, the biochar producer should make a case and provide appropriate justification where appropriate.

3.5.4 The minimum greenhouse gas savings for solid biomass for bioenergy (on a life cycle basis) have been recommended by the European Commission to be a 35% saving compared to the fossil fuel equivalent, rising to a 50% saving in 2017 and a 60% saving in 2018 for solid and gaseous biomass used in electricity and heat generation.

3.5.5 The recent UK Bioenergy Consultation “Biomass Electricity and Combined Heat & Power plants – ensuring sustainability and affordability” recommends that the maximum greenhouse gas emissions which new bioenergy facilities must achieve (on a life cycle basis) are 240 $kgCO_2eq/MWh$, decreasing to 200 $kgCO_2eq/MWh$ in 2020.

3.5.6 The BQM proposes that biochar systems must achieve a favourable greenhouse gas (GHG) balance over the life-cycle. Favourable in this context requires that the maximum net life-cycle GHG emissions per unit of feedstock consumed has to be **lower** than the respective life-cycle GHG emissions per unit feedstock were that biomass to be combusted instead in a modern bioenergy facility.

3.5.7 Since the primary energy value of different feedstocks differs, as does the carbon stability of biochar carbon and the efficiency of energy conversion technologies, the BQM cannot provide a single value of net GHG emissions per unit of feedstock that should not be exceeded. Hence, the biochar producer should develop an LCA to calculate the net GHG emissions of the biochar system and make the comparison against the bioenergy emission targets given in 3.5.5.

A suggested methodology for calculation of net GHG emissions for biochar systems and comparison against 3.5.5 is included in Appendix F, though there are many other LCA models and tools which could also be utilised.

12. The complete methodology can be found in Annex I of the “Sustainability requirements for the use of solid and gaseous biomass sources” report published by the European Commission in 2010; http://ec.europa.eu/energy/renewables/bioenergy/sustainability_criteria_en.htm
13. Proposal for a Directive of the European Parliament and of the Council amending directive 98/70/ec relating to the quality of petrol and diesel fuels and amending directive 2009/28/ec on the promotion of the use of energy from renewable sources, COM(2012) 595. Available from: http://ec.europa.eu/energy/renewables/biofuels/doc/biofuels/com_2012_0595_en.pdf

4. Waste controls and the BQM

4.1 Waste controls

4.1.1 The European Waste Framework Directive[14] defines a waste as "any substance or object which the holder discards or intends or is required to discard". Once a material is considered a waste it must go through a recovery operation recognised by the Waste Framework Directive to be considered a non-waste and waste management controls are then removed.

4.1.2 If biochar is made from a waste material it will be classed as a waste until an end of waste status is given.

4.1.3 A waste material cannot be applied to soil unless an exemption has been registered or a permit has been granted by the relevant UK environmental regulatory authority[15].

4.1.4 There are two scenarios for waste material to be converted and used as quality biochar and a third that would see it used in a non-soil application such as a fuel if it failed to qualify as a biochar. These are:

- Apply for an end-of-waste status for the material through an "end of waste – product to land" submission. If successful, the material will no longer be considered a waste, and will receive a "high" (or possibly "standard") grade biochar status, according to the quality properties specified in Section 6.

- If an "end of waste" submission fails, then the char would still be considered a waste and an exemption would need to be registered or a permit granted for the material to be applied as biochar to soils. It is possible that a char classed as a waste could be designated as "standard grade" biochar but only if it complies with the quality properties specified in Section 6.

14. Directive 2008/98/EC
15. Environment Agency in England and Wales; Scottish Environmental Protection Agency in Scotland; Northern Ireland Environment Agency in Northern Ireland.

4.1.5 Even if the char is deemed unfit to be used as biochar in agricultural and horticultural soils due to its contamination levels being above those specified for quality biochar (Section 6), it may still be possible to use it for some other purpose, e.g. as a fuel. Version 1.0 of the BQM does not provide any guidance on non-soil applications of char nor on use of biochar as land remediation technology (e.g. removal of heavy metals from contaminated soils). Note that an exemption has already been granted in Scotland in an Interim Position Statement by SEPA[16]. For certain waste types to be processed into biochar at small scale, and then applied to land for either agricultural or ecological benefit a simple exemption registration is required.

4.1.6 A similar exemption has been proposed in a draft Regulatory Position Statement by the Environment Agency for England but not yet approved. The non-waste biochar will be categorized according to this mandate as "high grade" or "standard grade" according to the properties specified in Section 6. It is more likely that non-waste biochar will be categorized as "high grade", although "end of waste – products to land" accredited biochars would qualify for this category as well (providing they meet the specified properties). It is also expected that some non-waste materials will not achieve "high grade" status and will end up in the "standard grade" category. End-of-Waste RequirementsThe "End of Waste – Products to Land" guidance outlines three points which must be met in order for a waste to be recovered and end of waste status achieved:

- the waste has been converted into a distinct and marketable product. Evidence of this could include: distinction between original waste and converted product and intended market(s) for the product;
- the waste-derived product can be used in exactly the same way as non-waste virgin material, e.g. the product serves the same purpose or has the same functions as non-waste virgin material and;
- the waste-derived product can be stored and used with 'no worse' environmental effect when compared to the raw material it is intended to replace. Evidence of this could include analytical comparisons to non-waste virgin materials on the market for delivering a particular function or purpose today[17].

4.1.7 The criteria for end of waste are interpreted and applied by the relevant environmental regulatory authority who will consider whether, in its view, a waste-derived product has achieved end of waste status within the meaning of the Waste Framework Directive (2008/98/EC) and relevant European, English, Scottish, Northern Irish and Welsh case law and experience on the definition of waste; in particular, the Court of Appeal OSS end of waste test and whether that product can then be applied to land.

4.1.8 Further details and instructions on how to begin an end of waste submission can be found at:

- http://www.environment-agency.gov.uk/business/sectors/138659.aspx
- http://www.sepa.org.uk/waste/waste_regulation/idoc.ashx?docid=08a49c7b-2e0d-478a-b1ff-94275aab6203&version=-1

4.1.9 Producers and users of biochar should note that, even if an end of waste submission is accepted and complied with, the material will become waste again and subject to waste management controls if, at any stage, it is discarded or there is a requirement or intention to discard it, for example if:

- it is disposed of; or
- it is stored indefinitely with little prospect of being used; or
- under the rules of a certification scheme, approved standard, or for any other reason, the material has to be reprocessed or disposed of as waste.

16. SEPA Position Statement, WST-PS-031, Manufacture and use of Biochar from Waste, 2012.
17. Points taken from: http://www.environment-agency.gov.uk/business/sectors/138659.aspx.

4.1.10 The material may also become waste again if, prior to use, it is stored for such a time or in such a manner that it is no longer suitable for the use it is destined for.

4.2 End-of-Waste Requirements

4.2.1 In addition, if a non-waste material is mixed with waste materials, the resulting mix will normally be considered to be a waste and subject to waste management controls. If non-waste material is mixed with non-waste materials, the resulting mix will not be considered a waste.

4.2.2 Figure 1 in Section 6 illustrates the point at which biochar ceases to be a waste and summarizes the concepts discussed in sections 4.1 and 4.2.

4.3 Compliance with the Industrial Emissions Directive

4.3.1 The Industrial Emissions Directive[18] (EID) applies to the incineration, pyrolysis and gasification of waste materials and primarily aims to limit pollution from such processes. Even if a waste-derived biochar achieves end of waste status, the conversion process from feedstock to biochar would still be covered by the EID, as the feedstock is classed as a waste. There are, however, a number of exceptions.

4.3.2 Facilities which process only certain low-risk wastes may be exempt from the requirements of the EID, most notably:

- Vegetable waste from agriculture and forestry;
- Wood waste with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coating, and which includes in particular such wood waste originating from construction and demolition waste.

4.3.3 Furthermore, pyrolysis and gasification are only included "in so far as the substances resulting from the treatment are subsequently incinerated".[19] This appears to mean that biochar (providing it is not intended to be incinerated) is not included in the requirements of the EID. Any syngas and vapours/liquids which are generated through pyrolysis and are incinerated would be included.

4.3.4 Residues from thermal treatment of wastes are included in the provisions of the EID. Residues in the context of the EID are defined as "any solid or liquid material … defined as waste[20] in Article 1(a) of Directive 75/442/EEC, which is generated by the incineration or co-incineration process". One requirement arising from the EID is that the residue arising should contain less than 3% organic carbon content, hence if a waste recovery operation were to be defined as a EID process, a biochar residue would not be possible since biochar is defined as a material containing at least 10% organic carbon.

4.3.5 In the context of biochar production, biochar is not incinerated or co-incinerated, and so cannot be considered a residue of incineration. Any solid or liquid ash from the incineration of syngas and vapours/liquids would be required to meet the conditions of the EID on residues.

4.3.6 Experimental plants used for research, development and testing in order to improve the incineration process and which treat less than 50 tonnes of waste per year are exempt from the requirements of the EID.

18. Points taken from http://www.environment-agency.gov.uk/business/sectors/138659.aspx
19. EID 2010/75/EU; Article 3.40
20. Article 1(a) of Directive 75/442/EEC defines waste as: "waste means any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force"

5. Production

5.1 Types of Biochar Producing Technology

The equipment used to create biochar can vary greatly in complexity; from a simple drum of biomass heated over a fire to an automatic-feed continuous flow unit recycling heat and possibly producing bio-electricity.

5.1.1 Units which condense out the liquid fraction from the pyrolytic vapours generated and treat the liquids separately from the non-condensible gases can be distinguished from those units which do not separate out condensable liquids from non-condensible gases.

5.1.2 Units which produce pyrolytic vapours from the unit (e.g. kilns and stoves) can be distinguished from those which re-cycle the pyrolytic vapours either back into the retort or into a furnace, fire-box or burner where they are burnt in air or other gases to release their energy content. Synthesis and produced gas must be combusted before being emitted to the atmosphere or captured and subsequently used or converted into by-products.

Image courtesy of Ondrej Masek, UKBRC.

5.1.3 Vapours must be either combusted or condensed into liquids and converted or otherwise used or disposed of according to appropriate regulation.

5.1.4 All flammable products in exhaust gas must be recovered or otherwise combusted before being emitted to the atmosphere. Particulate emissions must be within the regulatory requirements, as should emissions of carbon monoxide, volatile organic compounds, and particulates. There is no single regulatory requirement or guidance document on emission limits and developers are advised to consult the appropriate regulator for guidance.

5.1.5 Interim guidance has been established by the Commonwealth of Massachusetts in 2010[21] and the limits for particles is given in Table 2. The Clean Air Act of 1993 in the UK prohibits dark smoke being emitted from a chimney of a building or from a unit which serves the furnace

5.1.6 or any fixed boiler or industrial plant. An exception can be made if the smoke is "solely due to the lighting up of a furnace which was cold and that all practicable steps had been taken to prevent or minimise the emission of dark smoke".

No charcoal kiln control system shall emit visible emissions greater than ten percent (10%) opacity. No charcoal kiln control system shall emit more than the following emissions:

- 1.5 pounds (0.68 kg) per hour of particulate matter;
- Either 0.24 pounds (0.10 kg) per hour volatile organic compounds (VOCs) or the emission rate equivalent to ninety-nine percent (99%) VOC control efficiency, whichever results in a lower emission rate; and
- 1.75 pounds (0.8 kg) per hour of carbon monoxide (CO).

FACILITY SIZE	50 ≤ 500 KG FEEDSTOCK PER HOUR	≥ 501 KG FEEDSTOCK PER HOUR
Emission Limit (g particles per GJ in fuel content of biomass input) (normal conditions)	**85**	**43**
Emission Limit (g particles per GJ in fuel content of biomass input) (air critical conditions)	**43**	**43**
Smoke	No dark smoke shall be emitted where dark smoke is defined as being at shade 2 or greater on the Ringelmann chart (Clean Air Act 1993)	

Table 2: Requirements for Clean Biochar Production in Commonwealth of Massachusetts, USA

21. MASSDEP interim requirements for the installation and operation of biochar/charcoal production units, Commonwealth of Massachusetts, Executive Office of Energy & Environmental Affairs, Department of Environmental Protection, 30th November 2010.

5.1.7 The Renewable Heat Incentive[22] set the following standards for biomass boilers; 30 grams per gigajoule (g/GJ) net heat input for particulate matter (PM), and 150 g/GJ net heat input for oxides of nitrogen (NOx)

5.1.8 Further data is required to enable emission limits to be set for biochar production units. The BBF will seek to establish an emissions dataset across a range of production units to inform the proposed emission standards.

5.1.9 It will be the responsibility of the manufacturer of the production unit to prove compliance with emission standards by way of a compliance certificate issued by an accredited testing laboratory.

5.1.10 However, until such time as the emission standards have been published producers should use best endeavours to minimise emissions during production of biochar. As a minimum all production sites should comply with the requirements of the Clean Air Act.

5.2 Complying with Legislation

5.2.1 All relevant legislation and legal obligations relating to industrial operations must be complied with.[23]

5.2.2 Where the EID applies to pyrolysis systems, any combusted products and resultant emissions or residues must comply with requirements. The EID rule that the ash of combusted products must contain less than 3% organic carbon does not apply to high grade or standard grade biochar products, as:

- the biochar is not combusted; and
- the biochar is not a residue in this context.

5.2.3 If, however, the biochar is deemed to be unsuitable for addition to soil and enters an alternative end of waste route (such as for fuel products) the rule in 5.2.2 might apply, and it is the responsibility of the producer to define this with the regulators.

Images courtesy of Ondrej Masek, UKBRC.

22. The Renewable Heat Incentive is a government financial scheme to promote the use of renewable heat.
23. A useful summary of regulatory requirements can be found on the Biomass Energy Centre web page at: http://www.biomassenergycentre.org.uk/portal/page?_pageid=73,1&_dad=portal&_schema=PORTAL

5.2.4 Activities involving pyrolysis and carbonisation are covered by the existing provisions of the EID regulations, with the exception of charcoal making. Charcoal fines are one potential source of biochar and use of fines as a soil amendment could be preferable to existing disposal practices. Where fines are disposed of, they are a waste and it would be necessary to go through end-of-waste for their use as biochar.

5.2.5 The issues around the sustainability of charcoal making are complex because if charcoal is not produced in the UK, then it will likely be imported and there is unlikely to be control over its production conditions or the sustainability of the biomass used. Hence, without controls over charcoal imports, there is no guarantee that strengthening regulation of charcoal making in the UK will have the intended effect of environmental improvement (and could have the opposite effect). The preferred solution would be to establish production and sustainability criteria for charcoal that would be applied to all sources, domestic or imported. However this is beyond the scope of the BQM and will not be considered further here.

5.2.6 As for any industrial process, it is the responsibility of the producer to keep up-to-date with regards to any changes in legislation regarding production, processing and application of biochar.

5.2.7 The Clean Air Act (1993), enforced through local air pollution regulations must be adhered to.

5.3 Sampling methodologies for batches of biochar

5.3.1 A batch sampling programme should be developed by biochar producers based on their own production process and the periods of production. A producer-led approach is necessary due to potential differences in contaminant concentrations in current versus historical production.

5.3.2 A suggested methodology for testing batches of biochar is BS EN 12579 for compost, which establishes a sampling protocol that has been designed to give a representative sample of the batch(es) or portion of production from which it is obtained.

5.3.3 It is the responsibility of the producer to demonstrate that they have a consistent and reasonably uniform quality biochar product.

Image courtesy of Ondrej Masek, UKBRC.

6. Testing Requirements for Quality Biochar

6.1 Quality Properties of Biochar

6.1.1 The necessary testing required for a BQM grading is: elemental analysis (HCN), potential toxic elements ('heavy metals') content and potential organic pollutants *(polycyclic aromatic hydrocarbons (PAHs))*, (and, for biochar fed to livestock, benzene, ethyl-benzene, toluene and xylene – (BETX) (see Table 3). These necessary basic properties are important to differentiate a quality biochar from any other material.

6.1.2 For some biochar samples it may be necessary to test for polychlorinated biphenyls (PCBs), furans and dioxins (PCDFs and PCDDs). These compounds are associated with the presence of chlorine in the feedstock. Provided that the feedstock contains very low levels of chlorine (i.e. no higher than the concentration of chlorine found in plants growing in non-saline environments) the risk of *dioxin* formation at toxic levels is low. At present, however, we do not have sufficient understanding of the relationship between chlorine in the feedstock, pyrolysis production variables and conditions and formation of PCBs, furans and dioxins.

6.1.3 Therefore, where there is a non-trivial risk of the PCBs, PCDDs and PCDFs forming, the BQM proposes a precautionary approach and testing. If the feedstock is: a waste that has been contaminated by plastics or other chemicals containing chlorine; non-waste feedstocks grown in environments with potentially high concentrations of chlorine; food waste; waste treated with wood preservatives or coatings; and biomass grown in soil contaminated with high brine levels, then testing for PCDDs (dioxins), PCDFs (furans) and PCBs should be undertaken.

6.1.4 As understanding of the risks of these chemicals being produced during pyrolysis improves, the BQM will be updated with more specific advice and recommendations.

6.1.5 Both feedstock composition and the pyrolysis process have an influence upon the basic properties and toxicant concentration in the resultant quality biochar. It is important therefore to describe the feedstock and pyrolysis production conditions and, where necessary (e.g. where a novel feedstock is being used), to test this material in order to determine its characteristics (for many feedstocks, existing published or otherwise available data on characteristics and properties will be sufficient).

6.1.6 Additionally, for advanced understanding of biochar and its benefits for soil enhancement, quality biochar can be tested for the properties marked as "optional" in Table 3.

NECESSARY BASIC PROPERTIES	CRITERIA	UNIT	SUGGESTED METHOD(S)[24]
Heavy metal content	Declaration	See Table 4	See Table 4
PAHs	Declaration	See Table 4	See Table 4
BTEX (where biochar fed to animals)	Declaration	See Table 4	See Table 4
PCB's, Dioxins and Furans (if required)	Declaration	See Table 4	See Table 5
pH	Declaration	pH	Rajkovich et al. (2011)[25]; DIN 10390; BS EN 13037;
Moisture content	Declaration	% by dry mass	ASTM D1762-84; BS EN 13040
Organic Carbon (Corg)	≥10%, irrespective of the quality biochar grade	% of dry mass	ASTM D4373-02; BS EN 13039
Total Carbon (C)	Declaration	% of dry mass	BS EN 15104
Hydrogen (H)	Declaration	% of dry mass	BS EN 15104
Long-term carbon stability	Declaration (optional method)	% of dry mass	Accelerated ageing (oxidative) method
OPTIONAL PROPERTIES	**CRITERIA**	**UNIT**	**SUGGESTED METHOD(S)[24]**
H:Corg	0.7 (maximum) irrespective of the quality biochar grade	Molar ratio	Ratio of Corg and H
Total Nitrogen (N)	Declaration	% of dry mass	BS EN 15104
C:N	Declaration	Molar ratio	Ratio of C and N
Total Ash	Declaration	% of dry mass	BS EN 13039 ASTM D1762-84
Total Phosphorus (P)	Declaration	% of dry mass	Modified dry ashing followed by ICP (Enders and Lehmann 2012)[26] BS EN 13650
Total Potassium (K)	Declaration	% of dry mass	Modified dry ashing followed by ICP (Enders and Lehmann 2012) BS EN 13650

Table 3: Necessary and optional properties to test for in quality biochar. Continued on following page...

24. These are only suggested methodologies. Laboratories should be able to use any other available methodology as long as they are certified by accredited certification bodies.
25. Rajkovich, S., Enders, A., Hanley, K., Hyland, C., Zimmerman, A.R., and Lehmann, J. (2011).Corn growth and nitrogen nutrition after additions of biochars with varying properties to a temperate soil.BiolFertil Soils.DOI 10.1007/s00374-011-0624-7.Published Online.
26. Enders, A. and Lehmann, J. (2012) Comparison of wet digestion and dry ashing methods for total elemental analysis of biochar. Communications in Soil Science and Plant Analysis. 43:1042–1052.

OPTIONAL PROPERTIES	CRITERIA	UNIT	SUGGESTED METHOD(S)[24]
Water holding capacity	Declaration	ml per gramme	Funnel and filter paper method; Hilgard cup method (simple); DIN 51718; TGA 701 D4C
Bulk density	Declaration	kg or tonnes per m^3	Mass and volume determination.
Particle size distribution	Declaration	mm or μm	ASTM D2862-10
Neutralising Capacity	Optional	% $CaCO_3$	Rayment & Higginson (1992)[28]
Electrical Conductivity	Optional	dS/m	Rajkovich et al. (2011) BS EN 13038
Cation Exchange Capacity (K, Ca, Mg, Na)	Optional	cmol+/kg	Ammonium-acetate (or $BaCl_2$ extraction) then ICP-OES
Porosity	Optional	Ratio of pore volume / bulk Volume	e.g. mercury intrusion porosimetry
Specific surface area / total surface area	Optional	m^2/g	Adsorption method (e.g. BET); ASTM D 6556-10; ISO 9277
Labile carbon content / volatile matter	Optional	% of dry mass	Incubationstudies; ASTM D1762-84
Long-term stable carbon	Optional	% of dry mass	Accelerated ageing (oxidative) method
Available P	Optional	mg/kg	2% formic acid followed by spectrophotometry as described by Wang et al (2012)[29]
Mineral N	Optional	% of dry mass or mg/kg	KCl or $CaCl_2$ extraction followed by spectrophotometry (Rayment and Higginson 1992)
Release dynamics of nutrients (P, K, N)	Optional	% of dry mass or mg/kg	Soil column leaching experiments
Impact on soil aggregation	Optional	Size declaration	To be confirmed
Soil water potential (available water content)	Optional	g/g or g/cm3	Tension table and pressure plate
Priming potential (impacts on SOC)	Optional	% / %	Incubation studies
Thermal analysis	Optional	uV / mg	Thermogravimetry-differential scanning calorimetry (TG-DSC)

Table 3: Necessary and optional properties to test for in quality biochar. Continued from previous page.

28. Rayment, G.E. and Higginson, F.R. (1992).Australian Laboratory Handbook of Soil and Water Chemical Methods. Reed International Books, Australia/ Inkata Press, Port Melbourne.
29. Wang, T., Camps Arbestain, M., Hedley, M., and Bishop, P. (2012). Predicting phosphorus bioavailability from high-ash biochars. Plant and Soil.DOI 10.1007/s11104-012-1131-9.Published Online.

6.2 Permissible limits of toxicants

6.2.1 All quality biochar must be tested for all the *toxicants* listed in Table 5 and, if required, the chemicals listed in Table 6.

6.2.2 The tested biochar will be certified as **"high grade" or "standard grade"** depending on its quality characteristics.

6.2.3 The quality grade will be determined according to the concentration of toxicants in the biochar tested, which will be compared against the maximum permissible limits listed in Table 5 and Table 6 (if required).

6.2.4 A "high grade" certification will most likely be assigned to materials produced from virgin non-waste biomass feedstocks, and a few materials accredited with end of waste status. Any quality biochar certified with this status will not be subject to application controls (see Section 7).

6.2.5 A "standard grade" certification will most likely be assigned to materials with a waste status. Any non-waste material failing to comply with the quality characteristics for "high grade" biochar will be certified as "standard grade biochar". Any quality biochar certified with this status will be subject to application controls (see Section 7).

6.2.6 If a "high grade" biochar is mixed with a "standard grade" biochar, it will automatically lose its "high grade" certification.

6.2.7 Suggested testing methodologies are also provided in Tables 5 and 6.

Images courtesy of Ondrej Masek, UKBRC.

Toxicant	Suggested test Method[30]	Maximum limit suggested for high grade quality biochar[31]	Maximum limit suggested for standard grade quality biochar[32]	Unit	Frequency of testing
Arsenic	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	10	100	mg/kg	According to batch sampling programme (see 5.3)
Cadmium	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	3	39	mg/kg	
Chromium	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	15	100	mg/kg	
Copper	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	40	1,500	mg/kg	
Lead	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	60	500	mg/kg	
Mercury	DIN EN1483 (E12); BS ISO 16772	1	17	mg/kg	
Manganese	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	3,500	Limit set by regulators?	mg/kg	
Molybdenum	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	10	75	mg/kg	
Nickel	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	10	600	mg/kg	
Selenium	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	5	100	mg/kg	
Zinc	DIN EN ISO17294-2 (E29); BS EN 13650 (soluble in aqua regia)	150	2,800	mg/kg	
PAHs (sum of USEPA 16)	DIN EN 15527 2008-09; DIN ISO 13877: 1995-06 – Principle B with GC-MS (toluene extraction with ASE); BS EN 15527:2008	Less than 20	Less than 20	mg/kg TM	
BETX	To be confirmed	To be confirmed	To be confirmed	To be confirmed	

Table 4: Limits for quality biochar and appropriate methods for measurement.

30. Taken from "Standardized Product Definition and Product Testing Guidelines for BiocharThat Is Used in Soil. International Biochar Initiative, 2013.
31. Ibid
32. International Toxicity Equivalent

6.2.8 Quality biochar must be tested for the toxicants listed in Table 5 only if there is a risk that the biomass feedstock used for its production might contain excessive concentrations of chlorine due to its nature, storage or pre-treatment (see 6.1.2).

6.2.9 Any quality biochar tested for these toxicants must comply with the maximum permissible limits listed in Table 5.

6.2.10 All tests must be carried out by an accredited laboratory.

6.2.11 Any material failing to comply with the quality criteria listed in this section will not be certified as BQM quality biochar and their application to soils for agricultural, horticultural or food-related purposes is not advised.

Toxicant	Suggested test Method	Maximum limit suggested for high grade quality biochar	Maximum limit suggested for standard grade quality biochar	Unit	Frequency of test
Dioxins/Furans	AIR DF 100,HRMS; BS EN 1948 series	**Less than 20[1]**		ng/kg	According to batch sampling programme (see 5.4)
PCBs	AIR DF 100,HRMS; BS EN 1948 series	**Less than 0.5[2]**		mg/kg I-TEQ[3]	

Table 5: Safe limits for quality biochar and appropriate methods for measurement

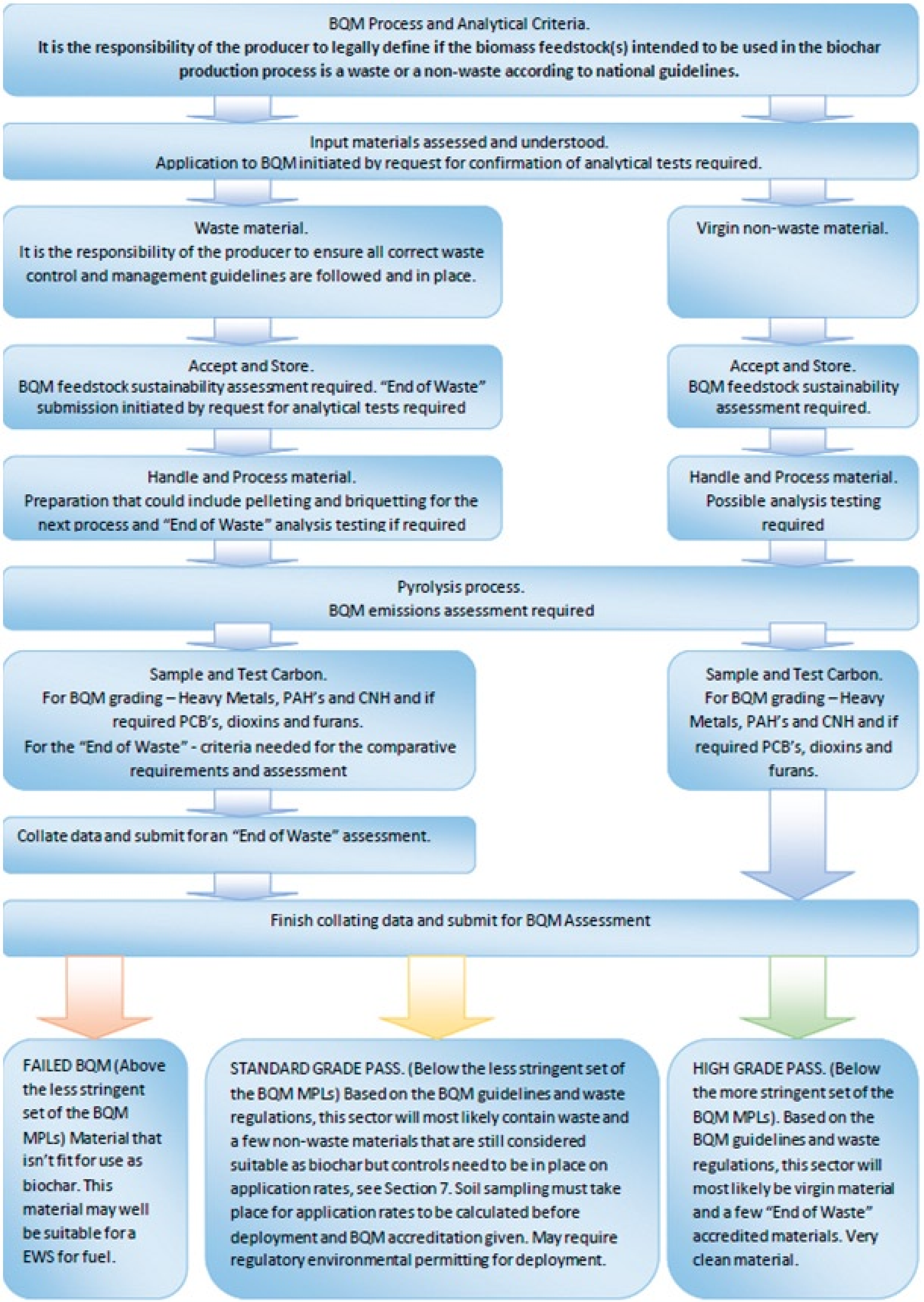


Figure 1: Certification process for standard and high grade biochar

7. Use of the Biochar

7.1 Application of quality biochar in soils

7.1.1 Quality biochar must be used safely and responsibly so as not to harm humans, ecosystems or cause pollution.

7.1.2 If quality biochar is categorised as high grade, it is unlikely to cause harm to humans or ecosystems due to its very low levels of potential toxicants. Although there will be no need for application controls in soils for this grade of biochar, users will still have to follow agricultural and handling best practices (see Section 7.2).

7.1.3 For quality biochar categorised as standard grade, application controls and good agricultural and handling practices will have to be followed.

7.1.4 Application controls for "standard grade" biochar should take account of the background soil properties where the application will take place, including potential toxicants and organic carbon content, in order to comply with relevant soil regulations and to avoid disrupting soils. Therefore, before any "standard grade" biochar application takes place, the soil should be tested for the background properties of toxicant concentrations listed in Table 7 of Appendix E.

7.1.5 Application controls for "standard grade" biochar should include an estimate of the potential toxicant limiting application rate (PTLAR) in the agricultural or ecological context where it is intended to be used. The PTLAR is the rate at which standard grade biochar can be applied without exceeding MPLs of potential toxicants in soil.

7.1.6 Suggested MPLs of potential toxicants in soil are listed in Table 7 of Appendix E. These MPLs are identical to the maximum permissible concentration of PTEs in soil provided by the Code of Practice for Agricultural use of Sewage Sludge.[33] Any elements or compounds not included in the code of practice were derived from the soil guideline values provided by the Environment Agency.

7.1.7 A suggested methodology to calculate PTLARs is provided in Appendix E.

7.1.8 In order to avoid an application of "standard grade" biochar reaching the PTLAR in one time-step, two methods are proposed for providing guidance on year-by-year application rates. In Method One in any one year the maximum amount of standard grade biochar that can be applied is 20% of the total PTLAR.

7.1.9 In Method Two, the application rate limits approach suggested by the code of Practice for Sewage Sludge is proposed. Using this approach, "Standard grade" biochar application should not exceed the maximum permissible average annual rate of contaminant addition over a 10 year period required by the Code of Practice for Agriculture Use of Sewage Sludge[33]. The annual rate of application of contaminants to any site shall be determined by averaging over the 10 year period ending with the year of calculation (year 10 of application, see Appendix E).

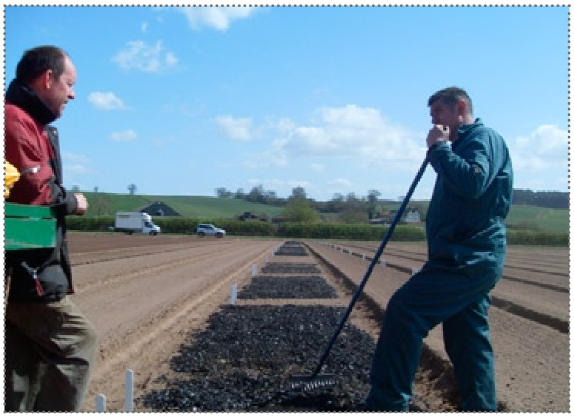
33. http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf

7.1.10 There may be situations where the limits on application rates are not applicable, for example, if biochar is used in land remediation for contaminated sites. These special cases should be discussed in consultation with environmental regulators.

7.1.11 Since no benefits are expected from the addition of quality biochar to carbon rich soils due to the offset of any carbon storage benefit by the loss of soil organic carbon when soils are disrupted by the application process, the BQM does not mandate the use of biochar (irrespective of its quality grade) in soils with **over 10% of soil organic matter.**

7.1.11 Additionally, any ecological reasons that might constrain or bring into question the application of quality biochar in areas classified as semi-natural or environmental designations will have to be considered.

Image courtesy of Simon Shackley, UKBRC.



Images courtesy of Jason Cook, UKBRC.

7.1.12 Special care is needed to avoid damaging soil ecology, biodiversity and the environment in general, but in particular in semi-natural-areas or environmental designations. Examples of environmental designations are the following:

- Special Areas of Conservation (SACs), which are sites that have been adopted by the European Commission and formally designated by the government of each country in whose territory the site lies;
- Sites of Community Importance (SCIs), which are areas that have been adopted by the European Commission but not yet formally designated by the government of each country;
- Candidate SACs, which are sites that have been submitted to the European Commission, but not yet formally adopted;
- Special Protection Areas (SPAs), which are strictly protected sites classified in accordance with Article 4 of the EC Birds Directive;
- National Parks;
- Areas of Outstanding Natural Beauty (AONB);
- Local and National Nature Reserves (LNRs, NNRs);
- Sites of Special Scientific Interest (SSSIs)[34].

7.1.13 If application of quality biochar is intended on land covered by any of these environmental designations, contact should be made with appropriate nature conservation agencies in order to discuss the issues and understand any possible restriction.

7.1.14 Most biochars contain some nitrogen. This nitrogen may count towards the total amount which is allowed to be applied in a *Nitrate Vulnerable Zone (NVZ).* The amount of nitrogen measured in the quality biochar and the amount of quality biochar applied should be used to calculate the total nitrogen addition if the intention of applying biochar in NVZs exists. Total nitrogen is the relevant number to use unless the proponent has strong evidence that available nitrogen is the more applicable value.

34. More information on semi-natural areas can be found in: http://www.naturalengland.gov.uk/ourwork/farming/funding/ecs/sitings/final_designations.aspx

7.2 Good practice for biochar application

7.2.1 Dust from biochar handling can pose a risk to health if it becomes airborne and is inhaled. Biochar should be kept at a moisture content of at least 20% by mass to reduce the risk of dust and appropriate protection should be worn by those handling dusty biochar.

7.2.2 Care should also be taken not to apply light or dusty biochar in windy conditions (for example at wind speeds greater than 10km/h) as biochar may be blown away from the intended site and find its way into operators' eyes. Moistening biochar before field application is recommended to reduce the risk of wind disturbance.

7.2.3 Biochar is often odourless, but sometimes smells 'smoky' (if it has a powerful smoky odour it is likely that it will exceed standard grade biochar MPLs for PAHs). Care should be taken that biochar applications do not cause unpleasant smells which annoy farm neighbours or member of the public.

7.2.4 Good practice rules for storage, handling and application of organic fertilisers should be followed[35].

Images courtesy of Jim Hammond, UKBRC.

35. E.g. http://www.agindustries.org.uk/document.aspx?fn=load&media_id=2024&publicationId=248

8. Quality Assurance and Certification

8.1 Certification

Note: We would like biochar producers to be able to certify biochars as meeting the BQM standard. This section lays out the main requirements of certification.

8.1.1 In order to become a BQM-certified quality biochar producer, compliance must be demonstrated from an approved certification body[36] operating according to UKAS scheme.

8.1.2 As part of the certification process, the producer will be required to:

- Keep and retain specified records for a minimum of four years; and
- Make them available to the certification body for certification purposes.

Details of the records to be kept are given in section 8.2.

8.1.3

8.2 Records management

8.2.1 To be able to demonstrate compliance with the BQM, producers must maintain copies of supply documentation provided to the customer for each supply of biochar.

8.2.2 The documentation must include:

- date of supply;
- customer's name, contact details and nature of business;
- the name and contact details of the producer, including the address of the site of production;
- quantity supplied by weight/volume;
- the designated application the material is destined for;
- a statement that the processed quality biochar was produced in compliance with the BQM.
- a statement of the approved industry standard(s) it meets (e.g. BQM);
- a statement that it has been certified by an appropriate certification scheme; and
- confirmation that information on good practice relating to the storage, handling, application and use of quality biochar (as set out in Section 7) has been highlighted to the customer.

36. The Compost Quality Protocol states that: "The approved certification body must also obtain *accreditation* on an annual basis from the United Kingdom Accreditation Service (UKAS) to BS EN 45011: 1998 General requirements for bodies operating certification systems (or any subsequent amendments)"

8.2.3 Records must also be kept of incoming waste and non-waste feedstocks used for the production of BQM-certified biochar. As a minimum, a record of each load delivered to site must be kept giving:

- date;
- European Waste Catalogue (EWC) code and description (where relevant);
- place of origin (where known);
- quantity of weight/volume;
- carrier;
- supplier; and
- whether the load was accepted.

8.2.4 Records of all testing carried out to demonstrate compliance with the approved standard must be made and retained.

8.2.5 For the purposes of the BQM the producer must make records available for inspection by the regulator, farm auditor or certification body (if requested).

8.2.6 These requirements are additional to any statutory record-keeping obligations. However, some records may be used to fulfil both a regulatory obligation and evidence of compliance with the BQM.

8.2.7 The biochar quality properties should be labelled and communicated to the customer.

Appendix A: Definitions and Acronyms

Accreditation: Third-party verification related to a conformity assessment body conveying formal demonstration of its competence to carry out specific conformity assessment tasks[37].

Ash: The inorganic matter, or mineral residue of total solids, that remains when a sample is combusted in the presence of excess air.

Biochar: the porous carbonaceous solid produced by the thermochemical conversion of organic materials in an oxygen depleted atmosphere which has physiochemical properties suitable for the safe and long-term storage of carbon in the environment and for soil improvement.

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 th e biodegradable fraction of industrial and municipal waste (including municipal solid waste). In this context, material of biological origin is defined as follows: Material derived from, or produced by, living or recently living organisms[38].

Certification: Third-party attestation related to products, processes, systems or persons. Note: In the context of this BQM, the scope of assessment by the independent certification body must cover biochar product, the pyrolysis process, the producing organisation's *quality management system* and training of those persons who affect biochar quality. Certification provides verification that the product meets the approved standard and the requirements of the BQM.

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. Contaminants include fossil fuels and fossil-fuel-derived chemical compounds, glass, and metal objects[39].

Designated market sector(s): The sector(s) listed in Appendix B in which this BQM enables quality biochar to be used.

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. Dilutants may be found in a diverse range of feedstocks, such as agricultural residues, manures, and municipal solid wastes[40].

Direct land use change emissions: Direct land use change is the conversion of land, which was not used for e.g. crop production before, into land used for a particular feedstock production, e.g. for biofuel or biochar production. The emissions caused by the land conversion process can be directly linked to the biofuel load and thus be allocated to the specific carbon balance of that biofuel.

37. ISO/IEC 17000
38. RED (2009/28/EC)
39. IBI, 2013.
40. Ibid

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.

End of Waste: Is a legal status by which waste management controls are removed from a material. Environmental regulators can consider a product to have achieved 'end-of-waste' status.

Heavy metals: rrefers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations.

Hydrogen to organic carbon (H/Corg) ratio: The molar H/C ration is an indicator of the degree of carbonisation and therefore of the biochar's stability. The ratio is one of the most important characterising features of biochar. Values fluctuate depending on the biomass and process used. Values exceeding 0.7 are an indication of incomplete carbonisation (European Biochar Certificate, 2013).

Horticulture: The growing of fruits, vegetables, herbs, flowers or ornamental plants in gardens, orchards, nurseries on in growing beds.

Indirect land use change emissions: refers to the potential greenhouse gas emissions which may be caused by cultivating biomass (for bioenergy, biofuels, or biomaterials) on land which previously was used for other purposes, e.g. feed, food or fibre production, protected for its biodiversity or recreational value, etc. (If the land use is changed for a reason other than biomass cultivation for bioenergy then it is not ILUC).[41].

List of Wastes (LoW): The List of Wastes contains the 'waste codes', that is, the six-digit EWC codes for different types of waste in accordance with the List of Wastes (England) Regulations 2005 or List of Wastes (Wales) Regulations 2005 (as appropriate). For hazardous waste, the code includes an asterisk.

Mineral Additions: Mineral substances (for example, calcium compounds, clays or metal oxides) might be added to pyrolysis for the purposes of enhancing the resultant char.

Nitrate Vulnerable Zone (NVZ): is a conservation designation of the Environment Agency for areas of land that drain into nitrate polluted waters, or waters which could become polluted by nitrates. Nitrate Vulnerable Zones were introduced by the UK government in response to: the EU mandate that all EU countries must reduce the nitrate in Drinking Water to a maximum of 50 mg/l; and the negative impacts of excess nitrate upon aquatic ecosystems through eutrophication.

Polycyclic aromatic hydrocarbons (PAHs): PAHs refer to a family of compounds built from two or more fused-together benzene rings. Sources of PAHs include incomplete combustion of fossil fuels and organic matter, e.g. from auto engines, incinerators, forest fires, charcoal production and use, or other biomass burning.. Out of hundreds of different PAH compounds, only a small number are considered to be highly toxic and of regulatory concern. The US Environmental Protection Agency (EPA) has identified sixteen priority PAHs that are a cause of concern due to their potential toxicity.

41. Global Bioenergy Partnership, 2009

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 coatings 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 Persistent Organic Pollutants.

Potentially Toxic Element (PTE): Chemical element that has potential to have toxic effects on humans, flora or fauna, or can do so in combination with other chemical elements. Heavy metals are included in this category.

Quality management system (QMS): A system that demonstrates effective control of all operations and the associated quality management activities necessary to guarantee that biochar is fit for its intended purposes. Where specific controls are applied, they must be monitored and recorded, and their efficacy evaluated both during and after process validation. Corrective actions in the event of control failure must be defined.

Quality Protocol: A Quality Protocol sets out criteria for the production of a product from a specific waste type. Compliance with these criteria is considered sufficient to ensure that the recovered product can be regarded as having ceased to be waste and therefore no longer subject to waste management controls. In addition, the Quality Protocol indicates how compliance may be demonstrated and points to good practice for the use of the recovered product[42].

Source-segregated: Materials or biodegradable wastes of the types and sources sought that are stored, collected and not subsequently combined with any other non-biodegradable wastes, or any potentially polluting or toxic materials or products, during treatment or storage.

Toxicants: Chemical or physical agents that, depending on dose, can produce adverse effects in biological organisms. 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.

Waste: Any substance or object which the holder disposes of or is required to dispose. Once a material has become a waste this has implications for its use and waste management controls will apply. It must be exempted from waste management controls or designated as a non-waste in order for waste management controls to be released.

Waste management controls: Controls under legislation and regulations that govern the treatment, handling, containment, transportation and storage of waste.

42. Environment Agency, 2013

Appendix B: Designated Market Sectors

This Quality Mandate only applies to biochar that is destined for use in one of the following designated market sectors:

- land restoration and soft landscape operations;
- domestic or professional horticulture;
- agriculture and soil-grown *horticulture*; or
- forestry.

If good practice is followed, the BQM considers that quality biochar will not pose a risk to human health or the environment in the quantities and frequencies at which it is likely to be applied in these sectors. Good practice means the measures set out in Section 7.

Land restoration and soft landscape operations

Examples of the ways in which quality biochar may be used in these sectors are:

- soil manufacture and/or blending operations (including manufacture of turf dressings and root zone media);
- land reclamation and land remediation; and
- soft landscape operations (including soil improvement, turf maintenance, turf establishment and as a mulch).

Horticulture

Examples of the way in which quality biochar may be used in this sector are:

- as a direct soil improver/soil conditioner for domestic use; and
- blending with other non-waste materials to produce a horticultural grade growing medium for domestic use and professional applications.

Agriculture and soil-grown horticulture

Quality biochar can be used in agriculture and soil-grown horticulture as a soil improver, amendment or mulch (or, with other inorganic and/or organic constituents, a fertiliser) provided it is used in such a way that:

- it does not pose a risk to the environment; and
- its use does not compromise the future sustainable use of the soil to which it is applied.

The biochar user must be able to demonstrate that they have taken full account of any environmental impact resulting from its use.

Forestry

Examples of the ways in which quality biochar may be used in this sector are:

- improvement of in-situ soil in the planting area prior to tree planting,
- blending with in-situ soil for use as backfill for planting pits during preparation for tree planting, or
- applying coarse particle biochar as a surface mulch to suppress weeds during tree establishment.

Appendix C: Approaches to Sustainable Biomass Provision Certification

The different evaluation schemes and procedures listed below provide useful guidance for developers in considering sustainable biomass feedstock supplies. There are many overlaps between the schemes and one scheme is not recommended over another. Rather it is the responsibility of the applicant to prepare a convincing case based upon their own understanding of the information requirements to secure sustainable feedstocks. Suggestions for further appropriate certification schemes will be considered.

ISCC: global certification system scheme that covers all kinds of biomass and is recognised by the European Commission for all member countries without restriction. It operates in compliance with the European Renewable Energy Directive (EU RED) and offers an all-inclusive service for companies, easing national and international trade. More information on this certifications scheme can be found at:

http://www.iscc-system.org/en/

Roundtable on Sustainable Biofuels (RSB): is an international initiative coordinated by the Energy Centre at EPFL in Lausanne that brings together farmers, companies, non-governmental organizations, experts, governments, and inter-governmental agencies concerned with ensuring the sustainability of biofuels production and processing. Participation in the RSB is open to any organization working in a field relevant to biofuels sustainability. The RSB has developed a third-party certification system for biofuels sustainability standards, encompassing environmental, social and economic principles and criteria through an open, transparent, and multi-stakeholder process. More information on this certifications scheme can be found at:

http://rsb.epfl.ch/

Global Partnership for Bioenergy (GBEP): provide mechanisms for partners to organize, coordinate and implement targeted international research, development, demonstration and commercial activities related to production, delivery, conversion and use of biomass for energy, with a focus on developing countries. More information on this certification scheme can be found at:

http://www.globalbioenergy.org/

The UK Government **CPET guidelines** accept two certification bodies for wood and wood products:

- The Forest Stewardship Council (FSC)

  http://www.fsc-uk.info/

- The Programme for the Endorsement of Forest Certification (PEFC)

  http://www.pefc.org/

Alternatively, CPET accepts timber that is compliant with Forest Law Enforcement, Governance and Trade (FLEGT) regulation.

http://www.cpet.org.uk/flegt-regulation

Appendix D: Good practice for the storage, handling, application and use of quality biochar

Storage

Biochar should be stored in appropriate and safe conditions where risks to cause pollution or to health and safety are minimised. Good practice guidelines for the storage of soil amendments should be followed[43]. If the material is still considered a waste then the correct storage procedures will need to be followed in accordance with the correct regulations. On farms, guidelines should be followed where applicable. An example is GBR18, which although only applicable in Scotland may be considered a good practice guideline. A summary is presented in Table 6.

Fire risks

Biochar presents a potential fire risk. Care should be taken not to expose stored biochar to external sources of heat sufficient to cause ignition, and appropriate safety measures should be installed in biochar storage areas.

Biochar is capable of self-ignition. If it is stored in large volumes and/or is very dry, it may self-heat and eventually self-ignite. Therefore biochar must be:

- Stored at a moisture content of at least 20% throughout the container.
- Stored in separate containers, vessels or piles.

Dust Risks

To minimise dust, moisture content of 20% or more is recommended during handling of loose biochar.

Where exposure to dust cannot be avoided appropriate personal protective equipment should be used, such as face masks or eye protection. Extractor units may be installed to aid in dust removal.

Minimum storage distance from any surface water or wetland	10m
Minimum storage distance from a spring or uncapped borehole supplying water for human consumption	50m
Minimum application distance from a drainage ditch	2m (10m)
Minimum application distance from any surface water or wetland	5m (10m)
Minimum application distance from a spring supplying water for human consumption or an uncapped well or borehole	50m
Application on steeply sloping land	Not more than 15°

Table 6: GBR 18: Minimum distances for organic fertiliser storage and application of organic fertilisers from water courses. Good practice recommendations are shown in brackets.

43. E.g. http://www.agindustries.org.uk/document.aspx?fn=load&media_id=2024&publicationId=248

Appendix E: Suggested methodology to calculate Potential Toxicant Limiting Application Rate (PTLAR)

Step 1:

The process for calculating PTLAR is relatively straightforward, and is derived for each contaminant from the following equation:

$$\text{PTLAR} = \text{Sm} * \frac{(\text{MPLTS} - \text{BSC})}{\text{BCC}}$$

Where:

Sm is the mass of soil per hectare to the depth of biochar incorporation (tonnes/ha;)

MPLTS is the maximum permissible limits of potential toxicants in the receiving soil (mg/kg). Table 6 includes suggested MPLTS;

BSC is the background soil concentration for a given potential toxicant (mg/kg) at the application site;

BCC is the concentration of a given potential toxicant in the biochar (mg/kg).

The maximum application rate of biochar will then be set by the lowest (most stringent) PTLAR calculated for each potential toxicant.

Toxicant	MPLTS (mg/kg)
Arsenic	50 (derived fromsludgeCode of Practice)[44]
Cadmium	3 (derived from sludge Code of Practice)
Chromium	400(derived from sludge Code of Practice)
Copper	80 (derived from sludge Code of Practice for pH 5)[45]
Lead	300 (derived from sludge Code of Practice)
Mercury	1(derived from sludge Code of Practice)
Manganese	To be confirmed
Molybdenum	4(derived from sludge Code of Practice)[46]
Nickel	50 (derived from sludge Code of Practice for pH 5)[47]
Selenium	3(derived from sludge Code of Practice)
Zinc	200 (derived from sludge Code of Practice for pH 5)[48]
PAHs	To be confirmed
Dioxins, furans, PCBs	0.008 (total value for the sum of dioxins, furans and PCBs) (derived from soil guideline values of Environment Agency)[49]

Table 7: Maximum permissible limits of potential toxicants in soils

44. Derived from sludge Code of Practice, available at: http://archive.defra.gov.uk/environment/quality/water/waterquality/sewage/documents/sludge-cop.pdf
45. This MPLTS may increase if the pH of soils is higher. For more info see the link provided in previous reference.
46. The accepted safe level of molybdenum in agricultural soils is 4mg/kg. However there are some areas in UK where, for geological reasons, the natural concentration of this element in the soil may exceed this level. In such cases there may be no additional problems as a result of applying biochar, but this should not be done except in accordance with expert advice.
47. Ibid
48. Ibid
49. http://www.environment-agency.gov.uk/research/planning/64015.aspx

	MPLTS (mg/kg)	BSC (mg/kg)	Soil capacity SC (mg/kg) MPLTS-BSC)	BCC (mg/kg)	SM (t/ha)[50]	PTLAR (t/ha) =SM*(SC/ BCC)
Arsenic	50	2.5	47.5	8.56	2,990	16,600
Cadmium	3	0.5	2.5	3.18	2,990	2,350
Chromium	400	21	379	55.6	2,990	20,367
Copper	80	19	61	356.9	2,990	511
Lead	300	29	271	182	2,990	4,454
Mercury	1	0.5	0.5	0.05	2,990	29,900
Molybdenum	4	1	3	15.80	2,990	568
Nickel	50	13	37	51.1	2,990	2,167
Selenium	3	0.5	2.5	3.00	2,990	2,492
Zinc	200	51	149	1,190	2,990	**374**

Table 8: How to calculate PTLAR

50. Assuming 1.3 t/m3 (density of soil)*0.23 m (incorporation depth)*10,000(m2/ha)

Table 8 provides an example on how to calculate PTLAR, using theoretical data from one biochar sample.

Since PTLAR is the application rate of biochar at which a given potential toxicant would reach MPLTS, in this example, the application of biochar would be limited by the PTLAR of Zinc, 374 t/ha, since it is the lowest. The maximum amount of this biochar that can be applied on a hectare in any period of time is 374 tonnes.

Step 2:

Calculating the limiting rate for PTLAR. In order to avoid biochar application practices that could imply toxic doses of hazardous substances to the environment (e.g. applying 374 tonnes of Zinc or other toxicants in a single application) a limiting addition rate of the PTLAR calculated will have to be established.

In order to do this, BQM proposes two approaches:

Method One:

No more than 20% of the total PTLAR should be added to soil in any one year. An example for application over a five year time horizon is shown below, though the application rates are not realistic.

Where a site has received a previous biochar application, the toxicant addition will need to be considered prior to subsequent biochar application. Therefore, where a site receives repeated applications of biochar, the acceptable rates for subsequent applications will most likely decrease due to the decreasing difference between the receiving soil's PTE levels and the MPLTS.

The optimal application frequency will vary from site to site depending on site history proponent needs and economic costs. It is for this reason that the BQM does not include a detailed discussion of biochar application frequency.

Method Two:

This method entails calculating the average annual rate of contaminant addition over a 10 year period.

The application of biochar should not exceed the maximum permissible average annual rate of contaminant addition over a 10 year period required by the Code of Practice for Agriculture Use Of Sewage Sludge. Table 9 includes these maximum permissible limits:

The Code of Practice does not provide limits for manganese, PAHs, dioxins, PCBs or BETX. It is proposed therefore to utilise the MPLTS suggested for these potentially toxic substances in Table 7.

An example on how to evaluate biochar applications with respect to the maximum permissible annual application rate of zinc over a 10 year period is provided in Table 10. This calculation must be performed for each toxicant in biochar.

Year 1 of application	Year 2 of application	Year 3 of application	Year 4 of application	Year 5 of application
Maximum 75 t/ha (20 % of PTLAR)	Less than previous application rate	Less than previous application rate	Less than previous application rate	Less than previous application rate, and so on, until the PTLAR of zinc is reached.

Toxicant	MP average annual rate of contaminant addition over 10 years (kg/ha)
Arsenic	0.7
Cadmium	0.15
Chromium	15
Copper	7.5
Lead	15
Mercury	0.1
Manganese	Not available
Molybdenum	0.2
Nickel	3
Selenium	0.15
Zinc	15
PAHs	Not available
Dioxins/furans	Not available
PCBs	Not available
BETX	Not available

Table 9: MP annual rate of contaminants suggested by the Code of Practice for Agricultural Use of Sewage Sludge

According to this example, the average addition of zinc over a period of 10 years would exceed the maximum permissible annual application rate for zinc provided by the Code of Practice for Agriculture Use of Sewage Sludge. A new plan with lower application rates of biochar would therefore be required that complies with the required limit (15 kg/ha of Zn).

Year of application	1	2	3	4	5	6	7	8	9	10	Total biochar applied (t/ha)	Annual average in 10 years (kg/ha)	Maximum permissible annual application rate for Zinc according to Code of Practice (kg/ha)
Example of Biochar application rate (t/ha) according to needs	50	0	15	10	15	0	30	20	0	5	**145**		
Zinc in biochar (mg/kg)	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	1,190	**Total Zn applied (kg/ha)**		
Zinc application (kg/ha)[51]	59	0	18	12	18	0	36	24	0	6	**172.5**	**17.25**	**15**

Table 10: How to plan applications of biochar that comply with the limits for toxicant addition to soils

51. Zinc application=(zinc concentration in biochar*biochar application rate)/1000

Appendix F: Methodology for GHG Sustainability Appraisal of Biomass Feedstocks

Step 1:

Calculate the climate-relevant stable carbon in the biochar. One way to do this is to use the formula:

$$CO_2recal_{(100)} = BM_{tot} \times BC_{yield} \times CO_{2tot} \times CSF$$

Where:

BM_{tot} is biomass total dry weight (use one tonne)

BC_{Yield} is biochar yield (ratio)

CO_{2tot} is total CO2 eq. content of fresh biochar (one oven dry tonne)

CSF is Carbon Stability Factor over 100 years

(All expressed in $tCO_2eq.t^{-1}$ feedstock)

A

$$CSF = 1 - C_{lab} - C_{unstab}$$

C_{lab} is the fraction of carbon that is labile (lost in a few weeks)

C_{unstab} is the fraction of carbon that is unstable as determined by accelerated ageing methods or other appropriate methods.

Example: Using the example values provided for sewage sludge and softwood biochars in Table 10:

CO_2recal sewage sludge=
1*0.4*0.29*(44/12[52])*(1-0.005-0.12)=
0.373 tCO_2/odt feedstock=
373 $kgCO_2$/odt feedstock

CO_2recal softwood=
1*0.24*0.89*(44/12)*(1-0.008-0.1)=
0.68 tCO_2/odt feedstock=
680 $kgCO_2$/odt feedstock

Feedstock	Char yield (%)	Total organic Carbon content of char (%)	Unstable organic carbon content of biochar (%)	Labile fraction of carbon in biochar (%)
Biochar from sewage sludge	40.40	29.90	12%	0.5%
Biochar from softwood pellets	24	89	10	0.8

Table 11: Example carbon properties suggested for two quality biochars

52. Oxygen to carbon ratio in CO_2

Note: other methods for measuring climate-relevant carbon stability have been proposed, such as use of a 'recalcitrance' index (see Appendix I).

Step 2:

Calculate the life-cycle emissions associated with the production, processing and transportation of biomass feedstocks used in producing biochar, as well as all process emissions arising from the biochar producing technology. If the biochar system generates energy that could be used to offset fossil-fuel emissions, the offset emissions by this practice should be included here.

The carbon contained within the feedstock itself is exempted. However, the CO_2e (equivalent) impacts of DIRECT and INDIRECT land-use changes associated with the production of biomass feedstocks should be included if such land conversions take place.

The LCA method used is attributional (not consequential). We call this term: $CO_2e_{(LCA)}$. Express emission values as CO_2e per tonne of oven dry feedstock.

Example: calculate the Net CO_2 (equivalent) emissions or abatement arising from the biomass-biochar production chain:

Net $CO_2e_{(emissions)}$ =
-($CO_2recal_{(100)}$ - $CO_2e_{(LCA)}$)

Net $CO_2e_{(emissions)}$ for sewage sludge biochar=
-(373 - 140[53]) = -233 $kgCO_2$/odt feedstock

Net $CO_2e_{(emissions)}$ for softwood biochar=
- (680 - 140[54]) = -540 $kgCO_2$/odt feedstock

If preferred, the value can also be expressed as net CO_2e abatement by removing the minus sign in the last equation.

Step 3:

Calculate the carbon emission factor (CEF) for the feedstock assuming that the feedstock was used for bioenergy generation (instead of for producing biochar) using the most suitable counter-factual conversion technology. This, therefore, needs to take account of the energy efficiency of the counter-factual technology as well as justifying the technology selection. For instance, in many cases the counter-factual will be biomass combustion in a dedicated biomass or co-firing boiler. However, where a district heating system exists or is planned, a better counter-factual might be a Combined Heat and Power Plant (CHP).

The CEF is calculated as follows.

CEF = Net CO_2e (emissions) ÷ (Calorific Value of feedstock (MWh one oven dry tonne) × Efficiency of energy conversion)

CEF for sewage sludge biochar=
(-233)/(5.2 MWh/tonne[55])*0.38[56]) =
-118.27 $kgCO_2$/MWh

CEF for softwood biochar=
(-540)/(4.8 MWh/tonne)*0.38[57]) =
-296.27 $kgCO_2$/MWh

53. Example factor taken from Hammond, J., Shackley, S., Sohi, S., Brownsort, P., 2011.Prospective lifecycle carbon abatement for pyrolysis biochar systems in the UK.Energy Policy 39, 2646–2655. This paper considers that emissions from transport and feedstock supply are 20% of the overall emissions. However, this LCA does not include LUC emissions.
54. Ibid
55. Based on average calorific value for sewage sludge: 19 MJ/kg. Source: http://www.ecn.nl/phyllis2/
56. 38% efficiency for co-firing systems
57. Based on approximate calorific value for sewage sludge: 18 MJ/kg. Source: http://www.ecn.nl/phyllis2/

Step 4:

The CEF value is then compared to the UK government's proposed value of 200 $kgCO_2$/MWh which represents a 60% reduction relative to the fossil fuel alternative. The calculated CEF should be no more than 200 $kgCO_2$/MWh.

In the examples provided above, both -118.27 and -296 $kgCO_2$/MWh are below the target of 200 $kgCO_2$/MWh provided for 2020, and there are net savings from using the sewage sludge or softwood in a biochar system, which is in compliance with the criteria of Section 2.1.2 "the system must return a favourable carbon balance".

Appendix G: Determining Biochar Quality for Soil Application

A provider of "standard grade" BQM-compliant quality biochar may have to demonstrate that the biochar has agronomic or ecological benefit in order to achieve, an environmental permit, waste management license or exemption to apply biochar to land.

The three criteria that can be used for evaluating ecological, agricultural and/or horticultural benefits from applying biochar to land[58] are:

a) assessment of available N, P and other plant nutrients in the biochar relative to that in the soil;

b) effect of biochar addition on water retention, porosity, stability, tilth and workability;

c) assessment of the pH and liming equivalent neutralising value of the biochar and in soil.

Biochar may have other agricultural and ecological benefits that are not captured in the criteria listed above, such as impacts upon soil biological activity. Where appropriate, the proponent should include specific information and evidence of the above and other beneficial impacts, including pot and field trial results.

Where the biochar is part of a blend, e.g. added to compost, manure, digestates, etc., it is necessary for the developer to use as controls the effect of no additions, the organic amendment with no biochar and the effect of the organic amendment plus biochar.The benefits of adding biochar to the other constituents can then be observed with respect to the identified indicators listed above.

Appropriate evidence of benefits could include chemical analysis, laboratory tests, pot trials and field trials, amongst other sources of evidence.

Where it is proposed to incorporate biochar into non-agricultural and non-horticultural soils, other benefits need to be identified. This could include increasing soil organic carbon, removal of contaminants and/or ecological improvement. For instance, where evidence can be gathered to suggest that biochar addition enhances otherwise degraded habitats and assists in the creation of new habitats and restoration of an old habitat, this will count as ecological improvement.

58. These are taken from SEPA's guidance note WMX-TG7 on assessing agronomic or environmental benefits of applying wastes to land, for use when applying for an exemption from Waste Management Licensing Regulations. The guidance note can be found at http://www.sepa.org.uk/waste/waste_regulation/application_forms/exempt_activities/idoc.ashx?docid=ee5c40a9-a4e6-41e0-b7d8-db32aa4634f9&version=-1

Appendix H: Biomass Usage Threshold Calculation

The reasoning behind the calculation of the 4 odt per day biomass threshold for appraisal of the sustainability of biomass supply is based on the 1MW thermal or electrical capacity threshold provided by RED, and is the following:

- If a 1MW bioenergy facility operates 310 days per year on average, this equals an energy production of approximately 3,100 MWh per year or approximately 11,000 GJ;
- If it is assumed that the energy content of biomass in general is around 16 GJ per tonne of feedstock, and the average energy content of biochar is around 25 GJ per tonne, the total amount of energy generation per year (11,000 GJ) can be divided by the energy content of biochar, obtaining the amount of biochar generated per year (approximately 450 tonnes of biochar);
- Considering a 0.33 biochar production ratio per tonne of biomass feedstock, 450 tonnes of biochar would equal approximately 1,350 tonnes of biomass feedstock needed for processing per year, or approximately 4 tonnes per day.

Therefore, the “biomass usage” threshold value used as a requirement for a sustainability assessment would be of 4 tonnes of feedstock a day.

Appendix I: Methods for Calculating Stable Organic Carbon Content

Written with the help of Dr Andrew Cross, School of GeoSciences, University of Edinburgh.

There is considerable technical debate, and as yet no consensus, amongst experts regarding the best method for calculating the stability of carbon over a climate-change relevant timescale. Even the relevant timescale over which stability should be calculated is unclear. Specialists have gravitated towards 100 years, though it must be noted that this is a much less stringent requirement for long-term carbon storage than is being proposed for CO_2 capture and its storage in geological formations (where storage for 1000 years or more is widely assumed as the requirement).[59]

For simplicity, at this stage we will consider 100 years an appropriate timescale. There are several different published methods for calculating how much of the biochar carbon is stable over a period of c. 100 years or longer. It is up to the proponent to select one of these methods or an alternative method and to provide a rationale for their use.

Method One: Accelerated Ageing.

The biochar samples are exposed to a 30% solution of hydrogen peroxide (H202) that is a powerful oxidant. Over a period of c. 10 days, the H_20_2 aims to simulate what happens to the biochar over 100 years in soil. The precise experimental set-up requires calibration to take account of different climatic conditions of the receiving soil. The benefits of this method is that it is relatively straightforward, hence can be widely replicated in laboratories over the world and not too expensive. The disadvantages are that it cannot simulate the interactions of biochar with Soil Organic Matter and minerals that might act as protection from slow oxidative processes. This would imply under-estimation of stability, however, which gives a useful margin of error.

Key Reference:

Cross, A. and Sohi, S. (2013), A method for screening the relative long-term stability of biochar, *GCB Bioenergy*, **5, 215–220**

59. Shackley, S. and Gough, C. (2006), Carbon Capture and its Storage: An Integrated Assessment, Ashgate, Aldershot.
60. IBI 2012; EBC 2012.
61. Schimmelpfennig, S. & Glaser, B. (2012) One step forward toward characterization: some important material properties to distinguish biochars, Journal of Environmental Quality 41(4), 1001-1013.

Method Two: H:C ratios as a Proxy Measure of Stable Biochar-Carbon.

Elemental analysis allows calculation of the H:C (organic) ratio. The lower the H:C ratio, the more carbonised the char. From comparison with other carbonised materials, biochar must have a hydrogen to organic carbon (H:Corg) ratio of no higher than 0.7[60]. The O:C ratio can also be used to measure the degree of polarity of the biochar and an O:C ratio of no higher than 0.4 has been selected for characterising material as biochar[61]. Where O is calculated by difference, however, it is probably a less reliable indicator to use that the H:Corg ratio. The benefits of this approach is that elemental analysis is affordable, widespread and is likely to be undertaken in any case for basic biochar characterisation. The disadvantages are that it is hard to calibrate H:C or O:C ratios to represent a degree of stability that can be related to 100 years or another timescale.

Key References:

Schimmelpfennig, S. & Glaser, B. (2012) One step forward toward characterization: some important material properties to distinguish biochars, *Journal of Environmental Quality* **41(4), 1001-1013**;

Spokas, K. (2010), Review of the stability of biochar in soils: predictability of O:C molar ratios, *Carbon Management*, **1(2), 289-303**.

Method Three: Recalcitrance index (R50).

This index was developed based on thermal stability of range of different biochar / black carbons. R50 is calculated using TG thermograms of the target and control sample (graphite). This has been tested through comparisons of R50 with short-term stability measurements and physicochemical properties (e.g. O:C). Stability or recalcitrance is reported as an index between 0-1, and in the work of Harvey et al. (2012) is split into 3 classes (Class A: R50>0.7, Class B: < 0.5 R50 <0.7 and Class C: R50 <0.5) reflecting relative recalcitrance, e.g. class A comparable to soot/graphite, class B intermediate C sequestration potential and Class C uncharred plant biomass.

Key reference:

Harvey, O., Kuo, L., Zimmerman, A., Locuouarn, P., Amonette, J., Herbert, B. (2012), An index-based approach to assessing recalcitrance and soil carbon sequestration potential of engineered black carbons (biochars), *Environmental Science and Technology*, **46: 1415-1421.**

60. IBI 2012; EBC 2012.
61. Schimmelpfennig, S. & Glaser, B. (2012) One step forward toward characterization: some important material properties to distinguish biochars, Journal of Environmental Quality 41(4), 1001-1013.

Appendix J: Example of an Emissions Compliance Certificate

This certificate provides evidence that the tested biochar unit meets the air quality requirements of the Biochar Quality Mandate. It must be issued by an accredited testing laboratory.

1. TEST HOUSE		
a) name and address of testing laboratory		
b) name and signature of the person authorised by the testing laboratory to issue the certificate	Name:	
	Signature:	
c) date of issue of this certificate together with certificate reference number	Date:	dd/mm/yyyy
	Ref:	
d) Details of laboratory accreditation	Date:	dd/mm/yyyy
	Accreditation number:	

2. PLANT	
a) name of the plant tested	
b) model of the plant tested	
c) manufacturer of the plant tested	
d) (i) the date the plant was tested* (ii) please confirm that NOx, CO, OGC and PM have been tested on the same occasion	dd/mm/yyyy yes/no
e) list of all the plants in the type-testing range* of plants to which the certificate applies, if any. Please include the installation capacity of each model. *This must follow the ratio rules: If the smallest plant in the range is 500kW or less, the largest plant in the range can't be more than double the smallest. If the smallest plant in the range is over 500kW, the largest plant in the range can't be more than 500kW greater than the smallest.	

3. FUELS	
a) types of fuels used when testing	
b) based on the testing, list the range of fuels that can be used in compliance with the emission limits set out in Table x	
c) moisture content of the fuel used during testing	xx%
d) maximum moisture content* of the fuel which can be used with the certified plant(s) so as to ensure that the emission limits are not exceeded.	yy%

4. TESTS	
a) Confirm which standards have been used to test the emissions.'	
i. Carbon Monoxide ii. Organic gaseous compounds iii. NOx iv. Particulate matter	
b) please confirm the plant was tested at ≥85% of the installation capacity of the plant	yes/no
c) please confirm the test shows that emissions from the plant were no greater than the values set out in Table #.	yes/no
d) measured* emissions of compounds in g/GJ net heat input i. Carbon Monoxide ii. Organic gaseous compounds iii. NOx iv. Particulate matter	

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