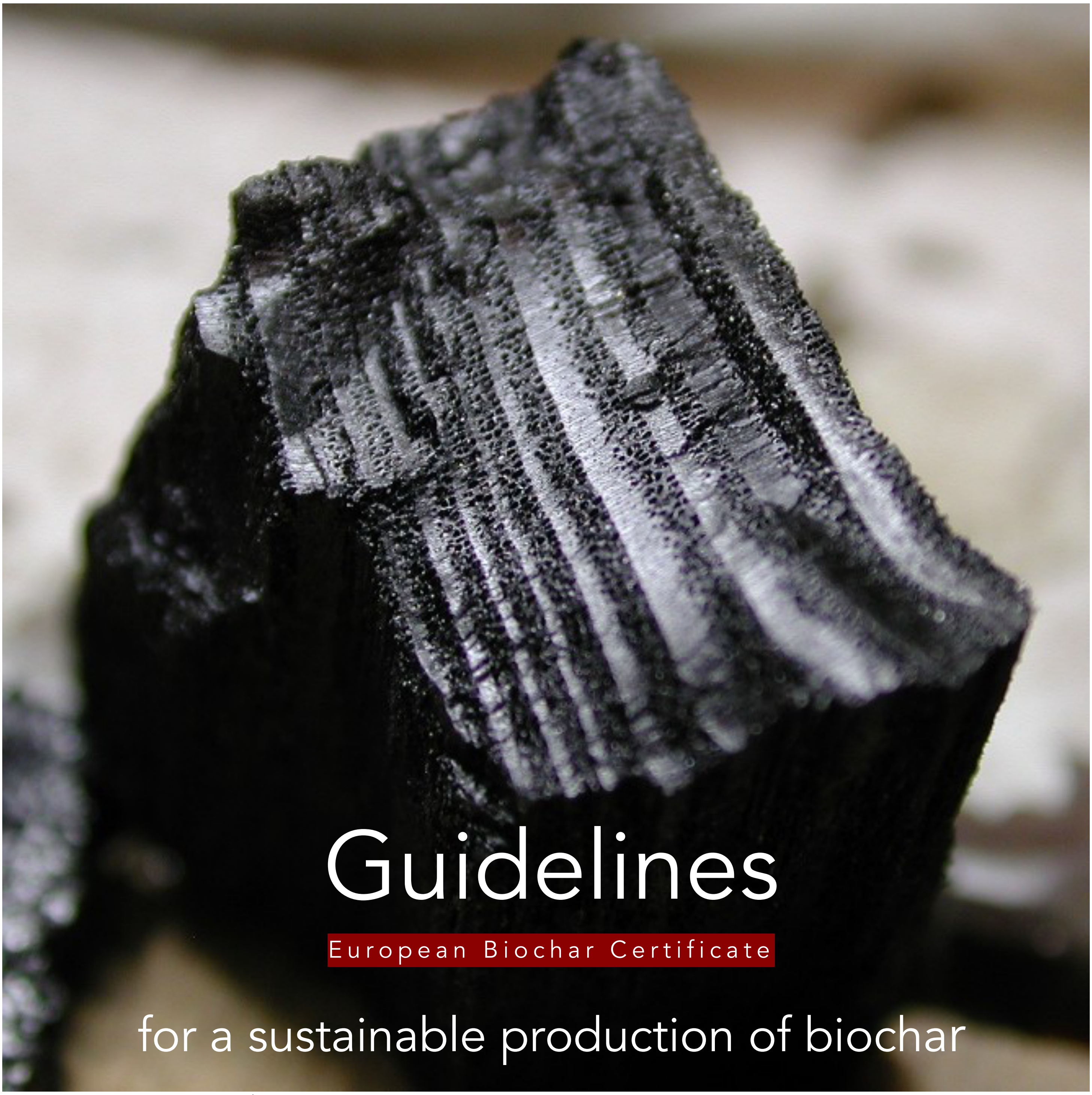

Version 10.1E of 10th January 2022

Please cite as:

EBC (2012-2022) 'European Biochar Certificate - Guidelines for a Sustainable Production of Biochar.' European Biochar Foundation (EBC), Arbaz, Switzerland. (http://european-biochar.org). Version 10.1 from 10th Jan 2022

Impressum

These guidelines are effective since 1st January 2012 and constitute the basis for biochar certification in Europe and throughout the world. The EBC standard is developed by the Ithaka Institute and is own by Carbon Standards International.

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EBC foundation | certificate

Table of contents

A. Summary of the EBC to prepare the inspection

Companies that do not produce but process and trade certified biochar should consult Chapter 11 directly.

1. Inscription

1.1 Producers of biochar register on the EBC website (https://www.european-biochar.org/en/registration). The producer will then receive their login to the secured EBC website where they are requested to provide all necessary information about the company and the pyrolysis technology they use.

1.2 Following a first verification of the technical information and a personal phone contact with the producer through the Carbon Standards International, the company information are transmitted to the accredited inspection and certification body: bio.inspecta AG (https://www.bio-inspecta.ch/en/services.html).

1.3 The producer will receive an offer and contract for the EBC certification from bio.inspecta AG.

1.4 Once the producer has signed the inspection contract, Carbon Standards International will coordinate an appointment for a technical pre-audit with the biochar producing company which is usually done via a video conferencing system.

1.5 During the technical pre-audit, a company-specific quality assurance and sampling plan will be prepared and noted in the technical EBC inspection sheets. In addition, instruction is given in regard to the EBC methodology, the EBC documents and the protocols to be kept and the procedure for the annual inspection by bio.inspecta AG.

1.6 The company to be certified appoints a quality manager who will be the direct contact person for the inspection body, bio.inspecta AG, who will handle the entire certification process.

2. Production batch

2.1 A production batch starts with its registration on the EBC website. The production batch receives a unique ID number and QR code.

2.2 A production batch lasts a maximum of 365 days including all possible interruptions in production.

2.3 The pyrolysis temperature in °C shall not change by more than 20% during production. At a declared pyrolysis temperature of, for example, 600 °C, short-term fluctuations between 480 °C and 720 °C are thus permitted.

2.4 The composition of the biomass must not change by more than 20%. If, for example, a mixture of 50% grain husks and 50% landscape conservation wood is pyrolysed, the proportions may vary in the range 40% to 60% (±(50% x 20%) = ±10%).

2.5 If a biochar producer registers for the first time a biochar production batch, a representative sampling has to be carried out by an accredited sampler within the first two months after registration.

2.6 After a production batch has expired, a subsequent, new production batch must be registered on the EBC website.

2.7 If the new production batch is produced with the same parameters as the preceding batch, the analysis of the preceding batch is valid until a sample of the new batch is taken and analysed.

2.8 The sampling of a new batch following a production batch produced with the same parameters should be done within a year after the last sampling and analysis. Sample taking should be finalized during the inspection visit.

3. Sampling and sending the sample for analysis

3.1 The representative sample of a production batch is taken during the initial audit and thereafter during each annual inspection by an accredited sampler in accordance with the sampling plan contractually specified in the initial audit and sent to an EBC accredited laboratory.

3.2 The sampler is either the same person as the controller sent by the inspection body bio.inspecta AG or a company internal or external sampler who participated successfully in the official EBC sampling training.

3.3 The sample has to be registered on the EBC website where the sample ID and the laboratory order for the EBC-analysis are generated.

3.4 The sealed sample has to be sent with the EBC sample ID and the order for analysis to the selected EBC accredited laboratory.

3.5 In accordance with the sampling and quality assurance plan specified in the contract, the production company shall ensure the sampling and sealed storage (usually daily) of the retained samples.

4. Permissible biomass for the production of biochar

4.1 All biomasses included in the EBC Positive list may be used individually or in combination as feedstock for the production of EBC biochar. For each certification class certain restrictions apply, which are set out in the EBC Positive List. For example, not all biomasses that may be used for EBC-Urban may be used for EBC-Feed. Within a batch, the type of biomass may not be changed, and the mixing ratios may not change by more than 20% (cf. 2.5).

4.2 Mineral additives according to the EBC Positive List may be added up to 10% of the mass. No mineral additives are permitted for EBC-Feed.

5. Specifications for pyrolysis technology

5.1 The use of excess heat or the use of liquid and gaseous pyrolysis products must be ensured.
5.2 Nationally defined emission limit values must be complied with.

6. Properties of biochar

6.1 The biochar for all application classes must be analysed at least according to the EBC Basic Analysis Package. For EBC-Feed the analyses of the EBC-Feed package are additionally required.
6.2 The following limit values and declaration requirements must be observed:

EBC -Certification Class		EBC-Feed	EBC-AgroOrganic	EBC-Agro	EBC-Urban	EBC-ConsumerMaterials	EBC-BasicMaterials
Elemental analysis	Declaration of Ctot, Corg, H, N, O, S, ash						
	H/Corg	< 0.7					
Physical parameters	Water content, dry matter (@ < 3mm particle size), bulk density (TS), WHC, pH, salt content, electrical conductivity of the solid biochar						
TGA	Needs to be presented for the first production batch of a pyroylsis unit						
Nutrients	Declaration of N, P, K, Mg, Ca, Fe						
Heavy metals	Pb	10 g t^{-1} (88%DM)	45 g t^{-1} DM	120 g t^{-1} DM	120 g t^{-1} DM	120 g t^{-1} DM	*declaration, no limit values for certification*
	Cd	0.8 g t^{-1} (88% DM)	0.7 g t^{-1} DM	1,5 g t^{-1} DM	1,5 g t^{-1} DM	1,5 g t^{-1} DM	
	Cu	70 g t^{-1}DM	70 g t^{-1}DM	100 g t^{-1} DM	100 g t^{-1} DM	100 g t^{-1} DM	
	Ni	25 g t^{-1} DM	25 g t^{-1} DM	50 g t^{-1} DM	50 g t^{-1} DM	50 g t^{-1} DM	
	Hg	0.1 g t^{-1} (88% DM)	0.4 g t^{-1} DM	1 g t^{-1} DM	1 g t^{-1} DM	1 g t^{-1} DM	
	Zn	200 g t^{-1} DM	200 g t^{-1} DM	400 g t^{-1} DM	400 g t^{-1} DM	400 g t^{-1} DM	
	Cr	70 g t^{-1} DM	70 g t^{-1} DM	90 g t^{-1} DM	90 g t^{-1} DM	90 g t^{-1} DM	
	As	2 g t^{-1} (88% DM)	13 g t^{-1} DM	13 g t^{-1} DM	13 g t^{-1} DM	13 g t^{-1} DM	
Organic contaminents	16 EPA PAH	declaration	4±2 g t^{-1} DM	6.0+2.2 g t^{-1} DM	declaration	declaration	not required
	8 EFSA PAH	1.0 g t^{-1} DM					4 g t^{-1} DM
	benzo[*e*]pyrene benzo[*j*]fluoran-thene	< 1.0 g t^{-1} DM for each of both substances					
	PCB, PCDD/F	See chapter 10	Once per pyrolysis unit for the first production batch. For PCB: 0.2 mg kg^{-1} DM, for PCDD/F: 20 ng kg^{-1} (I-TEQ OMS), respectively				

Tab.1 Overview of the most important analytical parameters for EBC biochar

6.3 Specifications, additional limit values, or more stringent limit values that apply only to certain countries are regulated in the respective country annex.

6.4 Die Pflanzenkohle der Klassen EBC-Feed, EBC-Agro, EBC-AgroOrganic und EBC-Urban muss auf einen Wassergehalt eingestellt werden, der die Staubbildung und damit auch die Selbstentzündung verhindert (empfohlen sind 30%). Pflanzenkohle der Klassen EBC-ConsumerMaterials und EBC-BasicMaterials kann nur dann mit einem geringeren Wassergehalt verkauft werden, wenn die entsprechenden Sicherheitsvorkehrungen, insbesondere im Hinblick auf Explosions- und Gesundheitsschutz, getroffen wurden und die Pflanzenkohle ausschließlich an Geschäftskunden (B2B) mit entsprechenden Sicherheitsvorkehrungen verkauft wird.

7. Health and safety

7.1 The workers must sign that they have been informed about possible dangers at the workplace and that they have the necessary personal protective equipment.

1. Objective of the guidelines and certification

For thousands of years, charcoal has been one of civilisation's basic materials. By far the most common use of charcoal was for cooking, for heating and for smouldering when producing metal tools. However, for centuries charcoal and biochar have also been used for conditioning soils, or as litter (bedding) materials, as medicine and also as a feed additive. Over the course of the last century most of this traditional knowledge has been lost yet is being rediscovered since 2010.

Thanks to wide-ranging multidisciplinary research and field trials, the understanding of the biological and physico-chemical processes involved in the production and use of biochar has made great progress. A significant increase in the agricultural use of biochar has already been recorded since 2015. From 2020 onwards, a further acceleration in both agricultural and industrial use of biochar occurred. Agricultural applications range from soil conditioners, composting additives, and carriers for fertilisers to manure treatment and stable bedding, silage additives and feed additives. Industrial applications are particularly relevant to the construction, plastics, paper, and textile industries.

Traditional kiln production of charcoal and biochar without the combustion of pyrolytic gases is unsatisfactory with regards to its carbon efficiency and its overall environmental footprint. Accordingly, those kilns are unsuitable for the production of larger amounts of biochar to be used in agriculture or industry. Modern pyrolysis plants as well as certain types of farmer-scale kilns such as flame curtain pyrolysis systems are now ready to produce biochar from a large variety of different feedstocks in an energy efficient way and without harming the environment. As both biochar properties and the environmental footprint of its production are largely dependent on the pyrolysis parameters and the type of feedstocks to be used, a secure control and assessment system for its production and analysis had to be introduced.

In issuing these guidelines Carbon Standards International presents an assessment mechanism based on the latest research, practices, and legislation. By requiring the use of this assessment system, the European Biochar Certificate (EBC) will enable and guarantee sustainable biochar production, processing and sale. It is introduced to provide customers with a reliable quality standard, while giving producers the opportunity to prove that their products meet well-defined and recognized quality standards. It further aims to provide a firm state-of-the-art knowledge transfer as a sound basis for future legislation (e.g., EU fertilizer regulations or carbon-sink regulations).

Biochar technology continues to develop very rapidly. Numerous research projects around the world are investigating the properties of biochar and their interaction with other substances, materials, and the environment. Every year sees new manufacturers of pyrolysis equipment entering the market and the areas in which biochar and biochar products are used is growing rapidly. The European Biochar Certificate is closely aligned with this research and technical momentum and will accordingly be revised regularly to consider the latest findings and developments. Limit values and test methods will be adapted to reflect the latest findings and amended or updated as necessary.

The goal of these guidelines is to encourage and ensure the control of biochar production and quality based on well-researched, legally backed-up, economically viable and practically applicable processes. Users of biochar and biochar-based products will benefit from transparent and verifiable monitoring and quality assurance. It is our moral obligation as well as the duty of every biochar user's duty to make sure that a good idea is not be corrupted. The certificate was designed to serve this goal.

Currently, the European Biochar Certificate is a voluntary industry standard in Europe. In Switzerland, however, it is obligatory for all biochar sold for use in agriculture. Several other countries aligned their biochar related regulations with the EBC.

2. Definition of biochar

Biochar is a porous, carbonaceous material that is produced by pyrolysis of biomass and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing. It is not made to be burnt for energy generation.

Biochar is produced by biomass pyrolysis; a process whereby organic substances are broken down at temperatures ranging from 350°C to 1000 °C in a low-oxygen process. Although torrefaction, hydrothermal carbonisation and coke production are carbonisation processes, the end products cannot however be called biochar under the above definition. Biochars are therefore specific pyrolysis chars characterised by their additional environmentally sustainable production, quality and usage features. Gasification is understood as being part of the pyrolysis technology spectrum and can, if optimized for biochar production, be equally certified under the EBC.

Biochar is defined by its quality characteristics, by the raw materials used, its sustainable production and end use.

Biochar is a hyper versatile material with an increasing number of applications in agriculture, environmental engineering, and basic industry. Each application, like the use as a soil amendment, stormwater filter, or additive for building materials, textiles, and plastics, demands specific biochar qualities. Thus, each application requires proper certification parameters that must be specified, controlled, and guaranteed.

3. The EBC certification classes

To keep pace with the growing number of biochar uses, the EBC has introduced a number of certification classes. According to the requirements and safety regulations of the different applications, different parameters are controlled, and limit values apply. With the publication of EBC v10.0, the certification class EBC-BasicMaterials is introduced as the basic and fundamental certification class. It defines what can be considered a biochar or not according to the EBC and complies with all requirements of the EU-REACH regulation [1]. All present and future certification classes meet at least the requirements of EBC-BasicMaterials and thus meet all requirements of the EU-REACH regulation, too. All EBC-certification classes are entitled for C-sink certification.

The definition of a certification class (e.g., EBC-Urban or EBC-ConsumerMaterials) is a statement of admissibility of biochar for a given purpose regarding applicable laws, regulations, and relevant industry standards. The assignment to a certification class is not a statement about the excellence of biochar (i.e., good, better, or best biochars for a specific purpose/use) – but it does distinguish between biochars that are admissible or inadmissible for a defined form of application (e.g., in agriculture or construction). Each application and thus certification class has its specific requirements. Every biochar and biochar-based product must be labelled according to the EBC certification class under which it is traded. If, e.g., a biochar is sold as a building material it must be labelled as EBC-BasicMaterial. An EBC-Agro labelled biochar cannot be traded as building material. EBC-Feed labelled biochar cannot be sold as soil amendment. However, the biochar of one production batch can fulfil the requirements of several certification classes. Different packaging units from one and the same production batch can thus be sold under different labels (e.g., EBC-Feed, EBC-Agro, and EBC-ConsumerProducts). However, a packaging unit must not be labelled with more than one certification class.

Biochar with **EBC-Feed** certification meets all requirements of the EU feed regulation [2]. In addition to the EBC-Feed certification, a biochar producer must be approved as a feed producer in accordance with the respective national requirements. For this purpose, the EBC advises producers of feed biochar and biochar-based feed products to obtain a complementary GMP+ certification as animal feed producers. EBC and GMP+ collaborate regarding biochar analysis and risk assessment and both sides strongly recommend double certification of biochar feed products. EBC-Feed biochar must not be sold as a soil amendment unless the certification confirms that the required additional certification parameters as defined for the certification classes EBC-Agro and EBC-AgroOrganic are fulfilled, and the biochar is labelled accordingly.

Biochars certified with **EBC-Agro** and **EBC-AgroOrganic** meet all requirements of the new EU fertilizer product regulation [3]. Several EU countries such as Austria, Sweden, and Hungary have approved the use of biochar according to the requirements of EBC-Agro. Based on these national approvals, such biochars can be exported and used in all other EU countries. Several EU and EFTA countries apply their own restrictions for the agricultural use of biochar. Switzerland, for example, requires the certification according to EBC-AgroOrganic; however, they only allow woody biomass as a feedstock for pyrolysis. Germany currently requires a minimum carbon content of 80% for biochar that must be produced from untreated wood. Sweden has defined limits beyond the EU regulation and EBC-Agro, which are covered by the Sweden Annex of the EBC. The EBC-AgroOrganic certificate meets all requirements of the EU Commission regulation on organic production [4]. The respective specifications and limit values are continuously adapted to align with the ongoing development of relevant European legislation and scientific advances.

EBC-Urban provides a strong standard for the use of biochar in tree planting, park maintenance, sidewalk embellishments, ornamental plants, and rainwater drainage and filtration. The main risk of all those uses is ground- and surface water contamination and work safety, which EBC-Urban certification prevents effectively. As the urban use of biochar is not subject to agricultural legislation, some parameters, and their respective limit values were replaced by limit values that are better adapted to the special matrix of biochar. For example, the EBC-Urban limit value for PAHs is limited to the eight carcinogenic PAHs using the same limit value as for EBC-Feed and EBC-Agro. PAHs are ubiquitous in urban environments (e.g., from tyre abrasion and car exhaust), and urban soil applied biochar which is a strong adsorber of PAHs will act as a net adsorber of those environmental toxins when low biochar PAH-contents are guaranteed (as is the case when EBC-Urban biochar is used).

Biochar certified under **EBC-Urban** must not be used as soil amendment for food or feed production. If biochar shall be used in urban community gardens or home-gardening projects, EBC-Agro or EBC-AgroOrganic quality is recommended. EBC-Urban can further be used for remediation of polluted soils, sediments or groundwater, the production of ornamental plants, and tree nurseries for non-food species. EBC-Agro and EBC-AgroOrganic fulfill all requirements of EBC-Urban and can be used for any urban soil applications.

The certification classes **EBC-ConsumerMaterials** and **EBC-BasicMaterials** cover all necessary environmental requirements for non-soil applications.

EBC-ConsumerMaterials is destined for biochar to be used in products that may come into direct skin contact with consumers or food-grade products. Examples would be takeaway coffee cups, plastic computer cases, toothbrushes, carpets, textiles, flowerpots, freshwater pipes, etc. However, this does not include medical and healthcare products or food. The biochar must be included in the consumer products in such a way that no coal dust is released because of product use.

The **EBC-BasicMaterials** certificate guarantees sustainably produced biochar, which can be used in basic industry such as to produce building materials, road construction asphalt, electronics, sewage drains, and composite materials like skis, boats, cars, rockets without risk to the environment and users. However, precautions in handling, storing, and labeling the materials are required, as described in the dedicated sections of the EBC (see chapter 11).

Both EBC-ConsumerMaterials and EBC-BasicMaterials must not be used in agriculture or other soil applications such as planting urban trees, remediating polluted areas, or mine reclamation. EBC-BasicMaterials must not be sold directly to private customers (B2C) but is traded exclusively to other businesses (B2B) where adequate handling (i.e., avoidance of dust generation, respiratory protection, avoidance of skin contact) can be ensured.

EBC-**BasicMaterials** defines what can be considered "biochar" and used as a sustainable raw material. Other solid residues obtained from pyrolysis or gasification of biomass that exceed EBC-BasicMaterials limit values must be considered as (potentially) toxic waste and must be disposed of as waste material according to local, national, or international laws. Pyrolytic products from feedstock that are not listed on the EBC feedstock positive list (e.g., industrial wastes or fossil carbon like lignite) should not be considered biochar and must not be traded under the EBC label.

For all certification classes, the same sustainability criteria regarding the production of biochar (i.e., emissions, feedstock storage, the definition of batches, control of pyrolysis parameters), sampling, and on-site inspection do apply.

Specific industry classes defining biochar qualities for the use in construction materials, polymers, textiles, and other materials will be developed from 2022 onwards depending on the demand from the respective industries.

If European biochar producers are interested in having new certification classes included into the EBC, a formal application should be sent to the EBC. The EBC Scientific Committee will review the application in detail and either add the certification class or publish the reasons for the refusal.

4. Biomass feedstock

4.1 Only biomass and no fossil carbon may be used to produce biochar. The EBC positive list (Appendix 1) indicates which types of biomasses are permissible for each application class.

4.2 The clean separation of non-organic substances such as metals, construction waste, electronic scrap, etc. must be guaranteed.

4.3 To produce biochar for soil and agriculture (EBC-Feed, EBC-Agro, EBC-AgroOrganic, EBC-Urban), the biomass used must not contain any paint residues, solvents or other potentially toxic impurities.

4.4 To produce EBC-Feed, EBC-Agro, EBC-AgroOrganic, and EBC-Urban qualities, unavoidable contamination of the biomass by plastic and rubber waste must not exceed 1% (m/m). To produce biochar for materials (EBC-ConsumerMaterial, EBC-BasicMaterials) plastic and rubber contents of up to 10% can be accepted, though these are subject to declaration and require the written approval of Carbon Standards International. In the latter case, Carbon Standards International may define additional requirements for the pyrolysis process, request additional analyses to ensure the safety of the product and its application, and deduce plastic derived carbon from the C-sink potential of the biochar. Based on ongoing research showing the complete elimination of plastic feedstock under defined pyrolysis conditions, higher limit values for feedstock plastic contamination may be introduced in 2022/23.

4.5 When using primary agricultural products (e.g., miscanthus or short rotation forestry), it must be guaranteed that these were grown in a sustainable manner and that the soil organic carbon was preserved.

4.6 Biochar may only be produced from forest wood if sustainable management of the corresponding forest can be proven by PEFC or FSC certificates or by comparable regional standards or laws.

4.7 Mineral additives such as rock powder and ashes as detailed in the EBC positive list (Appendix 1), which may be used to control the quality of biochar, are subject to declaration and require written approval from the EBC. Carbon Standards International may request additional quality controls with regard to organic and inorganic contaminants. To produce EBC-Feed, no mineral additives are admitted yet.

4.8 Complete records of the processed biomasses and additives must be kept and archived for at least five years.

The pyrolysis of non-plant biomasses such as sewage sludge, livestock manure, manure containing biogas digestates or bones and slaughterhouse wastes may also produce valuable raw materials that could be used in the interests of the bioeconomy and climate protection. It is planned to include these raw materials mid 2022 in the EBC feedstock list following a key review publication about the product safety and conditions of use.

If biochar producers are interested in adding new biomass or mineral additive materials on the EBC-feedstock list, a formal application should be sent to Carbon Standards International. The EBC Scientific Committee will review the application in detail and either add the feedstock or publish the reasons for the refusal. The EBC is prepared to add national appendixes to align the general EBC certification with national laws regarding eligible feedstock.

5. Definition of biochar batches and their registration

A biochar production batch is defined as:

5.1 Each production batch has to be registered on the EBC website. The EBC will allocate a unique ID number with corresponding QR code for the production batch. The ID number and the QR code ensure the traceability of the biomass feedstock, the conditions of production, and the quality of the biochar.

5.2 A production batch lasts a maximum of one calendar year including all possible interruptions in production.

5.3 The pyrolysis temperature in °C must not change by more than 20 % during production. With a declared pyrolysis temperature of, for example, 600 °C, short-term fluctuations between 480 °C and 720 °C are thus permitted. Documented production interruptions, both planned and unplanned, are permitted provided that the specified temperature range is maintained after resuming the production. Depending on the pyrolysis process, biochar from the plant start-up and shut-down process may need to be carefully separated and documented and must not be marketed as EBC-Feed, EBC-AgroOrganic or EBC-Agro. The precise handling of biochar from the start-up and shut-down process is regulated during the technical audit and documented in the online instruction manual.

5.4 The blend of different types of biomass listed in the EBC positive list may not change by more than 20 percentage points. For example, if a mixture of 50% cereal husks and 50% landscape conservation wood is pyrolyzed, the proportions may vary in the range 40% to 60% [±(50% x 20%) = ±10%].

5.5 If a biochar producer registers for the first time a biochar production batch, a representative sampling has to be carried out by an accredited sampler within the first two months after registration.

5.6 After a production batch has expired, a subsequent, new production batch must be registered on the EBC website.

5.7 If the new production batch is produced with the same parameters as the preceding batch, the analysis of the preceding batch is valid until a sample of the new batch is taken and analysed.

5.8 The sampling of a new batch following a production batch produced with the same parameters should be done within a year after the last sampling and analysis. Sample taking should be finalized during the inspection visit.

5.9 Complete production records must be kept, providing detailed descriptions and dates of any production problems or stoppages. Furthermore, the daily taking of the retention sample must be recorded (see chapter 6.3 retention sample).

5.10 The daily production quantities of biochar must be documented.

5.11 On the last production day of a batch, the date and time of the end of the biochar production batch and the total production quantity of the complete biochar batch have to be reported on the EBC website.

5.12 Production batches cannot be reported retroactively. The start of a production batch is at the earliest the date of registration on the EBC website.

As soon as either point 5.3 or point 5.4 are no longer fulfilled, a production batch is considered completed. A new production batch with the changed parameters must be registered on the EBC website and an appointment with an accredited sampler must be arranged. The annual inspection visit takes place once per calendar year, irrespective of the number of batches produced.

6. Biochar sampling

The accredited controlling inspector is entitled to take additional samples at any time and send them to the accredited laboratory or to the EBC.

6.1 Representative sample

Since 2021, the biochar samples sent to the accredited laboratory for EBC analysis must be taken by an accredited sampler. The sampling plan is drawn up during the initial audit and has to be approved by Carbon Standard International, and is documented in the online instruction manual (chapter 13.5). The accredited sampler must follow the company-specific sampling plan.

The accredited controlling inspector of q.inspecta is entitled to take additional samples at any time and send them to the accredited laboratory or to Carbon Standard International.

6.2 Sending of the representative biochar sample to the accredited laboratory

The representative samples for analysis must be sealed by the accredited sampler and registered on the EBC website before shipping the sample. The producer sends the sealed sample to the EBC-accredited laboratory selected by the producing company.

6.2.1 The accredited laboratory shall send the results of the analysis to the biochar producing company and a copy to the accredited inspection body, Carbon Standard International and the Ithaka Institute.

6.2.2 The Ithaka Institute has the right to use the results of analysis in anonymised form for statistical purposes.

6.3 Retention Sampling

In addition to the EBC analysis sample, the manufacturer is obliged to take regularly (in general every day) retention samples. The exact procedure is determined during the initial audit. If no deviating protocol is determined during the initial audit, the following applies:

Daily, a fresh sample of one liter, either from the cross-flow or from the collected daily production has to be taken. The cross-flow sample can be taken both manually and automatically from the daily production [5].

The daily sampling time has to be entered in the production record. The daily samples must be collected for one month at a time in a sample container as a composite 30-liter sample. After one month the composite sample shall be sealed. The next 30 cross-flow samples shall be collected in a new sample container until this container is also sealed and stored.

The monthly retention sample of at least 30 liter must be kept dry and protected for two years. The retained samples serve to protect the producer who will thus be able to prove in the event of any complaints from authorities or customers that the relevant biochar was free of pollutants and that it was of the quality guaranteed by the EBC certificate.

During the initial audit, company-specific regulations for the creation and storage of reserve samples can be defined.

7. Biochar properties

The aim of the EBC certificate is to guarantee compliance with all environmentally relevant limit values and to declare those biochar properties which are relevant for the respective application class and that can be analyzed at reasonable cost.

There are numerous additional analytical possibilities to characterize and classify biochar even more comprehensively. However, many of these would go beyond reasonable cost limits. We do not seek to analyze, regulate and guarantee all possible parameters, but rather those that are necessary to ensure safety and sustainability.

The limit values mentioned in the following chapter are only valid in conjunction with the permissible test procedures and permissible analytical methods. These are detailed for the individual parameters in Appendices 1-3.

Additional or more stringent limit values that apply only to certain countries are regulated in the respective country annex (see Annex A5ff).

7.1 The biochar's organic carbon (C_{org}) content must be declared.

The organic carbon content of biochar varies between about 35 % and 95 % of dry matter, depending on the biomass feedstock and the pyrolysis temperature. For example, the carbon content of pyrolyzed straw is usually between 40 and 50% and that of wood and nutshells between 70 and 90%.

In previous versions of the EBC certificate, a limit value of 50% organic carbon content was applied to biochar. All pyrolysis products below this limit were considered as pyrogenic carbonaceous materials (PCM). However, a large number of scientific papers published in recent years have shown that a carbon content of > 50% is not a sufficient criterion for such a distinction. In particular, biochar from crop residues such as straw and grain husks have proven to be well suited for various agricultural and industrial applications, even though the carbon content is usually below 50%. Since the use of crop residues and other secondary plant biomasses is desirable both for climate protection and for closing nutrient cycles, the former limit of 50% has been reconsidered. The term PCM is not used anymore within the EBC.

7.2 The molar H/C_{org} ratio must be less than 0.7

The molar H/C_{org} ratio is an indicator of the degree of carbonisation and therefore of the biochar stability. The ratio is one of the most important characterising features of biochar and is indispensable for the determination of the C-sink value. Values fluctuate depending on the biomass and process used. Values exceeding 0.7 are an indication of non-pyrolytic chars or pyrolysis deficiencies [6].

7.3 The molar O/C_{org} ratio should be below 0.4

In addition to the H/C_{org} ratio, the O/C_{org} ratio is also relevant for characterising biochar and differentiating it from other carbonisation products [6]. Compared to the H/C_{org} ratio, direct measuring of the O content is expensive and not standardized. Therefore, the calculation of the O content from C, H, N, S and ash content is accepted.

The O/C_{org} ratio can sometimes exceed 0.4 due to post-pyrolytic treatment or by co-pyrolysis with oxidative or catalytically acting additives. In this case, the EBC would carry out a plausibility check and grant an appropriate exemption, provided that product quality and environmental protection are guaranteed.

7.4 Volatile Organic Compounds (VOC) are determined by thermogravimetric analysis (TGA).

During the pyrolysis process aromatic carbon, carbonates and a multitude of diverse volatile organic compounds are formed. The latter constitutes a large part of the pyrolysis gas that partially condensates on biochar surfaces and pores. These condensed pyrolysis gas compounds are substantial constituents of biochar materials [7,8], are essential for certain biochar functions and thus necessary for the characterisation of biochar.

However, a quantitative determination of VOCs cannot be carried out at reasonable cost.

For an independent estimation of the true pyrolysis temperature, which can deviate from the temperature measured at the reactor for various reasons, the weight loss of volatile compounds of biochar is determined by gradually increasing the temperature in the absence of air using the thermogravimetric analysis (TGA). The TGA diagram can thus be used to determine both the absolute VOC content and the maximum temperature to which the biochar was exposed during pyrolysis.

The total VOC content and its temperature-dependent degassing are considered as a criterion for the evaluation of the pyrolysis process. For this reason, it is considered sufficient that the TGA analysis need only be carried out in the first control year of a pyrolysis unit.

7.5 The biochar nutrient contents must be declared at least for nitrogen, phosphorus, potassium, magnesium, calcium and iron.

The nutrient contents of different biochars depends on the feedstock selection and can account for up to a third of the total weight. It should be noted that these nutrients are only partially available to plants due to covalent bonds (especially in the case of nitrogen) and/or the high adsorption capacity of the biochar and may only be reincorporated into the biological cycle over decades. The nutrient availability of the phosphorus found in biochar is for instance only about 15% in the first year, that of nitrogen a mere 1%, while availability of potassium can reach 50% [9].

For the use in agriculture and animal husbandry nutrient information is legally required. For material uses, the nutrient contents are generally less relevant, but depending on the application, they may influence certain material properties, especially with higher contents of calcium, potassium and magnesium, which is why the declaration of the nutrient contents is also mandatory for both material certification classes.

7.6 The following limit values for heavy metals must not be exceeded

For EBC-Agro, the following maximum values for heavy metal contents are based on the EU-Fertilising Products Regulation EU 2019/1009 [10], the German Federal Soil Protection Ordinance [11]; and for EBC-AgroOrganic on the EU regulations 2019/2164 on organic production, and the Swiss Ordinance on Risk Reduction related to Chemical Products (ChemRRV). By precautionary principle, EBC-Urban and EBC-ConsumerMaterials must meet the same heavy metal limit values as EBC-Agro. As biochar certified under EBC-BasicMaterials has to be included into material matrices from where the biochar cannot leach, no limit values for heavy metals apply.

As of 2022, silver is added to the list of heavy metals that must be quantified and the content of Ag must be declared. No limit value is applied. Additional parameters and methods apply to EBC Feed, which are described in Chapter 10.

Tab. 2: Limit values for heavy metals according to the EBC application classes.

	EBC-Feed	EBC-AgroBio	EBC-Agro / EBC-Urban / EBC-ConsumerMaterials	EBC-BasicMaterials
Pb	10 g t^{-1} (88%DM)	45 g t^{-1} DM	120 g t^{-1} DM	no limit value, only declaration required
Cd	0.8 g t^{-1} (88% DM)	0.7 g t^{-1} DM	1,5 g t^{-1} DM	
Cu	70 g t^{-1}DM	70 g t^{-1}DM	100 g t^{-1} DM	
Ni	25 g t^{-1} DM	25 g t^{-1} DM	50 g t^{-1} DM	
Hg	0.1 g t^{-1} (88% DM)	0.4 g t^{-1} DM	1 g t^{-1} DM	
Zn	200 g t^{-1} DM	200 g t^{-1} DM	400 g t^{-1} DM	
Cr	70 g t^{-1} DM	70 g t^{-1} DM	90 g t^{-1} DM	
As	2 g t^{-1} (88% DM)	13 g t^{-1} DM	13 g t^{-1} DM	
Ag	no limit value, only declaration required			

Heavy metals are an essential component of all ecosystems. Even in natural soils that are hardly influenced by human activities, every plant absorbs more than 50 geogenic elements of the periodic table and amidst those there are all essential heavy metals. Heavy metals are only toxic if their concentration is exceedingly high and they are bio-available, which is why the limit values listed in Table 2 have been defined for each type of application.

With the exception of a few heavy metals that are volatile or semi-volatile at the prevailing pyrolysis temperatures (e.g., mercury), the amount of heavy metals originally contained in the biomass is retained in the biochar. While the weight of the original biomass is reduced during pyrolysis by more than 50% due to the loss of carbon, hydrogen, and oxygen, heavy metals remain which leads to increased concentration, i.e., the heavy metal content in the biochar is higher than in the original biomass.

As long as the biomass was not grown on contaminated soils or has increased heavy metal contents due to plant treatments (e.g., copper spraying in viticulture) or due to contamination with wastes, the concentration effect from pyrolysis is not critical. Heavy metal contents beyond the limit values thus indicate above all the contamination of the biomass used and thus represent an additional control of the biomass quality.

In industrial applications, including the use of biochar in asphalt, concrete and composite materials, the risk of heavy metals being leached into the environment or harming users of these industrial materials is generally quite low. For this reason, EBC-BasicMaterials only requires the declaration of heavy metal contents but does not define limit values. We expect to set further application specific EBC limit values in the future. However, at the present stage of industrial development accurate, use-specific limits cannot yet be determined meaningfully by the EBC. It is incumbent upon industrial manufacturers that seek to incorporate biochar into their products to comply with the respective limit values pertinent to their industry. In addition, all industrial producers and users are urged to carefully consider end of the life handling of their industrial materials to prevent pollutants from entering the environment.

7.7 pH, salt content, bulk density, and water content must be declared.

The pH value of biochar is an important criterion for the targeted use in substrates as well as for the fixation of nutrients in animal husbandry as well as in industrial products. The salt content, measured via electrical conductivity of the biochar leachate, may indicate a contamination of the feedstock, and should therefore be measured. Bulk density (on dry matter base) and water content are necessary specifications for trading biochar as well as for the production of consistent substrate mixtures and materials requiring consistent carbon contents.

The biochar of the classes EBC-Feed, EBC-Agro, EBC-AgroOrganic, and EBC-Urban must be adjusted to a water content that prevents dust formation and thus also spontaneous combustion (see also chapter 9.3). Appropriate storage must prevent the biochar from drying. EBC recommends a water content of 30% for this purpose. There are no guidelines regarding water content for EBC-ConsumerMaterials and EBC-BasicMaterials, which may only be traded B2B. However, if the biochar is sold with a water content of less than 30% or a water content that cannot effectively prevent dust formation, the manufacturer and trader must indicate the associated hazards following relevant standards and local, national, and international requirements. This includes but may not be limited to spontaneous ignition, dust explosion, and the health hazards of inhaling (fine) dust. Appropriate safety precautions must be indicated.

7.8 The determination of the water holding capacity (WHC)

Water holding capacity (WHC) provides guidance for mixing biochar with liquids, e.g., liquid fertilizer, digestate, storm water management. It is also a valuable indication of its effectiveness in increasing a soil's water holding capacity and for humidity buffering when e.g., applied to the root zone. WHC may also help to evaluate the moisture absorption and buffering capacity of construction and other biochar-based materials.

7.9 Electrical conductivity of the solid biochar

The electrical conductivity of biochar is a highly important indirect parameter to compare batches and the homogeneity of biochar within a given batch. Moreover, it was shown that certain effects of biochar in soil, in the digestions system, in anaerobic digesters, in composting, and in certain composite and construction materials may be related to the electrical conductivity of the solid biochar. It should not be confounded with the electrical conductivity of the aqueous leachate of biochar, which is used to estimate the salt content.

7.10 Specific surface area and pore size distribution are recommended as additional parameters

The specific surface area according to BET is an important characterization and comparison criterion for the physical structure of biochar. It should be noted, however, that no method provides absolute values for the specific surface area, but only relative values which allows for standardized comparisons. The BET surface area is often over- and misinterpreted: The BET does not allow any statement about the colonization potential for microorganisms. A higher BET surface does not necessarily mean a higher potential for contaminant binding. For a more precise evaluation of the pore properties, at least data on pore size distribution would be required. Due to the costs, the measurement of specific surface area and pore size distribution are recommended as additional parameters but are not mandatory.

7.11 Limit values for PCB and PCDD/F must be observed

In modern pyrolysis plants, only minimal quantities of PCBs, polychlorinated dibenzo-p-dioxins and furans (PCDD/F) are produced [12]. For this reason, except for EBC-Feed, it is considered sufficient that PCB and PCDD/F must only be quantified once in the first control year of a pyrolysis unit. These pollutant contents depend mainly on the chlorine content of the pyrolyzed biomass. All biomasses authorised on the positive list have a low chlorine content and only very low contents of these organic pollutants must be expected for the resulting biochar. If the control bodies of the EBC consider the risk of chlorine contamination of the source biomass to be relevant, additional PCB and PCDD/F analyses may be required. The limit values are based on the soil protection regulations in force in Germany and Switzerland [11,13].

The limit values for PCB are 0.2 mg kg^{-1} (DM), and for PCDD/F they are 20 ng kg-1 (I-TEQ OMS), respectively.

7.12 Limit values for PAH contents must not be exceeded

Certification Class	EBC-Feed	EBC-AgroOrganic	EBC-Agro	EBC-Urban	EBC-ConsumerMaterials	EBC-BasicMaterials
16 EPA PAH	declaration	4±2 g t^{-1} DM	6.0+2.2 g t^{-1} DM	declaration	declaration	not required
8 EFSA PAH	1.0 g t^{-1} DM					4 g t^{-1} DM
benzo[*e*]pyrene benzo[*j*]fluoranthene	< 1.0 g t^{-1} DM for each of both substances					

The pyrolysis of organic materials causes the formation of polycyclic aromatic hydrocarbons (PAH) [14]. The PAH content of biochar depends primarily on the pyrolysis conditions like temperature and the separation of biochar and pyrolysis gases in the reactor and discharge [15,16]. Appropriate production technologies with both classical kilns and modern pyrolysis reactors can avoid undesired PAH-contamination of biochar, correct process control provided. The type of biomass feedstock used for biochar production has a negligible influence on the PAH content [17].

During biochar production, PAHs are usually released with the pyrolysis gases and are destroyed when these pyrolysis gases are combusted to produce thermal and electric energy. However, depending on the process conditions, a smaller or larger part of the released PAHs can be adsorbed by the simultaneously produced biochar. Moreover, if biochar is cooled down in the presence of PAH-containing pyrolysis gas, significant amounts of PAHs condensate on the biochar surfaces within the complex porous system. Thus, biochar and pyrolysis gas must be separated at temperatures that do not allow condensation and sorption of PAH on the biochar. Controlled vapor quenching may support avoidance of PAH accumulation.

In principle, biochar with a very low PAH content can be produced even by the simplest of means, as demonstrated by the Kon-Tiki flame curtain kiln [18]. However, some industrial pyrolysis and gasification technologies developed over the past decades resulted in biochars with elevated PAH levels [19], which are an indication of unsatisfactory or unsuitable production conditions. The technical feasibility to produce biochar with very low PAH contents is demonstrated by all EBC-certified biochar companies and their technology suppliers since 2012.

Individual PAH differ widely in their toxicity [20]. The type and degree of toxicity (e.g., genotoxicity, carcinogenicity, ecotoxicity) depends on the molecular structure, the concentration, the bioavailability, the exposure route, and the temporal course of the exposure. The bioavailability of a PAH molecule is determined by the matrix to which the toxin is bound when exposed to humans, animals, or ecosystems.

As shown by Hilber et al. [21,22], biochar that is amended to soil acts more as sink than a source of PAHs. As PAHs are ubiquitous in agricultural and urban environments such as soil or the atmosphere, low-PAH-biochars that are used in soil adsorb more PAHs from the soil than they release into the soil. The high adsorption capacity distinguishes biochars from other amendments like compost, digestate, manure, and other fertilizers. The use of identical PAH limit values for low and high PAH-adsorbing materials can thus be questioned.

Biochar is not only a potent adsorber of PAHs [23] but also the bioavailability of biochar-bound PAHs is extremely low [21]. Compared to compost, digestate, fertilizer, atmospheric depositions, or hay which are all important entry points of PAHs into agronomic systems [24,25], PAH-bioavailability from biochar is most likely the lowest. The risks of bioavailable PAHs for plants, soil biota, animals, and humans are rather well known and investigated [20,26–28]; however, to our knowledge, only one initial investigation about the risks of exposure to biochar bound PAHs was published yet [29]. In the absence of a proper risk assessment, the precautionary principle led the regulators to apply for biochar the same limit values for PAH contents as for compost or digestate. Another reason for applying the same PAH limit values to all soil amendments is the principle of not allowing total PAH concentrations in soil to build up over time and keeping total concentrations below the limit values set in regulations to protect soil from pollution.

Hilber et al. 2019 [30] demonstrated that using low PAH limit values is prudent and reasonable. When biochars with higher contents of PAHs (up to 60 mg Σ16 EPA-PAH per kg biochar) were introduced in the rumen of a fistulated bovine, more than half of the PAHs from the biochar were released in the digestive system of the cow and may thus have impaired the biological system. Therefore, applying the precautionary principle and complying with existing regulations for other substrates and materials in agriculture and industry, the EBC limit values for PAHs were set for the various application classes on the following existing legal regulations and considerations:

In the upcoming amendment to the new EU fertilizer regulation, a limit value of 6 mg kg^{-1} DM will be set for the sum of 16 EPA-PAH [3,31]. Since 2021, this limit value applies to EBC-Agro. The list of 16 individual PAH compounds was compiled by the U.S. Environmental Protection Agency to allow monitoring and regulation of PAHs. These 16 compounds were selected from hundreds of PAHs [32] based on environmental relevance, toxicity, and ability to measure them.

The reason for using the 16 EPA-PAHs as reference and the selection of such low limit values is, as explained above, not based on biochar science or biochar-based risk assessments but is entirely based on limit values that were established for other soil-amendments like compost, digestate, plant substrates, and (contaminated) soil itself. In absence of investigations how PAHs in biochar may pose risks to the environment and health, it was easier and faster to use the lowest known limit values for any type of soil amendment and apply it for biochar, too. The alternative to this pragmatic decision would have been to wait until systematic research provides the evidence to define reference substances and limit values specifically for biochar to protect soils, plants, animals, workers, and consumers - an unacceptable delay for biochar mainstreaming. For this reason, the EBC defended these low PAH limit values in its standards since 2012.

According to both the Swiss Ordinance on Risk Reduction related to Chemical Products (ChemRRV [13]) and the EU Organic Farming Regulation [4], a limit value of 4 mg kg^{-1} DM applies to the sum of 16 EPA-PAH, which is, therefore, assigned as limit value for EBC-AgroOrganic. However, such low limits are extremely difficult to analyse and can only be assured at a 50% accuracy. There is no scientific proof that the 4 mg kg^{-1} of the organic farming ordinance is safer or less risky than the 6 mg kg^{-1} from the upcoming EU fertilizer regulation.

For animal feed, no EU or member state limit value for PAHs exist so far, and thus no PAH limit value for feed grade biochar neither. However, with the publication of Hilber et al. [30], we know that PAHs might get desorbed in cattle rumen and thus may harm animals that are regularly fed with biochar containing fodder. Moreover, the EBC should not allow that biochar with too high amounts of PAHs entered the soil via the animal feed pathway. As the current EU laws do not prohibit feeding an animal with substances that would not be permissible as a soil amendment, it is extremely important that biochar used as an animal feed additive is subjected to PAH quality control.

The absence of governmental regulations for PAHs in animal feeds allows us to question if selecting the 16 EPA-PAH compounds is the best choice for monitoring PAHs on biochar. Using a limit value for the simple sum of those 16 PAHs attributes equal importance to each of the individual substances in the interpretation of the analysis. Although all 16 PAHs are among EPA's priority environmental pollutants, this list can be divided into eight PAHs with insufficient or no evidence of carcinogenicity and eight carcinogenic PAHs[1]. Therefore, the latter compounds should be given special attention [33] and, consequently, the EBC defines limit values for Σ8 EFSA PAHs as follows.

In 936 biochar analyses using the EBC-accredited methods, we found that the eight non-cancerogenic PAHs accounted for more than 80% of all analysed PAHs. Given the high number of analyses this can be considered a common distribution of PAHs adsorbed by biochar in common pyrolysis and gasification technologies [16]. The current Σ16 EPA-PAH limit values for biochar are thus based on the assumption that this is the general distribution of the individual PAH compounds. It is, however, technically possible to reduce the content of smaller (non-cancerogenic) PAHs in post-pyrolytic treatments whereas the more complex (cancerogenic) PAHs remain in the biochar because of the higher affinity of biochar for higher molecular weight-PAHs. Hence, the 4 mg Σ16 EPA PAHs kg^{-1} of such a biochar could mainly consist of cancerogenic

[1] *The eight cancerogenic compounds within 16 EPA PAH = 8 EFSA PAH* are Benzo[*a*]pyrene, Benzo[*a*]anthracene, Chrysene, Benzo[*b*]fluoranthene, Benzo[*k*]fluoranthene, Dibenzo[*a*,*h*]anthracene, Indeno[1,2,3-*cd*]pyrene, Benzo[*ghi*]perylene

substances like Benzo[*a*]pyrene (BaP). Such high contents of cancerogenic substances would pose a considerable health risk when applied to feed and soil. To avoid such risks due to potential post-pyrolytic treatment of highly PAH-contaminated biochars, the EBC introduced in 2022 a new limit value for the eight cancerogenic compounds that are included in the 16 EPA PAHs (see footnote).

The EBC follows the European Food Safety Authority's (EFSA) suggestion to evaluate food safety by monitoring the total concentrations of these eight cancerogenic PAHs to evaluate food safety [34]. In the data set of the 936 EBC Σ16 EPA PAHs analyses, 99% of all analysed samples that complied with the EBC-Agro limit value of 6 mg Σ16 EPA PAHs kg^{-1} contained less than 1 mg Σ8 EFSA PAHs kg^{-1}. As we do have assurance from the EBC-certification control that none of the 936 samples were subjected to post-pyrolysis treatment to reduce selected PAH-species, we can assume with sufficient confidence that the 936 sample represent the common distribution of PAHs adsorbed by biochar in common pyrolysis and gasification technologies. In the case of post-pyrolytic treatment or the use of novel pyrolysis technologies that reduce selectively the lighter (non-cancerogenic) PAHs, the new limit value of 1 mg Σ8 EFSA PAHs kg^{-1} is safer than the (higher) Σ16 EPA PAHs limit values that could mask elevated amounts of cancerogenic PAHs.

For the above reasons, 1 mg Σ8 EFSA PAHs kg^{-1} is defined as new limit value for EBC-Feed, EBC-Urban and EBC-ConsumerMaterials. To improve the safety of EBC-Agro and EBC-AgroOrganic, the 1 mg Σ8 EFSA PAHs kg^{-1} there applies as an additional limit to the existing limit values defined for the Σ16 EPA PAHs kg^{-1}. For EBC-BasicMaterials a limit value of 4 mg Σ8 EFSA PAHs kg^{-1} is defined. The Σ16 EPA-PAH needs to be declared for all certification classes, except for EBC-BasicMaterials. The EU-REACH regulation's list of eight carcinogenic PAHs has two substances that differ from the 8 EFSA and the 16 EPA compounds[2]. To comply with the EU-REACH regulations, the EBC includes from 2022 onwards these two additional PAHs into its analytical program and controls that neither benzo[e]pyrene nor benzo[*j*]fluoranthene is contained at higher concentrations than 1 mg kg^{-1} for all application classes.

The **EBC-Urban** limit value for PAHs is defined by the eight carcinogenic PAHs which provides reliable safeguards for workers, citizens and soil. Because PAHs are ubiquitous in urban environments (e.g., from car exhaust, tyre abrasion, domestic heating, and atmospheric deposition), and because biochar applied to urban soil is a strong adsorber for PAHs, EBC-certified biochar will act in the urban environment as a net adsorber of those environmental toxins.

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[2] The COMMISSION REGULATION (EU) No 1272/2013 referes to Benzo[*a*]pyrene, Benzo[*e*]pyrene, Benzo[*a*]anthracene, Chrysene, Benzo[*b*]fluoranthene, Benzo[*j*]fluoranthene, Benzo[*k*]fluoranthene and Dibenzo[*a,h*]anthracene as PAHs that are classified as carcinogens. Compared to 8 EFSA PAH, which are a subset of the 16 EPA PAH, Indeno[1,2,3-*cd*]pyrene and Benzo[*ghi*]perylene are missing in the EU-regulation. However, Benzo[*e*]pyrene and benzo[*j*]fluoranthene are not part of either the 8 EFSA PAHs or the 16 EPA PAHs. Therefore, benzo[*e*]pyrene and benzo[*j*]fluoranthene have not yet been quantified in routine analysis of biochar but are added to the EBC-analyes since 2022 to guaranty conformity with the EU-REACH regulation.

The limit values for **EBC-ConsumerMaterials** are stricter than the EU-REACH regulation for consumer products which bans all products containing more than 1mg kg^{-1} of one of the eight individual carcinogenic PAHs [1]. The EBC assumes it as consistent to use the same limit value of cancerogenic PAHs for soil, feed, food, water, ecosystem, and consumer product applications.

The limit value for Σ8 EFSA PAHs in **EBC-BasicMaterials** is 4 mg kg^{-1} because the biochar particles are embedded and firmly bound into mineral or polymeric matrices (e.g., concrete, asphalt, plaster, composites) and direct contact with living organisms can be avoided. This limit is mainly based on what can be regarded as harmless to employees handling the raw materials with adequate safety measures (packaging, storage, and ventilation) and suitable personal protective equipment. Moreover, the EBC applies for BasicMaterials also and additionally the EU limit value for products where skin contact can be expected which is a maximum of 1 mg kg^{-1} for each individual compound of the 8 EFSA PAH and for the additional EU-PAHs benzo[e]pyrene, and benzo[j]fluoranthene.

Thanks to the above outlined requirements, all EBC certified biochars are compliant with the EU-REACH commission regulation [1]. Still, the Σ16 EPA-PAH must be declared for all EBC certification classes except for EBC-BasicMaterials.

It should be noted that due to the high adsorption capacity of biochar, most of the analytical methods used for example for soil analysis of PAHs are not suitable for biochar [19]. It is therefore strongly recommended to always use the service of EBC accredited laboratories to perform PAH analyses even outside of the context of EBC certification.
The very low PAH limit values only allow an analytical accuracy of 50% for the 4 mg Σ16 EPA PAHs kg^{-1} limit value and of 40% for the 6 mg Σ16 EPA PAHs kg^{-1} limit value which implies an accuracy of ± 2 mg kg^{-1} dm and ± 2.2 mg kg^{-1} dm, respectively. In general, it should be noted that with such a low analytical accuracy even under professional laboratory conditions, it is not considered appropriate to set two limits so close together. Although the EBC follows the various EU regulations for organic and conventional agriculture, the EBC can only urge the EU authorities to harmonise these two limit values.

8. Pyrolysis

8.1 Biomass pyrolysis must be operated in an energy efficient manner.

Except for the preheating of the pyrolysis reactor, the use of fossil fuels for heating the pyrolysis reactor is prohibited. The use of waste heat from other industrial processes, such as bio-digesters or cement production or the use of solar thermal energy is permitted. If the pyrolysis reactor is electrically heated, the use of renewable energy sources or the use of surplus electricity is recommended.

8.2 The pyrolysis gases produced during pyrolysis must be recovered or burned. They are not allowed to escape into the atmosphere.

A significant portion of the global charcoal and biochar production is still made using obsolete technology [35] where most of the original feedstock carbon is released as toxic emissions to the atmosphere. Although the material quality of biochar produced in such kilns may meet EBC requirements, the environmental impact of such production techniques is highly negative.

However, if pyrolysis gases are trapped and are cleanly burned or used as bio-oil for the chemical industry, the environmental impact is neutral and even improved compared to biomass burning or natural decomposition. The EBC certificate guarantees that only climate positive biochar production technology is used and does not release unburned pyrolysis gases to the atmosphere.

8.3 Syngas combustion must comply with national emission limit values.

With emission limit values and regulations differing from one country to the next, any further definition of emission limit values for pyrolysis facilities would exceed the purpose and proportionality of these guidelines. Therefore, manufacturers must provide a guarantee that their facilities comply with national emission regulations. An annual, government accredited emission measurement of the production plant is recommended.

For certification of the C sink potential of biochar, the pyrolysis unit must have an EBC type certificate (see Guidelines for the certification of the C-sink potential) or at least three independent, accredited emission measurements including the methane or hydrocarbon content in the waste gas stream.

8.4 Biochar production must be energy and carbon efficient

Approximately 35 to 60 % of the energy contained in the biomass feedstock is eventually contained in the pyrolysis gas, which is usually burned in the pyrolysis unit. Part of the energy released during the combustion of these gases is often used to heat the biomass for pyrolysis. Excess heat must be used to at least 70%, e.g., for drying biomass, for district heating, for generating electricity or for similar sustainable purposes. For a transitional period of maximum 3 years after installation of the pyrolysis plant, an exemption for missing waste heat recovery can be applied for. In the meantime, a solution for efficient waste heat recovery must be developed.

Alternatively, the pyrolysis oil and/or gas can also be captured and used for energy storage, e.g. to deliver peak loads in district heating in winter by burning pyrolysis-oil that was collected during summer. The material use of the bio-oil and/or the upgrading of the pyrolysis gas into basic chemicals such as methanol are also conceivable options to reach eventually a carbon efficiency of at least 70%.

9. Work safety and health

9.1 Fire and dust protection regulations are to be complied with local and national regulations throughout the entire production, transportation, and user chain.

9.2 All workers must be informed in writing about possible risks and dangers of and around the production facility and sign the document. This concerns, in particular, the self-ignitability of char dust, respiratory protection, contact with bio-oil and tars and possible gas leakage.

9.3 During transportation and bulk transfers, attention must be paid to the biochar being sufficiently moist to prevent dust generation or dust explosions (cf. chapter 7.7).

9.4 Workers must be equipped with suitable protective clothing and breathing masks where necessary.

10. Biochar for use as a feed additive (EBC-Feed)

Biochar is a traditional feed additive that was often used to treat digestive problems of livestock. Since 2010, biochar is increasingly also used as an additive to daily feed mixtures. The use of biochar (i.e., vegetal carbon) as a feed additive is authorized by the EU-Feed regulation L 159 / 25 Nr . 575 / 2011 [2]. The EU provides different and additional limits for the use of biochar as feed compared to its use as a soil additive (Directive 2002/32/EC of 7 May 2002 on undesirable substances in animal feed [2] and Regulation (EC) No 396/2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin [36]. Therefore, the certification of EBC-Feed requires the analysis and control of additional parameters compared to those presented in chapter 7 and Annex 1 of the EBC Guidelines. Some analytical methods and calculations have to be adapted. **The permissible test methods as well as the analytical methods for the individual parameters are detailed in Annex 2.**

10.1 Approval as animal feed producer

Producers of EBC-Feed certified biochars must mandatorily register as feed producers with the relevant authorities in accordance with applicable regional, national and/or EU regulations and submit proof of this to the EBC.

The aim of EBC-Feed is to guaranty that the biochar quality is apt for animal feeding and that its production is sustainable. The equally important aspects of feed safety and hygiene during production, and especially storage and transport, can only be controlled by the EBC to a limited extent and thus not fully be guaranteed.

10.2 Biomass - only pure plant biomass feedstocks are permitted

When the EBC-Feed Certificate was introduced, only untreated trunk wood was approved as the source material for feed grade biochar production. In the meantime, however, a sufficient number of scientific studies have been published [37], which show that biochar produced from other plant biomass had just as positive an effect on feed efficiency and animal health as wood based biochar. For this reason, all pure plant biomasses are approved since 2020 for the production of EBC-Feed biochar according to the EBC feedstock list. Mineral additives are not permitted. Feedstocks with chemical additives, contaminations, or the risk of contaminations due to non-controllable source are excluded (e.g., chemically treated wood, paper sludge, green waste from municipal collection, etc.).

10.3 Separation of impurities

A significant risk to feed safety comes from possible impurities that can contaminate the biochar via the feedstock, the production process, or during storage. These are mainly pieces of metal, plastic, glass, and stones. Thus, rigorous control of the feedstock is necessary before it enters the pyrolysis process. To prevent metal and other impurities originating from the pyrolysis plant, it is necessary to regularly check the plant (check that no screws are missing, parts are broken or that abrasion occurs, etc.). To exclude the possibility of impurities entering the feed biochar after production, the biochar must be packaged and stored tightly sealed.

It is recommended to pass both the biomass before entering the pyrolysis unit and the biochar between discharge and packing through a magnetic metal separator. Also, stones and glass fragments pose a risk of injury to the animals if swallowed, mainly because of possible sharp edges and corners, and may also be present, for example, in source materials such as forest wood chips or crop residues otherwise commonly assumed to be clean. To at least eliminate this risk, in addition to using a stone separator, grinding the biochar to < 3 mm is recommended; silicate (glass) and stone per se are not toxic or harmful.

Feed manufacturers must be able to guarantee that marketed feed products are free of impurities following government requirements. According to Regulation (EC) 183/2005, a feed producer is responsible for feed safety. The EBC control processes (technical pre-audit, annual EBC inspection, visual inspection of random samples, laboratory analysis of a representative sample from each batch, reserve samples, documentation) provide assistance in this regard, but cannot replace the manufacturer's guarantee. In the event of complaints from users or other complaints and disputes, certification as an EBC-Feed offers only limited security. To meet the responsibility for feed safety, EU Regulation 183/2005 strongly recommends that feed producers implement a Hazard Analysis and Critical Control Point (HACCP) system ("Feed business operators [..] shall put in place, implement, and maintain, a permanent written procedure or procedures based on the HACCP principles"). We therefore recommend additional external quality assurance by a certification body specialized in feed, such as GMP+ (https://www.gmpplus.org). Their certification process includes HACCP.

10.4 Pyrolysis temperature and intensity

Although contaminated feedstock is not allowed within EBC feed, trace contaminations, e.g., with pharmaceuticals or mycotoxins, can never be excluded completely. To assure the pyrogenic degradation of these organic micropollutants the pyrolysis temperature has to reach at least 500 °C for at least 10 min [38].

10.5 Heavy metals

According to feed regulations, the content of heavy metals including arsenic, lead, cadmium and mercury must be stated. The use of biochar as feed is based on the following limit values to be calculated on 88% of the dry matter content: arsenic: 2 mg kg^{-1}; lead: 10 mg kg^{-1}; cadmium 0.8 mg kg^{-1} and mercury: 0.1 mg kg^{-1}.

10.6 Σ8 PAHs below 1 mg kg^{-1},

The limit value for the Σ8 EFSA PAHs is set to of 1 mg kg^{-1} (see chapter 7.12). To comply with the EU-REACH regulations, benzo[e]pyrene and benzo[j]fluoranthene must not be contained at higher concentrations than 1 mg kg^{-1}.

10.7 Dioxine, furane, dioxin-like PCB (WHO-PCB) und non-dioxin-like PCB (DIN-PCB).

The EU feed regulations prescribe strict limits for polychlorinated dioxins, furans and PCBs, which are well below the limits of the soil protection ordinance. Therefore, (1) each batch of feed biochars must be analyzed for these substances, and (2) the accredited test method must have a lower detection limit. Consequently, special test methods and limit values for feed grade biochar apply here.

For PCDD / PCDF, a trigger value of 0.5 ng TE kg^{-1} at 88% DM and a limit of 0.75 ng TE kg^{-1} at 88% DM apply. For dl-PCB, a trigger value of 0.35 ng TE kg^{-1} at 88% DM applies. For PCDD / PCDF + dl-PCB the limit value is 1.25 ng TE kg^{-1} at 88% TS. For the sum 6 of DIN PCB, a limit value of 10 µg TE kg^{-1} at 88% DM applies.

10.8 Fluor < 150 mg kg^{-1} (88% TS)

The fluor content must be lower than <150 mg kg-1 (88% TS). However, fluorine salts are usually volatile in pyrolysis conditions and will rarely occur in biochars in significant concentrations.

10.9 Dry matter, crude ash, ash insoluble in hydrochloric acid

The specification of dry matter, crude ash content and HCl-insoluble ash are prescribed standard values of the EU feed regulations and must be stated on the product label. The content of the ashes must be determined by combustion at 550 ° C and given on an 88% dry matter basis.

10.10 Crude protein, crude fibre, crude fat

The indication of crude protein, crude fiber and crude fat contents are prescribed standard values of the EU feed regulations. Crude protein, crude fiber and crude fat are completely decomposed in the course of complete pyrolysis and are therefore no longer present in biochar. A biochar is considered to be completely pyrolyzed if the H / C_{org} ratio is <0.7, which is the prerequisite for EBC certification. Thus, the analysis of crude protein, crude fiber and crude fat is not required and set by definition as 0 g kg^{-1}. The information is mandatory and must be stated on the product label.

11. Certification of companies that process biochar and manufacture biochar-based products

In agriculture and animal husbandry, biochar is rarely used in its pure form. More often it is part of a processed product such as a soil amendments, potting soil, compost, fertilizer, bedding material, feed, or as an additive to anaerobic digestion or silage. In addition to the producers specialized in biochar manufacturing, a growing industry has developed, acquiring and processing biochar as a raw material for biochar-based products.

To guarantee and properly label products made with EBC certified biochar, the entire supply chain including production, processing, packaging and labeling of the products needs to be inspected and certified.

Products containing biochar are only allowed to use the EBC logo and the inscription "Manufactured with EBC certified biochar" if the biochar processing company and their biochar-based products have also been certified according to the following guidelines.

11.1 Exclusive use of EBC certified biochar

The risks associated with the use of non-certified biochar in agriculture, livestock farming and in products ultimately destined for agricultural use, such as compost or biogas slurry, are very high, since in this case pollutants such as PAHs, dioxins and heavy metals may enter the human food chain and accumulate permanently in soils and the environment.

Therefore, products made with biochar can only become EBC certified if the processing company uses exclusively EBC certified biochar for their biochar-based products. The certified company may not use, store, or trade any biochar for agronomic purposes that is not EBC certified.

Without EBC exemption, no non-EBC certified biochar may be used, stored and traded by the certified company.

11.2. Incoming goods inspection

All incoming biochar or biochar-based products must have the corresponding EBC certificate (EBC-Feed, EBC-AgroOrganic, EBC-Agro, EBC-Urban, EBC-ConsumerMaterials, EBC-BasicMaterials) marked on the delivery documentation and labels. The incoming goods inspection must be documented. Unlabeled biochar and biochar-based products without an EBC exemption permit must not be processed.

11.3 Storage

Biochar and biochar-based products must be stored in such a way that no contamination can occur. Particular attention should be paid to gaseous pollutants (for example engine exhaust gases) as these can be absorbed by the biochar. Biochar processors must ensure that neither different EBC certification classes nor different batches from different or the same manufacturers are mixed without documentation. The quality and origin of stored biochar as well as a traceable identification number and product name must be marked clearly visible on the storage or packaging material.

11.4 Processing journal

Each processing step of biochar and biochar-based products must be documented in a processing journal. The quantity and quality of all processed biochar and the amount of biochar contained in the final products must be documented.

If the biochar or biochar-based products are merely repackaged or relabeled, the quantity and quality of the original and final products must still be listed in the processing journal.

The control of the flow of goods (balance between incoming biochar and biochar products, specific processing, and the outgoing biochar and biochar products) must be tracked and always documented.

12. Labeling and Advertising with EBC Certification

12.1 Trademark protection and compulsory information

12.1.1 Registered trademarks

Carbon Standards International owns the following EU trademarks:

(1) EU guarantee mark No 018071838 'EBC' (word mark) and

(2) EU guarantee mark No 018071835 'Certified Biochar EBC European Biochar Certificate (EBC)' (figurative mark), reproduction:

(hereinafter referred to as 'EU trademarks').
Each of the EU trademarks are registered in respect to the following list:

Class 01: Chemical substances, chemical materials and chemical preparations and natural elements, in particular biochar, activated carbon activated adsorbents, activated carbon filters for the purification of gases, and activated carbon filters for the purification of liquids; Growth and fertilizers and chemicals used in agriculture, forestry and horticulture, in particular fertilizers (in part) consisting of biochar (biochar); Putties, fillers and glues for industrial purposes, in particular coal for filters for removing organic contaminants from water; Filter materials [chemical, mineral, vegetable and other raw materials], in particular activated carbon.
Class 04: Fuels, in particular of biochar (charcoal, charcoal).
Class 05: Biochemical feed additives made from biochar.
Class 19: Building materials and components, not of metal, (partially) consisting of biochar.
Class 31: Foodstuffs and animal feed (in part) consisting of biochar (biochar); Litter and bedding materials for animals (partially) consisting of biochar (biochar).
Class 40: Production of coal by biomass pyrolysis; Processing of biochar (biochar) as a raw material for the production of various products.

(hereinafter referred to as 'the goods and services claimed')

12.1.2 Right to use the EU trademark

Carbon Standard International grants:

(1) Manufacturers of EBC certified biochar, as well as of products containing EBC certified biochar,

(2) Processors and traders of EBC certified biochar and products containing EBC certified biochar and

(3) Users of EBC certified biochar (e.g., farmers, operators of composting plants, operators of biogas plants) as well as of products containing EBC certified biochar (e.g. farmers, gardeners, animal keepers).

the right to use these EU trademarks for the aforementioned goods and services under the following conditions:

The EU guarantee trademark No 018071838 "EBC" (word mark) may only be used alone or with the following additions

(1) "Zertifikat" / "Certificate", oder "Zertifizierung" / "Certification" oder "zertifiziert" / "certified"

(2) "Agro", "AgroOrganic", "Feed", "Urban", "ConsumerMaterials", "BasicMaterials"

The EU guarantee trademark No 018071835 "Certified Biochar EBC European Biochar Certificate (EBC)" (figurative mark) may only be used as registered. Additions or modifications are not permitted.

12.1.3 Advertising with laboratory analysis according to EBC standard

If an analysis of the biochar has been carried out by an accredited laboratory (see list at www.european-biochar.org/en/ct/10) in accordance with the EBC standard, but no EBC certification was obtained, the lack of certification must be pointed out in a suitable form when advertising the analysis result. Misleading statements in this regard should be avoided in any case. Permissible are for example formulations like "laboratory analysis after EBC standard*", footnote: "not certified".

12.1.4 Contractual penalty

If the user of the warranty marks culpably violates the statutes of these trademarks, he is liable to pay a fine of 500, - EUR to 10,000, - EUR to the Foundation Ithaka Institute. The amount of the fine to be paid shall be determined by Carbon Standard International at its reasonable discretion and, in the event of dispute, reviewed by a court of law as to its appropriateness. Accordingly, Carbon Standard International deprives the user of the right to use the warranty marks.

12.2 Mandatory information on biochar

The shipping label for unprocessed EBC biochar must indicate at least the following information about the biochar:

- The application class of the biochar (EBC-Feed, EBC-AgroOrganic, EBC-Agro, EBC-Urban, EBC-ConsumerMaterials, EBC-BasicMaterials)
- Organic carbon content (C_{org})
- H / C_{org} – ratio
- Nutrient content (N, P, K, Ca, Mg, Fe)
- The highest temperature reached in the pyrolysis process
- pH
- WHC
- Electric conductivity of the solid biochar
- Water content
- Bulk density based on dry mass and milled to < 3mm

Furthermore, the QR code of the certified batch assigned by the EBC must be printed on the packaging and the delivery note. The analytical parameters of the biochar uploaded by the accredited laboratory can thus be accessed via this QR code.

12.3 Production date and QR code

In addition to the QR code of the biochar batch, the production date must be noted on each packaging unit. For large packaging or storing units whose contents are produced over several days, the production period must be marked.

12.4 Mandatory information about biochar containing products

The shipping label and the biochar product packaging label shall include the following information:

- The application class of the biochar (EBC-Feed, EBC-AgroOrganic, EBC-Agro, EBC-Urban, EBC-ConsumerMaterials, EBC-BasicMaterials)
- Organic carbon content of the biochar used in the product
- Biochar content in dry matter contained in the packaging unit

If biochars of different EBC application classes are used in one product, the end product may only bear the EBC application class(es) whose requirements have been met by each individual biochar.

If several EBC certified biochars are mixed in the product, a corresponding averaged values for the organic carbon and nutrient content based on the mass (dm) of the blended biochar portions must be reported. H / C_{org} – ratio, the highest temperature reached in the pyrolysis process, electric conductivity, WHC, and pH must be provided as the range of the lowest and highest value of the individual biochars used.

Certified resellers of biochar or biochar products do not need to name and identify the original company or production site of the biochar.

13. Control, quality management and certification

13.1 Principles of certification

The inspection of the European biochar certificate is coordinated worldwide by the independent, state-accredited inspection body bio.inspecta AG / q.inspecta GmbH. The inspection is carried out on site at each production facility. It takes place once a year. Producers are obliged to keep their production records up to date in accordance with their respective EBC instruction manual (see 12.5).

If a biochar producer desires to become EBC certified, their entire biochar production site must be inspected and certified, regardless of whether only one batch, several or all batches qualify for one of the EBC certificates.

Should an EBC certified producer produce a batch that cannot be certified to EBC BasicMaterials due to non-compliance with limit values, the producer must prove proper disposal of this waste according to local or national regulations. Otherwise, the certification of the plant may be permanently withdrawn.

Biochar processing companies may be exempted from the annual inspection visit to the production site if they can prove that they process less than 10 t of biochar per year. In such cases, compliance with the production and quality guidelines is evaluated by the government accredited inspection body by means of self-declaration and production protocols.

13.2 EBC-certified companies

For production, processing and trade of EBC biochar, a distinction is made between four company types:

a) Biochar producer (on-site inspection)

Biochar producers operate pyrolysis plants and manufacture EBC-certified biochar from biomass. Additionally, they may grind, screen, and/or package biochar. Only biochar produced by the company itself may be stored on the premises, otherwise additional certification as a processing company and trader is required.

If the biochar is further processed by other, non-pyrolytic process steps (e.g., by charging it with nutrients, mixing it into compost, fermentation, activation or blending with other products), an additional EBC certification as a processing company and trader is required.

A technical pre-audit by Carbon Standard International and an annual inspection visit by the accredited inspection body are mandatory. The representative sampling must be carried out by an accredited sampler.

(b) Processing companies and traders (on-site inspection if > 10 t p.a.)

Processing companies that purchase EBC-certified biochar and use it to manufacture new, biochar-based products, must be EBC certified. Common processes are the blending of biochar with additives, activation by thermal processes (production of activated carbon), enhancement by biological and/or chemical treatment or mechanical processing. Furthermore, the mixing of different EBC-certified production batches, which may also be purchased from different EBC-certified manufacturers, also falls under the category of processing (cf. chapter 11).

The trade of unpackaged, loose goods (e.g., containers) or repackaging of purchased biochar is also subject to the inspection and certification obligation for biochar processing plants.

The initial audit is carried out by the accredited inspection body, which also determines the processing protocols and the protocols for documenting the flow of goods with the processing companies.

(c) Trader of packaged goods – no certification needed.

The mere trade by third parties of pre-packaged biochar and biochar-based products labelled by the certified manufacturer according to EBC regulations is not subject to any further inspection and certification obligation.

Therefore, if a non-certified company or person sells EBC-certified biochar or biochar-based products, both the certified manufacturer and the unique ID number and QR code of the biochar batch must be clearly traceable. The certified manufacturer must therefore be named on the label and delivery note. Consequently, the label affixed by an EBC certified company must not be altered, pasted over or removed. If the original label is removed or covered over, the goods are no longer considered EBC certified. Additional labels, however, may be applied alongside the original labels.

If the original manufacturer is not named on the packaging or the delivery note and the goods are thus relabelled, the company placing the goods on the market must then be EBC certified, otherwise it may not label the goods as EBC certified.

The relabelling of closed packaging of certified biochar and biochar-based products or the sale under own trade name without mentioning the actual manufacturer is subject to the certification obligation as a private label trader.

(d) Private Label Traders (remote inspection)

If the biochar and biochar-based products are manufactured, packaged, and labelled by the manufacturer for another company, and the name and contact information of the manufacturing company do not appear on the packaging, the retailer marketing the goods under its brand name must be EBC certified as private label trader. Otherwise, the own brand retailer may not label the goods as EBC certified.

This also applies if closed packaged biochar goods are purchased from other manufacturers or distributors and then relabelled in such a way that the manufacturing company and its contact data are no longer recognizable as such. The company placing the goods under its own brand must necessarily be EBC certified. Otherwise, he may not label the goods as EBC-certified.

Provided there is no repackaging of the goods, EBC certification of private label traders does not require on-site inspection; it can be done via online declaration and remote assessment.

13.3 Registration for certification

To register for certification, please register your company on the EBC website (www.european-biochar.org) and provide all necessary information about your company and production. You will then be contacted by the team of Carbon Standards International (www.carbon-standards.com) who will assist you throughout the entire certification process.

It is highly recommended that new biochar producers contact Carbon Standards International before commencing operations to ensure all required recording procedures are initiated and incorporated into the production processes.

Carbon Standards International AG
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Switzerland
Tel. +41 (0) 62 552 10 90
info@carbon-standards.com

13.4 Technical pre-audit of biochar producers

The technical pre-audit of biochar producers is carried out by Carbon Standard International. The aim of the initial audit is to understand the technical production process to identify potential problems for the certification and quality management. During the technical pre-audit, the standard method and frequency of accredited sampling, the type of retained samples, the determination of dry weights, and the plant's own quality control program may be adapted, if necessary. All adaptations and precessions of the usual certification and quality management procedures, are documented in a specific online instruction manual prepared by Carbon Standard International.

The initial technical audit of biochar producers includes the following steps:

1) The company uploads the detailed technical description and flow charts of the production process to the EBC website.
2) In a video conference between the company to be certified and the Ithaka Institute, open questions are addressed, the technical production details are discussed, and the scope of the on-site visit clarified.

All detailed technical information shared between the production company, the Ithaka Institute, Carbon Standards International, and BioInspecta are subject to strict confidentiality and are protected by data protection law.

Fundamental changes in operational procedures must be reported to Carbon Standards International and may lead to a repetition of the technical audit and an adaptation of the EBC online instruction manual. The accredited inspection body may also order a new technical audit due to operational changes that prevent the inspection visit from being carried out in a meaningful way.

Processors and traders of biochar are subject to an initial audit by the inspection body bio.inspecta AG, but do not need a separate technical audit by the Ithaka Institute.

13.5 EBC instruction manual

The present EBC guidelines describe the basic requirements for EBC certification. For biochar producers, an EBC instruction manual based on these guidelines may describe the exact implementation of these rules where necessary. This includes:

- Organization of the operating documentation,
- Procedure for the annual inspection visits
- Responsibilities of the EBC quality manager
- Requirements for occupational health and safety
- Flow charts for representative sampling
- Flow chart and documentation for taking and storing the retention samples
- Additional analyses of critical or strongly varying parameters (e.g., PAH, heavy metals, contamination or impurities of biomasses, etc.).
- Determination of the dry matter content for each individual packaging unit, if the C-sink potential is to be determined for the individual batches

The EBC instruction manual is a contract between the EBC-certified company and Carbon Standards International. The instruction manual is treated confidentially by the inspection body and Carbon Standard International.

Processing companies and biochar traders do not receive a separate instruction manual.

13.6 EBC quality manager

The management of the certified company must appoint a quality manager who is familiar with the effects of the various production processes on the quality of the biochar. The quality manager must be authorised within the company to implement measures to ensure and control the quality of the biochar and to document them.

The quality manager is the contact person for the accredited inspection body (bio.inspecta) and Carbon Standards International as EBC label holder. If there is a change of personnel in the position of quality manager, the inspection body and Carbon Standards International must be informed immediately.

In the first year and later at least once per certification period, the quality manager is obliged to participate in external trainings of the EBC on the production, quality assurance and application of biochar. The training must be approved by the responsible management.

The quality manager must ensure the proper documentation and evaluation of the operational processes that influence the quality of the biochar. The documentation must be continuously updated and should be regularly submitted to the management of the company. Information about detected defects must be immediately forwarded to the responsible employees and the defects must be corrected.

The quality manager is the contact person for his colleagues in case of disturbances in the production process. He may delegate individual control and documentation tasks to other employees. In this case, he must instruct the responsible employees and monitor the proper execution of the assigned tasks.

14. References

Deutsche Bundes-Bodenschutz- und Altlastenverordnung (BBodSchV), 1999, latest amendment 31.7.2009

1. REACH COMMISSION REGULATION (EU) No 1272/2013 of 6 December 2013 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards pol. *EU-Regulation* **2013**, *1272/2013*.
2. EU-Parliament *Commission regulation (EU) No 575/2011 of 16 June 2011*; Brussels, 2011;
3. EU-Comission *Regulation (EU) 2019/1009 - EU fertilising products and amending regulations*; Brussels, 2019; p. 2019/1009;
4. EU-Comission *Commission implementing regulation (EU) 2019/2164 on organic production and labelling of organic products*; Brussels, 2019;
5. Gy, P. Sampling of discrete materials—a new introduction to the theory of sampling. *Chemom. Intell. Lab. Syst.* **2004**, *74*, 7–24, doi:10.1016/j.chemolab.2004.05.012.
6. Schimmelpfennig, S.; Glaser, B. One Step Forward toward Characterization: Some Important Material Properties to Distinguish Biochars. *J. Environ. Qual.* **2012**, *41*, 1001, doi:10.2134/jeq2011.0146.
7. Yang, H.; Kudo, S.; Hazeyama, S.; Norinaga, K.; Mašek, O.; Hayashi, J. Detailed Analysis of Residual Volatiles in Chars from the Pyrolysis of Biomass and Lignite. *Energy & Fuels* **2013**, 130531120623003, doi:10.1021/ef4001192.
8. Spokas, K.A.; Novak, J.M.; Stewart, C.E.; Cantrell, K.B.; Uchimiya, M.; DuSaire, M.G.; Ro, K.S. Qualitative analysis of volatile organic compounds on biochar. *Chemosphere* **2011**, *85*, 869–882.
9. Camps-Arbestain, M.; Amonette, J.E.; Singh, B.; Wang, T.; Schmidt, H.-P. A biochar classification system and associated test methods. In *Biochar for environmental management*; Lehmann, J., Joseph, S., Eds.; Routledge: London, 2015; pp. 165–194.
10. EU-Parliament *EU fertilizer regulation 2019/1009*; Brussels, 2019;
11. BBodSchV *Bundes-Bodenschutz- und Altlastenverordnung*; Deutsches Bundesamt für Umwelt: Berlin, 1999;
12. Bucheli, T.D.; Hilber, I.; Schmidt, H.-P. Polycyclic aromatic hydrocarbons and polychlorinated aromatic compounds in biochar. In *Biochar for Environmental Management*; Lehmann, J., Joseph, S., Eds.; Routledge: London, 2015; pp. 595–624.
13. ChemRRV *Verordnung zur Reduktion von Risiken beim Umgang mit bestimmten besonders gefährlichen Stoffen, Zubereitungen und Gegenständen*; Bern, 2020;
14. Fagernäs, L.; Kuoppala, E.; Tiilikkala, K.; Oasmaa, A. Chemical Composition of Birch Wood Slow Pyrolysis Products. *Energy & Fuels* **2012**, *26*, 1275–1283, doi:10.1021/ef2018836.
15. Buss, W.; Graham, M.C.; MacKinnon, G.; Mašek, O. Strategies for producing biochars with minimum PAH contamination. *J. Anal. Appl. Pyrolysis* **2016**, *119*, 24–30, doi:10.1016/j.jaap.2016.04.001.

16. Bucheli, T.D.; Hilber, I.; Schmidt, H. Polycyclic aromatic hydrocarbons and polychlorinated aromatic compounds in biochar. **2014**, 593–622.

17. Bucheli, T.D.; Hilber, I.; Schmidt, H.P. Polycyclic aromatic hydrocarbons and polychlorinated aromatic compounds in biochar. In *Biochar for environmental management: Science and technology.*; earthscan, London, U., Ed.; 2015.

18. Cornelissen, G.; Pandit, N.R.; Taylor, P.; Pandit, B.H.; Sparrevik, M.; Schmidt, H.P. Emissions and char quality of flame-curtain "Kon Tiki" kilns for farmer-scale charcoal/biochar production. *PLoS One* **2016**, *11*, doi:10.1371/journal.pone.0154617.

19. Hilber, I.; Blum, F.; Leifeld, J.; Schmidt, H.-P.; Bucheli, T.D. Quantitative Determination of PAHs in Biochar: A Prerequisite To Ensure Its Quality and Safe Application. *J. Agric. Food Chem.* **2012**, *60*, 3042–50, doi:10.1021/jf205278v.

20. WHO Evaluation of certain food additives and contaminants: eightieth report of the Joint FAO/WHO Expert Committee on Food Additives Available online: https://apps.who.int/iris/handle/10665/204410 (accessed on Nov 27, 2021).

21. Hilber, I.; Mayer, P.; Gouliarmou, V.; Hale, S.E.; Cornelissen, G.; Schmidt, H.-P.; Bucheli, T.D. Bioavailability and bioaccessibility of polycyclic aromatic hydrocarbons from (post-pyrolytically treated) biochars. *Chemosphere* **2017**, *174*, doi:10.1016/j.chemosphere.2017.02.014.

22. Hilber, I.; Bastos, A.C.; Loureiro, S.; Soja, G.; Marz, A.; Cornelissen, G.; Bucheli, T.D. The different faces of biochar: Contamination risk versus remediation tool. *J. Environ. Eng. Landsc. Manag.* **2017**, *25*, 86–104, doi:10.3846/16486897.2016.1254089.

23. Li, H.; Qu, R.; Li, C.; Guo, W.; Han, X.; He, F.; Ma, Y.; Xing, B. Bioresource Technology Selective removal of polycyclic aromatic hydrocarbons (PAHs) from soil washing effluents using biochars produced at different pyrolytic temperatures. *Bioresour. Technol.* **2014**, *163*, 193–198, doi:10.1016/j.biortech.2014.04.042.

24. Costera, A.; Feidt, C.; Dziurla, M.A.; Monteau, F.; Le Bizec, B.; Rychen, G. Bioavailability of Polycyclic Aromatic Hydrocarbons (PAHs) from Soil and Hay Matrices in Lactating Goats. *J. Agric. Food Chem.* **2009**, *57*, 5352–5357, doi:10.1021/JF9003797.

25. Berset, J.D.; Holzer, R. Organic Micropollutants in Swiss Agriculture: Distribution of Polynuclear Aromatic Hydrocarbons (PAH) and Polychlorinated Biphenyls (PCB) in Soil, Liquid Manure, Sewage Sludge and Compost Samples; a Comparative Study. *http://dx.doi.org/10.1080/03067319508041324* **2006**, *59*, 145–165, doi:10.1080/03067319508041324.

26. Honda, M.; Suzuki, N. Toxicities of Polycyclic Aromatic Hydrocarbons for Aquatic Animals. *Int. J. Environ. Res. Public Health* **2020**, *17*, doi:10.3390/IJERPH17041363.

27. Patel, A.B.; Shaikh, S.; Jain, K.R.; Desai, C.; Madamwar, D. Polycyclic Aromatic Hydrocarbons: Sources, Toxicity, and Remediation Approaches. *Front. Microbiol.* **2020**, *11*, 2675, doi:10.3389/FMICB.2020.562813/BIBTEX.

28. Wu, H.; Sun, B.; Li, J. Polycyclic Aromatic Hydrocarbons in Sediments/Soils of the Rapidly Urbanized Lower Reaches of the River Chaohu, China. *Int. J. Environ. Res. Public Health* **2019**, *16*, doi:10.3390/IJERPH16132302.

29. Sigmund, G.; Huber, D.; Bucheli, T.D.; Baumann, M.; Borth, N.; Guebitz, G.M.; Hofmann, T. Cytotoxicity of Biochar: A Workplace Safety Concern? *Environ. Sci. Technol. Lett.* **2017**, *4*, 362–366, doi:10.1021/ACS.ESTLETT.7B00267.

30. Hilber, I.; Arrigo, Y.; Zuber, M.; Bucheli, T.D. Desorption Resistance of Polycyclic Aromatic Hydrocarbons in Biochars Incubated in Cow Ruminal Liquid in Vitro and in Vivo. *Environ. Sci. Technol.* **2019**, *53*, 13695–13703, doi:10.1021/acs.est.9b04340.

31. EU-Comission EXPLANATORY MEMORANDUM Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=PI_COM:Ares(2021)44211&from=EN.

32. Achten, C.; Andersson, J.T. Overview of Polycyclic Aromatic Compounds (PAC). *Polycycl. Aromat. Compd.* **2015**, *35*, 177–186, doi:10.1080/10406638.2014.994071.

33. Andersson, J.T.; Achten, C. Time to Say Goodbye to the 16 EPA PAHs? Toward an Up-to-Date Use of PACs for Environmental Purposes. *Polycycl. Aromat. Compd.* **2015**, *35*, 330–354, doi:10.1080/10406638.2014.991042.

34. EFSA Polycyclic Aromatic Hydrocarbons in Food - Scientific Opinion of the Panel on Contaminants in the Food Chain. *EFSA J.* **2008**, *6*, doi:10.2903/J.EFSA.2008.724.

35. Brown, R.; Campo, B. del; Boateng, A.A.; Garcia-Perez, M.; Masek, O. Fundamentals of biochar production. In *Biochar for environmental management*; Lehmann, J., Joseph, S., Eds.; Routledge: London, 2015; pp. 39–62.

36. EU-Parliament *Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed - Council statement*; 2002; p. Official Journal L 140, 30/05/2002 P. 0010-0022;

37. Schmidt, H.-P.; Hagemann, N.; Draper, K.; Kammann, C. The use of biochar in animal feeding. *PeerJ* **2019**, *7*, e7373, doi:10.7717/peerj.7373.

38. Ross, J.J.; Zitomer, D.H.; Miller, T.R.; Weirich, C.A.; McNamara, P.J. Emerging investigators series: Pyrolysis removes common microconstituents triclocarban, triclosan, and nonylphenol from biosolids. *Environ. Sci. Water Res. Technol.* **2016**, *2*, 282–289, doi:10.1039/c5ew00229j.

39. Bucheli, T.D.; Bachmann, H.J.; Blum, F.; Bürge, D.; Giger, R.; Hilber, I.; Keita, J.; Leifeld, J.; Schmidt, H.-P. On the heterogeneity of biochar and consequences for its representative sampling. *J. Anal. Appl. Pyrolysis* **2014**, 1–6, doi:10.1016/j.jaap.2014.01.020.

Annex 1
Analytical Methods for EBC-biochar
Basic Package

Sample preparation (DIN 51701-3):
After homogenization, the sample is divided representatively into portions. This subsampling is done by quartering (quarter method) of the homogenized sample. Approximately 100 g of the original sample are used for the determination of the conductivity, the salt content and pH.
A portion of the sample is dried at 40 ° C and is divided into some subsamples after drying and homogenization. Approximately 250 g of the 40 ° C dried and uncrushed sample is used to determine the true density and the BET surface of the material. Approximately 50 g of the 40 ° C dried sample is finely ground in a vibratory mill. After homogenization the fine material is subsampled for further analysis (i.e., PAH, TGA, ash, CHN, S, trace and major elements). Unless otherwise specified, the particle size of the analytical samples is specified by the respective methods and standards.

Bulk density (analogue VDLUFA-Method A 13.2.1):
To calculate bulk density a dried, water free sample of at least 300 ml is poured into a graduated cylinder and the mass is determined by weighting. The volume of the sample is read after 10 times compression by means of falling. The bulk density (on dry matter base) in kg / m^3 is calculated from the mass and the volume of the sample.

Electrical conductivity (salt content) - Method of the BGK (Bundesgütegemeinschaft Kompost – German Federal Quality Association Compost), volume 1, method III. C2 – in analogy to DIN ISO 11265:
Adding 20 g of the sample to 200 ml desalinated water and shaking it for 1 hour, followed by filtration of the solution. The conductivity is then measured using the filtrated water. The correction of temperature is automatically done in the measuring device. The electrical conductivity is given for a solution at 25°C. The salt content is calculated using the factor 52.8 [mg KCl/l]/[10^{-4}/cm] and is given in mg KCl/l. This is based on the conductivity (14.12 * 10^{-4} S/cm) of a 0.01 molar KCl solution.

pH-value DIN ISO 10390 ($CaCl_2$):
A minimum of 5 ml of the air-dried sample is placed in a glass vessel. Five times the volume (25 ml) of a 0.01 M $CaCl_2$ solution is added. The suspension is overhead rotated for 1 h. The suspension obtained is directly measured with a pH meter.

Water content according to DIN 51718:
Method A / two-step method (Reference method for coal)

Raw moisture

The sample (100 to 1000 g) is spread evenly in a drying bowl crucible, weighed with 0,1 g accuracy and dried in an oven at (40 ± 2) ° C until the mass is constant. If necessary, the sample is divided and dried in more than one crucible.

Analysis: raw moisture (FG) in%

$$FG = \frac{m_E - m_R}{m_E} * 100$$

FG	=	raw moisture in %
m_E	=	mass of the sample before drying in g
m_R	=	mass of the sample after drying in g

Hygroscopic moisture

Hygroscopic moisture is the moisture held firmly within the pore structure of biochar. Measuring hygroscopic moisture will lead to an understanding of a particular biochar's ability to hold and release moisture.

A subsample of the air-dried and crushed (grain size < 1 mm) sample is weighed immediately after the subsampling into a TGA crucible and is dried in a nitrogen atmosphere at (106 ± 2) ° C to constant mass.

Evaluation: hygroscopic moisture (FH) in %

$$FH = \frac{m_E - m_R}{m_E} * 100$$

FH	=	hygroscopic moisture in %
m_E	=	mass of the sample before drying in g
m_R	=	mass of the sample after drying in g

Water content

Evaluation: water content (Wt) in %

$$W_t = FG + FH * \frac{100 - FG}{100}$$

W_t	=	water content in %
FG	=	raw moisture in %
FH	=	hygroscopic moisture in %

Ash content (550 °C) analogue DIN 51719:

To determine the ash content in biochar two programs of the TGA (30 or 60 min) could be used. The weight determination of the crucible is carried out automatically. Enter the sample number for corresponding crucible position. Add 1,0 g of the sample to the ceramic crucible and spread the substance evenly in the crucible. Weighing is done automatically relative to the crucible position.

Runs the following heating program in the oven:

- heating with a rate of 5 K / min to 106 ° C under a nitrogen atmosphere to constant mass (<0,05%).
- temperature increase with 5 K / min to 550 ° C under oxygen atmosphere,
- hold this temperature for 30 or 60 min to constant mass (m <0,05%).

The ash content is automatically determined and calculated for the sample used.

Carbonate CO_2 analogue DIN 51726:
1 g of pre-dried and ground sample is weighed to 0.2 mg and placed in the decomposition flask. The device consists of an absorption tower, which purges the air of carbon dioxide, the decomposition flask with an attachment to add the decomposition acid and three connected washing bottles. The carbon dioxide freed air is sucked through the system. After the system is purged and the washing bottles are filled with an absorbing solution of $BaCl_2$ and NaOH solution, 30 ml decomposition acid (hydrochloric acid with $HgCl_2$ as a catalyst and a wetting agent) are added to the decomposition flask. The content of the decomposition flask is boiled for about 10 minutes. The inert gas flow transports the carbon dioxide produced through the acidic solution in the first wash bottle in the other two wash bottles. In the second wash bottle, the carbon dioxide dissolves under consumption of base and is precipitated as barium carbonate. If something precipitates in the third wash bottle, the measurement must be repeated with a lower initial mass. The consumption of base in the second wash bottle is determined by a pH-titration using hydrochloric acid. The carbonate content of the sample is calculated from the base consumption and is calculated as CO_2.

CHN according to DIN 51732:
A TruSpec CHN is used to measure carbon, hydrogen and nitrogen (CHN)
The sample (80-100 mg of the pre-dried and crushed sample) is weighed directly (relative precision 0.1%) into a tin capsule. After that the capsule is closed and is placed in the machine for measurement. The TruSpec CHN determines CHN as a percentage of mass.

Sulphur according to DIN 51724-3:
The pre-dried and crushed sample is weighed in a ceramic crucible. With the aid of a catalyst layer of V_2O_5 and at high temperatures (> 1300 ° C) the sulphur is oxidized in an oxygen stream. The resulting SO_2 is detected in an Infrared cell and is calculated with the sample mass as total sulphur content.

Oxygen (calculation) according to DIN 51733:
The oxygen content is a parameter derived from calculations. It is assumed that the biochar sample consists essentially of ash, carbon, hydrogen, nitrogen, sulphur and oxygen. If one subtracts the ash, carbon, hydrogen, nitrogen and sulphur content in percent from 100 %, the result will be the oxygen content in percent.

C_{org}, H/C und O/C (calculation):
Other quantities and ratios can be calculated from the determined data.
C_{org} is derived from the total carbon content minus the inorganic carbon content (CO_2) in the sample. The H content is analysed through CHN-analysis (see above).

PAH analogue to DIN EN 15527: 2008-9 (extraction with Toluol); DIN EN 16181: 2019-08 with extraction method 2
2.5 g of the pre-dried and crushed sample is weighed and placed into a extraction thimble and is extracted with 50 ml of toluene at reflux for two hours. The resulting extract is concentrated to 10 ml. An aliquot of the extract is transferred to an injection vial and the PAH are analysed by gas chromatography.

Gas chromatograph:	Network GC System 7890N and 5975C MSD and inertXL AS 7693 Fa: Agilent Techn
Capillary column:	HP 5MS (30 mx 0.25 mm x 0.25 microns)
Temperature program:	90 ° C (0.5 min), 20 ° C / min to 250 ° C, 5 ° C / min to 275 ° C, 20 ° C / min to 320 ° C for 5 min
Transfer line:	280 ° C
MSD temperature:	150 ° C
Injection volume:	1 µl
Injector temperature:	250 ° C
Carrier gas:	helium (1.5 ml / min)

Trace metals after microwave-assisted digestion according to DIN 22022-2, DIN 22022-7, DIN EN ISO 17294-2 / DIN EN 1483:
(Pb, Cd, Cu, Ni, Hg, Zn, Cr, B, Mn, As, Ag)
The pre-dried and crushed sample is weighed and placed into the reaction vessel of the microwave. 6 ml of nitric acid, 2.0 ml of hydrogen peroxide and 0.4 ml of hydrofluoric acid are added. The reaction vessel is sealed and is placed in the microwave.
Program flow of the microwave pressure digestion:

heating (room temperature to 190 ° C) in 15 min
holding time at 190 ° C for 20 minutes
free cooling

additional only for ICP-OES:
Program flow of the fluoride masking (Boric acid, adding 5 ml of saturated solution):

heating (room temperature to 160 ° C) in 8 minutes
holding time at 160 ° C for 7 minutes
free cooling

After complete cooling, the reaction vessels are opened, and the digestion solution is transferred to in a 50 mL plastic volumetric flask and filled with deionized water.
The diluted solution is measured by ICP-MS (DIN EN ISO 17294-2).
To determine the levels of mercury DIN EN ISO 12846, DIN 22022-4; DIN EN ISO 17294-2, and DIN 22022-7 can be used.

Main elements after melting digestion DIN 51729, DIN EN ISO 11885 / DIN EN ISO 17294-2: (P, Mg, Ca, K, Na, Fe, Si, S)

The melting process is performed on the ashes of the biochar. 200 mg of the fine ash are weighed into a platinum crucible and thoroughly mixed with 2 g of lithium metaborate.
The platinum crucible is placed in a digestion oven. The digestion remains at least 15 minutes at 1050 ° C in the oven. The melt is dissolved in hydrochloric acid and filled to 500 ml.
The samples are measured with ICP-OES (DIN EN ISO 11885) or ICP-MS (DIN EN ISO 17294-2).

Water holding capacity (WHC) according to DIN EN ISO 14238, annex A

Water-holding capacity. This can be measured using the method DIN EN ISO 14238, annex A. The test consists of soaking the 2mm fraction of the material in water for a period of 24 hours. After this, the material should be placed on a dry sand bed for 2 hours for removing free water. The saturated material should then be weighed and then dried at 105°C in a compartment dryer. After drying the material should be weighed again to estimate the water holding capacity.

Electrical conductivity of the pyrogenic solid

To determine the conductivity of the solid biochar, it is first necessary to compress the finely ground biochar under standardized pressure. During this compression process, the electrical resistance is then measured vertically through the test specimen. Based on the measured resistance of the biochar and the geometry of the compacted matter, the specific conductivity can be determined using the following formulas:

$$\Omega specific = \Omega electric * \frac{A}{h}$$

$$LF = \frac{1}{\Omega specific * 1000}$$

$\Omega\text{specific} = \text{specific resistance in Ohm} * \text{cm}$
$\Omega\text{electric} = \text{electric resistance in Ohm}$

A	= Area of the compressed biochar = contact area of the electrode in cm2
H	= Height of the compressed biochar in cm
LF	= Conductivity in mS/cm

For the determination of the conductivity, a device for compressing the biochar, a multimeter with the capability of 4-wire measurement and a measuring construction in which the biochar can be compressed and the electrical resistance can be measured at the same time are required. The measuring construction consists of a pressure flask whose bottom and lid each consist of corresponding copper electrodes. The electrodes used are to be connected to an external multimeter.
In an exemplary setup, for example, a sample chamber volume of 10 cm³ results in a

relevant weighing range of 1-2 g of a sample dried at 40 °C and finely ground for analysis. A pressure in the range of 10 - 50 kN must be applied to this test setup using a hydraulic press (e.g., toggle press). When the specified target pressure is reached, the resistance is immediately read on the multimeter and converted using the above formulas. The average conductivity is obtained from the mean value of the solid conductivities under 10, 20, 30, 40 and 50 kN pressure.

Annex 2

Analytical Parameters for EBC-Feed

Trace metals *As, Pb, Cd, Hg*
DIN EN 15763:2010-04
For microwave digestion, 0.1 g to 1 g of the dried, ground and homogenized material is weighed into a plastic cup (PTFE, PFA) or quartz cup. After addition of 65% nitric acid in a ratio of 1+5 (sample+acid) and after addition of 30% hydrogen peroxide in a ratio of 1+2.5 to 1+10 (sample+hydrogen peroxide), digestion is performed at the maximum permissible temperature for the system (usually 190°C). Heating phase: 15 min; holding time: 30 min. After cooling, transfer quantitatively to a polypropylene vessel with volume marker and fill it to the mark with 0.1 M nitric acid. The measurement is carried out by ICP-MS or ICP-OES. For mercury, cold vapor AAS or atomic fluorescence spectrometry are used.

PCB
DIN EN 16167, DIN EN 16215
The material is crushed into powder (<1 mm) and dried at a maximum of 35 ° C. Alternatively, it can be dried chemically or by freeze-drying. 5-10 g of sample are extracted by Soxhlet extraction with toluene for 6 h with the addition of suitable internal standards. Alternatively, an ASE extraction can be used. The extract is concentrated and purified according to VDLUFA VII 3.3.2.2 with silica gel column chromatography. The quantification of the purified extract is done with GC-MS or GC-ECD.

PCDD/PCDF/coplanar PCB
DIN EN 16190:2019-10, DIN EN 16215 Nr. 152/2009 (modified by Nr. 2017/771)
HRGC/HRMS method
The material is crushed into powder (<1 mm) and dried at a maximum of 35 ° C. Alternatively, freeze-drying can be used. After the addition of isotope-labeled standards, 2 g of sample material are extracted with toluene in a Soxhlet for 20 h. Alternatively, special hot extractors such as the ASE can be used. After concentration, the extract is purified by multiple column chromatography and can be divided into different fractions. At this point it is also possible to obtain the DIN-PCB fraction. Finally, the components are measured with GC-HRMS.

Fluor
VDLUFA III 17.3.2, VDLUFA VII 2.2.2.1, DIN EN 16279:2012-09 (ion selective electrode; according to VDLUFA VII 2.2.2.1), BAFU F-7 2017 (DIN 38405-4:1985-07)
The dried and ground material is ashed and digested with sodium hydroxide. The cooled digestion is dissolved in hydrochloric acid with the addition of a complexing agent (TISAB). A pH value of 5.5 is then adjusted and the fluoride content is determined using an ion-sensitive electrode.

Carbon

Permitted test methods: DIN 51732
A TruSpec CHN is used.
The sample (80-100 mg of the pre-dried and crushed sample) is weighed directly (relative precision 0,1%) into a tin capsule. After that the capsule is closed and is put in the machine for measurement. The TruSpec CHN determines the carbon content, the hydrogen content and the nitrogen content in mass percent.

Dry matter

Permitted test methods: dry matter: DIN 51718; VDLUFA III 3.1;
A minimum of 50 g of the sample is taken and crushed as necessary, avoiding changes in moisture content. 5 g of biochar are weighed (±1 mg) and dried at 103°C for 4 h. After loading the oven, the drying time does not start until 103°C has been reached exactly. After cooling in the desiccator, it is weighed back (±1 mg).

Crude ash

Permitted test methods: analog **to DIN 51719, VDLUFA III 8.1; HCl-insoluble ash: VDLUFA III 8.2**
Approximately 5 g of sample is weighed to the nearest 1 mg into an annealed and tared ashing dish. The dish is placed in a muffle furnace and left at 550°C±5°C until no char particles are visible. After cooling in the desiccator, the sample is weighed back to 1 mg. For difficult samples, ammonium nitrate treatment is carried out according to method VDLUFA 8.1.

Annex 3
Additional Parameters

Gross calorific value / net calorific value according to DIN 51900:
To determine the calorific value a bomb calorimeter which fulfills the requirements of the stated standard is used. 0,3 to 0,8 g of pre-dried and ground sample is weighed into a combustion bag, capsule or crucible. The sample is mounted in the combustion bomb with an ignition wire and 10-20 ml of eluent in bottom part of the bomb. The bomb is placed into the calorimeter. The oxygen filling, the ignition and the measurement are done automatically. After combustion the bomb must be checked for signs of incomplete combustion. The gross calorific value is calculated using the calibration and measurement data. With further corrections, the net calorific value is calculated.

Ash content (815 °C) DIN 51719:
The ash content at 815 ° C is determined after determining the ash content at 550 ° C by rising the temperature from 550 ° C with 5 K / min to 815 ° C and holding until constant weight (mass difference ± 0,05%) is reached.

Volatile matter according to DIN 51720:
1,0 g of the pre-dried and ground sample is placed into a crucible (with lid). The sample must form a uniformly thick layer on the bottom of the crucible. The crucible is placed in the oven preheated at 900 ± 5 ° C. After 7 minutes (± 5 sec), the crucible is removed from the oven and reweighed after cooling to room temperature. The volatile matter content is calculated from the mass loss of the sample.

Thermogravimetric analysis (TGA):
The TGA curve is determined, similar to how the ash content is measured, with the TGA. For this purpose, 1,0 g of pre-dried and ground sample is weighed in the TGA crucible. During the temperature rise from 30 ° C to 950 ° C with 10 K / min, the crucible is weighed at frequent intervals in the TGA furnace. The result is shown graphically.

PCB
VDLUFA VII 3.3.2.2 (DIN-PCB; hot extraction, GC-MS) DIN EN 16167:2019-06 (use extraction method 2 with Toluol and not with light petroleum), DIN 38414-20 and DIN EN 16215
The sample is crushed into powder (<1 mm) and dried at a maximum of 35 ° C. Alternatively, it can be dried chemically or by freeze-drying. 5-10 g of sample are extracted by Soxhlet extraction with toluene for 6 h with the addition of suitable internal standards. Alternatively, an ASE extraction can be used. The extract is concentrated and purified according to VDLUFA VII 3.3.2.2 with silica gel column chromatography. The quantification of the purified extract is done with GC-MS or GC-ECD.

PCDD/PCDF/coplanar PCB
DIN EN 16190:2019-10, DIN EN 16215, (EG) Nr. 152/2009 (modified by Nr. 2017/771) HRGC/HRMS method

The sample is crushed into powder (<1 mm) and dried at a maximum of 35 ° C. Alternatively, freeze-drying can be used. After the addition of isotope-labeled standards, 2 g of sample material are extracted with toluene in a Soxhlet for 20 h. Alternatively, special hot extractors such as an ASE can be used. After concentration, the extract is purified by multiple column chromatography and can be divided into different fractions. At this point it is also possible to obtain the DIN-PCB fraction. Finally, the components are measured with GC-HRMS.

Specific surface area following DIN ISO 9277 (BET) and DIN 66137 (density)
The samples should be dried at 40°C and milled to a particle size < 3.15 mm. Nitrogen is used as the adsorption gas. Degassing temperature and time are set to 150°C and 2 hours. The degassing has to be done under vacuum. The multipoint BET method should be applied.

Chrom(VI)
DIN EN 16318: 2016-07
Chromium cannot be oxidized during pyrolysis and is instead reduced during pyrolysis, i.e., Cr(VI) is converted into less mobile and dramatically less toxic Cr(III) which is already regulated as the total Cr content of biochar. Nevertheless, this method is offered to provide analytical evidence of compliance with the requirements of the EU Fertilizer Product Regulation, if required.

Annex 4

A4.1 Representative sampling

In order to obtain a biochar sample as representative as possible (in terms of accuracy and precision), a batch must be sampled within the first seven days of production according to the following exact methodology. An incremental cross-stream sampling guarantees the most representative sampling of the product.

A. Pyrolysis systems with continuous production

1. On three consecutive days, 8 samples of 3 liters each are taken at intervals of at least one hour directly at the discharge of the freshly produced material. This sampling can also be done by an appropriately adjusted automated cross-stream sampler.
2. The 24 subsamples are combined to form a composite sub-sample.
3. The taking of each of the 24 samples (= 3 x 8 daily samples) as well as the homogenisation and sample division must be documented with the exact sampling times in the sampling protocol delivered by the inspection body (bio.inspecta).

B. Systems with non-continuous production processes

1. The quantity of biochar from which a representative sample is to be taken from must be at least equal to the production volume of one day.
2. The biochar pile to be sampled must first be thoroughly mixed by moving it from one pile to another three times with a front loader or shovel.
3. At 24 different spots of the pile, samples of 3 liters each are taken.
4. The 24 subsamples are combined to form a composite sub-sample.
5. The sampling has to be documented in the sampling protocol delivered by the inspection body (bio.inspecta).

C. Homogenizing and dividing of the sample

The mixed sample of 24 x 3 liters = 72 liters can either be sent directly to the accredited laboratory where it shall be homogenized and divided into a representative analytical sample or the company proceeds as follows to produce a small representative analytical sample on its own.

1. If the particle size of the composite sub-sample is larger than 3 mm, it should be milled to < 3 mm, otherwise no representative sample division is possible.

2. The milled composite sub-sample is either divided by a mechanical sample divider to 2 to 2,5 l or homogenized according to the following instructions:
3. The milled composite sub-sample (total 72 liters) is poured onto a clean surface and then shoveled three times from one pile to another.
4. A sub-sample of 1,5 l is then taken at 15 spots in the mixed pile.
5. The 15 subsamples are again poured together.
6. The new 22,5 l subsample has than to be homogenized thoroughly by turning and piling it 3 times upside-down.
7. From the mixed pile of the 22,5 l subsample, 15 subsamples of 150 ml each shall now be taken at 15 different spots in the pile and united.

The samples to be sent to the accredited laboratory have to be labelled with the QR code generated on the EBC website.

The expected uncertainties in regard to accuracy and precision were described in detail by Bucheli et al. [39] and will be taken into account by the EBC when evaluating the results. The aim of the prescribed sampling method is to achieve a well characterized cross-sectional sample.

A5. Country Annex: Sweden

The Swedish appendix considers Swedish legal requirements and relevant Swedish certificates regarding limit values for potential pollutants. The Swedish appendix overrules the respective EBC limit values as presented below.

EBC-certified biochar that is sold on the Swedish market must meet all requirements of the respective application class of the European Biochar Certificate and the Swedish annex. The Swedish annex applies together with European Biochar Certificate, is an addition to the EBC, and shall therefore not be read as a standalone document.

A5.1 List of requirements EBC Swedish appendix

The deviations and additions from/to European Biochar Certificate, made in the present Swedish appendix, concern only the application classes EBC-Agro and EBC-AgroBio.

A5.2 EBC-Agro

EBC sets limit values for lead (Pb) and cadmium (Cd) but, for EBC-certified biochar sold on the Swedish market, these limit values are replaced according to the table below.

EBC-reference	Analysis parameter	Value	Comment / reference
Chapter 7.6	Lead (Pb)	100 mg kg^{-1} (DM)	Limit value taken from SNF1998:944 and industry standard SPCR152.
Chapter 7.6	Cadmium (Cd)	1 mg kg^{-1} (DM)	Guide value taken from EU-Ecolabel, industry standard SPCR 120 and SPCR 152

A5.3 EBC-AgroBio

To certify the biochar according to the EBC-AgroBio for the Swedish market, an analysis of the silver (Ag) content must be included.

EBC-reference	Analysis parameter	Value	Comment / reference
Chapter 7.6	Silver (Ag)	NA mg kg^{-1} (DM)	The value must be known, but there is no limit value according to the regulations in KRAV.