

ANSI/ASABE/USBI S668 NOV2025ED
Methods for Measurement and Testing of Biochar



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Methods for Measurement and Testing of Biochar

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1 Introduction

Markets for biochar are growing rapidly in agriculture, industrial, infrastructure, and climate change mitigation services. However, many of the laboratory standards historically referenced for biochar testing originate from various standards development organizations and often lack methodological alignment, particularly concerning sampling procedures and sample preparation requirements. In some cases, referenced methods specify only equipment types or general testing principles, without clear procedural detail. As a result, few North American laboratories currently offer biochar analysis services. Those that do often determine on their own how to implement the referenced test methods, leading to variability in testing procedures and results across laboratories.

The intent of this standard is to:

- Provide clear guidance on which testing methods are most appropriate for biochar analysis, and whether the results from these analyses require interpretation in the context of biochar properties.
- Recommend analysis standards that are methodologically consistent by referencing as few analysis standard frameworks (e.g., ISO, EPA) as possible. Method selection (e.g., ISO vs. EPA) may depend on the regulatory requirements or accreditation standards applicable in the jurisdiction where the analysis is performed.
- Present a broad definition for biochar, relevant to a variety of production approaches, production conditions, and feedstocks.
- Be applicable for the analysis of all biochar materials regardless of the feedstock material used.
- Provide analytical methods that support regulatory compliance for biochar in a range of end-use applications, with a focus on compliance in the United States, Canada, and Mexico.
- Identify material properties that are relevant for the use of biochar that can be reliably analyzed using standardized analysis methods. Biochar end-uses that were explicitly considered under this standard include carbon removal credits, soil amendments, and environmental filtration and remediation materials. While other end-uses are relevant, biochar used in many other end-use applications will be subject to standards relevant to those industries (e.g., concrete, drinking and wastewater filtration, fertilizer amendments, etc.) and are not included in this standard.
- Establish a recommended analysis method for each identified material property.

Many of the analysis methods referenced in this standard were originally developed for the analysis of other materials but have been deemed usable for biochar as written or as modified by the applicable section.

2 Scope

This American National Standard provides recommended testing methodologies for biochar materials, including proximate and ultimate analysis, calorimetry, permanence assessment, physical property measurements (such as density and particle sizing), specific surface area and porosity analysis, environmental characterization (including PAHs, PCBs, dioxins, PFAS, and heavy metals), and general agricultural parameters (such as nutrient content, pH, liming potential, and salinity).

While certain analyses may be recommended for regulatory compliance or market claims (e.g., nutrient content or heavy metals), users should select the relevant tests based on intended end use, jurisdictional requirements, and customer specifications.

3 Normative References

The following referenced documents are indispensable for the use of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASTM D4373 Standard Test Method for Rapid Determination of Carbonate Content of Soils

ASTM D7582 Standard Test Methods for Proximate Analysis of Coal and Coke by Macro Thermogravimetric Analysis

EN 15919 Fertilizers – Extraction of Phosphorus Soluble in 2% Formic Acid

EPA 350.1 Determination of Ammonia Nitrogen by Semi-Automated Colorimetry

EPA 353.2 Determination of Nitrate-Nitrite Nitrogen by Automated Colorimetry

EPA 1633A Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS

EPA 3050B Acid Digestion of Sediments, Sludges, and Soils

EPA 3051A Microwave Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils

EPA 3540C Soxhlet Extraction

EPA 3546 Microwave Extraction

EPA 3550C Ultrasonic Extraction

EPA 6010D Inductively Coupled Plasma – Optical Emission Spectrometry

EPA 6020B Inductively Coupled Plasma – Mass Spectrometry

EPA 7471B Mercury in Solid or Semisolid Waste (Manual Cold-Vapor Technique)

EPA 7473 Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation, and Atomic Absorption Spectroscopy

EPA 8270E Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry

EPA 8082A Polychlorinated Biphenyls (PCBs) by Gas Chromatography

EPA 8280B Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs) by High-Resolution Gas Chromatography/Low-Resolution Mass Spectrometry (HRGC/LRMS)

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EPA 8290A Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs) by High-Resolution Gas Chromatography/High-Resolution Mass Spectrometry (HRGC/HRMS)

ISO 7404-5 Methods for the petrographic analysis of coals – Part 5: Method of determining microscopically the reflectance of vitrinite

ISO 9277 Determination of the specific surface area of solids by gas adsorption – BET method

ISO 10390 Soil, treated biowaste and sludge – Determination of pH

ISO 11047 Soil quality – Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc – Flame and electrothermal atomic absorption spectrometric methods

ISO 11265 Soil quality – Determination of the specific electrical conductivity

ISO 14780 Solid Biofuels – Sample Preparation

ISO 15901-1 Evaluation of pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption: Part 1: Mercury porosimetry

ISO 15901-2 Pore size distribution and porosity of solid materials by mercury porosimetry and gas adsorption: Part 2: Analysis of nanopores by gas adsorption

ISO 16559 Solid Biofuels – Vocabulary

ISO 16948 Solid Biofuels – Determination of total content of carbon, hydrogen and nitrogen

ISO 16967 Solid Biofuels – Determination of major elements – Al, Ca, Fe, Mg, P, K, Si, Na, and Ti

ISO 16968 Solid Biofuels – Determination of minor elements

ISO 16993 Solid Biofuels – Conversion of analytical results from one basis to another

ISO 16994 Solid Biofuels – Determination of total content of sulfur and chlorine

ISO 17828 Solid Biofuels – Determination of bulk density

ISO 18122 Solid Biofuels – Determination of ash content

ISO 18123 Solid Biofuels – Determination of volatile matter

ISO 18125 Solid Biofuels – Determination of calorific value

ISO 18134-1 Solid Biofuels – Determination of moisture content – Part 1: Reference method

ISO 18134-2 Solid Biofuels – Determination of moisture content – Part 2: Simplified method

ISO 18134-3 Solid Biofuels – Determination of moisture content – Part 3: Moisture in general analysis sample

ISO 18135 Solid Biofuels – Sampling

ISO 18287 Soil quality – Determination of polycyclic aromatic hydrocarbons (PAH) – Gas chromatographic method with mass spectrometric detection

ISO 18475 Environmental solid matrices – Determination of polychlorinated biphenyls (PCB) by gas chromatography – mass selective detection (GC-MS) or electron-capture detection (GC-ECD)

ISO 20978 Liming material – Determination of neutralizing value – Titrimetric methods

ISO 21945 Solid Biofuels – Simplified Sampling

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4 Definitions

For the purpose of this document, the terms and definitions given in ISO 16559 apply as noted in normative references.

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <https://www.electropedia.org>

4.1 biochar:

Biochar is a solid carbon-rich material produced through the thermochemical treatment of biomass under no or limited oxygen conditions. During this thermal conversion process, volatile compounds are depleted from the original biomass and the remaining material is thermally altered and converted into biochar. The chemical characteristics of the resultant biochar are such that it is resistant to chemical and biological degradation under typical environmental conditions and therefore the production of biochar is considered to be a form of carbon sequestration, so long as the material is not subsequently combusted. Biochar is composed of a combination of fixed carbon, volatile matter, and ash, all of which may contain a range of organic and inorganic compounds. The chemical and physical properties of biochar depend strongly on the original feedstock, production conditions, and any post-processing treatments applied. Biochar can be produced from any type of biomass including, but not limited to, woody materials, agricultural materials, purpose-grown crops, manures, digestates, wastewater treatment plant biosolids, food waste, and the organic fraction of municipal solid waste.

Biochar may be physically and chemically similar to, and sometimes identical to, other materials, including biocarbon, biocoal, and charcoal. The difference between these materials is related to end use. Biochar is always used for carbon-preserving purposes whereas biocoal and charcoal are directly combusted for heat and/or energy production while biocarbon is incorporated into large scale industrial processes (e.g. steel manufacturing) whereby the product is also typically consumed and the carbon converted back to carbon dioxide.

Conversely, some forms of biochar may be distinctly different from biocarbon, biocoal, and charcoal. For example, biochar end use applications can often accommodate materials that are very high in ash content. Biocoal, biocarbon, and charcoal applications typically strive to have low ash content.

Because the distinction in these materials is primarily related to the end-use of the material, this standard can be used for the analysis of any materials that could be used as biochar, including biocoal, biocarbon, and charcoal.

4.2 nutrients:

Nutrients are substances essential for the normal growth, development, and reproduction of plants. The plant availability of nutrients can be dependent on the chemical form in which a given nutrient is present, so the presence of a given nutrient does not necessarily mean that it can be easily taken up and utilized by plants.

Nutrients are sometimes broken into macronutrients and micronutrients, however, for the purposes of this standard, no such distinctions are made.

5 Biochar Requirements for Analysis

This standard applies to the measurement and testing of all types of biochar materials. However, some of the analytical methods may require an adjusted process for materials with high ash concentrations as described further in section 14. If ash concentrations are low then these effects may be minimal/not observable within the test data; however, as ash concentration increases the potential impacts can be greater and more likely observed. Regardless of whether the biochar ash content is high or low, it is important to understand these behavioral differences and to take them into consideration when evaluating biochar test results.

6 Sampling and Sample Preparation

The proper collection and preparation of samples is critical to any analysis of biochar materials. Incorrect sampling or sample preparation can lead to misleading test results or, in severe cases, results that are not representative of the material. More robust sampling systems should be used when sampling heterogeneous biochar materials or those with larger particle sizes.

6.1 sampling

ISO 18135 (sampling) and ISO 21945 (simplified sampling) provide guidance for how to develop sampling plans and provide various techniques for how to sample different material types and quantities. It is advised that anyone collecting biochar samples should review these principles and devise an appropriate plan based on the goals of the project.

6.2 sample preparation

ISO 14780 provides guidance on proper sample preparation including preparing samples for shipment and preparing samples for analysis. Those preparing biochar for shipment should review this guidance and discuss sample shipment with their laboratory.

6.3 preparation of a general analysis sample

When biochar is tested for parameters such as ash, volatile matter, and total carbon, the analysis is performed on a specially prepared sample (generally pre-dried, finely milled, and well-blended) to ensure small amounts are homogenous and will provide repeatable results when tested within a laboratory. This specially prepared material is referred to as the “General Analysis Sample.” The principles for creating a general analysis sample can be found in ISO 14780.

There are two possible approaches for managing the moisture content of the general analysis sample. One is to remove all of the moisture and conduct the analysis on a dry basis. The other is to expose the general analysis sample to the lab air, allowing it to equilibrate with the lab air before conducting analysis.

If the general analysis sample is dried and analyses are conducted on a dry basis, be advised that the dry material will reabsorb moisture from the atmosphere quickly so this material must be kept dry by storing in a properly functioning desiccator and it must be analyzed in such a fashion that limits the possibility of moisture uptake that would affect test results. Keep in mind that for hydrogen analysis, any uptake of moisture will result in an elevated hydrogen content due to the hydrogen contained within water.

Conversely, the general analysis sample can be equilibrated with the lab atmosphere by spreading it out in a large shallow pan for several hours or overnight. Moisture of the general analysis sample should then be subsequently measured as per section 8.1.2 and test results should be converted to both as received and dry basis.

Regardless of the approach to managing ambient humidity, it is sound laboratory practice to evaluate your lab conditions and to make every effort to ensure that changing moisture conditions are accounted for as much as possible.

7 Converting to different basis

Proximate and ultimate analysis results should be represented on an as received and dry basis. The test methods above often provide results on an as-determined/as-analyzed basis, which needs to be converted to the as received and dry basis values for reporting. To convert between the various basis, ISO 16993 should be used.

8 Proximate Analysis, Ultimate Analysis, and Calorific Value

This section outlines the recommended test methods for proximate (Moisture, Ash, Volatile Matter and Fixed carbon) and ultimate analysis (Moisture, Ash, Carbon, Hydrogen, Nitrogen, Oxygen, Sulfur). Additionally, it includes a test procedure for calorific value.

8.1 moisture

For conducting a proximate/ultimate analysis, moisture determinations can be broken down into two types, the determination of total moisture and the determination of moisture on the general analysis sample.

8.1.1 total moisture

Total moisture content should be determined per ISO 18134-1 or ISO 18134-2. Both methods reflect oven drying at 105°C for as long as necessary to meet end point criteria. ISO 18134-1 is the most accurate method as it takes into consideration the buoyancy of the sample tray during hot weigh backs, and testing is performed in duplicate, with the average reported. It is recommended for use in commercial testing laboratories. ISO 18134-2 is considered a simplified method. It omits the buoyancy correction and only requires a single determination. ISO 18134-2 may be used by commercial testing laboratories, but it is intended more for use at production sites and field applications.

NOTE: Instances have occurred whereby biochar samples have caught fire in the oven when drying at 105°C. This is not common but because the reason has not been determined analysts should be aware that this can happen.

8.1.2 moisture of the general analysis sample

If the general analysis sample has been completely dried using the principles of section 8.1.1, then it is not necessary to determine the moisture content of the general analysis sample, which is considered to be on a dry basis. If the general analysis sample is brought into equilibrium with the lab atmosphere as described in section 6.3, then the moisture content of the general analysis sample should be determined per ISO 18134-3. Parameters analyzed on moisture equilibrated general analysis samples are referred as being tested on an “as determined” or “as analyzed” basis. These values are converted to “as received” and “dry” basis for reporting (see converting to different basis in section 7).

8.2 ash

Ash testing should be conducted per ISO 18122 utilizing 550°C as the preferred ashing temperature. Most biochar materials will fully ash at 550°C and ashing at this lower temperature will preserve carbonate carbon (inorganic carbon) within the ash, allowing it to be used to determine the inorganic carbon content, which is used to determine organic carbon content and subsequently the H:C_{org} ratio (see section 9). In addition, ashing at 550°C may reduce the chances of increased oxidation of inorganic compounds in the mineral phase which will allow for better estimation, particularly in high ash samples, of Fixed Carbon and Oxygen when calculated by difference. Utilizing an ashing temperature of 550°C is considered standard for this method so when performing the analysis at this temperature the method (ISO 18122) should be directly referenced.

Some biochar material may not fully ash at 550°C, in which case, ashing should be conducted at 815°C. Materials that do not fully ash at 550°C can often be visually identified by inspecting the ash after combustion. If the ash remains black or very dark, this may be an indication that the material is not fully ashed and ashing at 815°C is necessary. Utilizing an ashing temperature of 815°C is not considered standard for this method, so when performing the analysis at this temperature, the method should be referenced as “ISO 18122 (815°C)”.

8.3 volatile matter

Testing for volatile matter should be conducted per ISO 18123.

8.4 fixed carbon

Fixed carbon is not directly measured, but is calculated by difference using the following equation:

$$\% \text{ Fixed Carbon} = 100 - \% \text{ Moisture} - \% \text{ Ash} - \% \text{ Volatile Matter}$$

NOTE: In high-ash biochar, fixed carbon values calculated by difference may be inaccurate or even reported as a negative value when using this calculation, highlighting a limitation of this indirect method. See section 14 for a detailed description of issues related to testing high ash biochar, which includes an alternate approach to calculating fixed carbon in section 14.1.

8.5 total carbon, hydrogen, and nitrogen

Testing for total carbon, hydrogen, and nitrogen should be conducted per ISO 16948 (CHN Analyzer). Because different types of biochar can be highly variable, particularly in carbon content, it is important to use calibration materials that encompass the range of carbon, hydrogen, and nitrogen values observed in the material being tested.

8.6 total sulfur

Total sulfur should be analyzed per ISO 16994. The base method uses ion chromatography detection in conjunction with an oxygen bomb combustion vessel to prepare samples. This method is effective for biochar materials that combust readily in an oxygen bomb (e.g., low ash biochar). ISO 16994 also incorporates language for using other forms of instrumentation (e.g., combustion analyzers), provided the results can be validated. Combustion analyzers are considered acceptable for all biochar material types and are preferred for biochar samples that are high in ash content.

8.7 oxygen

Oxygen is not directly measured, but is calculated by difference using the following equation:

$$\% \text{ Oxygen} = 100 - \% \text{ Moisture} - \% \text{ Ash} - \% \text{ Carbon} - \% \text{ Nitrogen} - \% \text{ Hydrogen} - \% \text{ Sulfur}$$

NOTE 1: If high levels of chlorine are present in the material, then subtracting the % chlorine in the equation above may provide a better estimation of % oxygen (e.g. biochar made from litter, manure, waste materials, and various agricultural residues may contain higher amounts of chlorine).

NOTE 2: With high ash biochar, oxygen may not be reported accurately and may even be reported as a negative value when using this calculation, highlighting a limitation when using this indirect method. See section 14 for a detailed description of issues related to testing high ash biochar, which includes an alternate approach to calculating oxygen content in section 14.2. At low ash concentrations, the amount of inorganic carbon is typically negligible, and therefore no correction is required.

8.8 thermogravimetric analysis (TGA)

Thermogravimetric analyzers (TGAs) are considered acceptable for determining moisture, ash, volatile matter, and fixed carbon content of biochar materials. Guidance for how to operate TGAs for use in conducting a proximate analysis is provided by ASTM D7582. It should be noted however that ashing should be conducted at 550°C.

NOTE: TGA results may vary from test results obtained using the methods outlined in section 8 for high ash biochar. See section 14 for a detailed description of issues related to testing high ash biochar, which includes a description of issues specifically related to TGA analysis in section 14.3.

8.9 calorimetry

Gross and net calorific value analysis should be conducted per ISO 18125.

9 Inorganic Carbon/Organic Carbon (C_{org})

Total carbon as determined per section 8.5 includes all carbon within the biochar sample and does not differentiate between inorganic carbon (carbonates) and organic carbon. This section provides two methods for determining the inorganic carbon fraction as well as the formula for calculating organic carbon. Both recommended analysis methods have potential biases that are noted within the applicable section.

9.1 dry combustion/elemental analyzer method

To determine the inorganic carbon content of biochar utilizing a dry combustion/elemental analyzer, biochar is first ashed at 550°C per ISO 18122 (see section 8.2). The carbon content of the ash is then directly measured per ISO 16948. The carbon content of the ash is converted back to a whole sample basis by multiplying the % carbon in ash by the ash content of the biochar on a dry basis (as determined by ISO 18122) divided by 100:

$$\% \text{ Inorganic Carbon in Biochar on a Dry Basis} = (\% \text{ Carbon in Ash}) \times \left(\frac{\% \text{ Ash Dry Basis}}{100} \right)$$

Please note that this method cannot be used if the biochar material does not fully ash at 550°C (all organic carbon removed). ISO 18122 includes steps for inspecting the ash and heating longer at 550°C if there are signs of incomplete ashing. If the sample cannot be fully ashed at 550°C then the method outlined in section 9.2 should be used to determine the inorganic carbon content.

NOTE: This method has potential biases. When biochar is ashed at 550°C a small amount of organic carbon could be converted to inorganic carbon resulting in an over estimation of the inorganic carbon fraction. Additionally, the conversion of carbonate to calcium oxide has been observed at 575°C. This was found to be more pronounced at lower levels of ash [1]. It is uncertain as to the extent that this occurs at 550°C, however it should be noted that this chemical conversion process could result in an underestimation of inorganic carbon.

9.2 off-gassing method

Inorganic carbon content may also be analyzed per ASTM D4373. This method is an off-gassing technique whereby the biochar is exposed to acid in an enclosed vessel. Inorganic carbon reacts with acid forming carbon dioxide. Pressure within the enclosed vessel is measured before and after acid exposure, whereby the resulting increase in pressure can be used to determine the amount of inorganic carbon in the biochar.

NOTE: This method has a potential bias in that all gases generated are quantified as carbon dioxide derived from inorganic carbonates in the biochar. It is expected that most gases generated should be carbon dioxide, however other reactions such as carbon reducing H^+ to H_2 gas may occur causing an overestimation of the inorganic carbon fraction.

9.3 calculation of the organic carbon fraction – C_{org}

Once the total carbon and the inorganic carbon fractions have been determined the organic carbon fraction can be calculated as follows:

$$\% C_{org} \text{ Dry Basis} = \% \text{ Total Carbon Dry Basis} - \% \text{ Inorganic Carbon Dry Basis}$$

10 Assessing Permanence

One of the primary purposes for manufacturing biochar is to sequester carbon as a climate change mitigation approach. Therefore, the degree to which the carbon is stable and exhibits persistence in the environment is a key property of biochar. There are a variety of metrics by which authorities assess permanence. This standard does not promote one metric over another but guides how the different metrics are determined.

10.1 hydrogen to organic carbon molar ratio - H:C_{org}

The hydrogen to organic carbon molar ratio requires the determination of total hydrogen as per section 8.5 and the determination of the organic carbon fraction as outlined in section 9. Once these two values have been generated, H:C_{org} is calculated as follows:

$$H:C_{org} \text{ Molar Ratio} = \frac{\% \text{ Hydrogen Dry Basis} / 1.0079}{\% C_{org} \text{ Dry Basis} / 12.011}$$

where 1.0079 is the atomic weight of hydrogen and 12.011 is the atomic weight of carbon.

10.2 oxygen to organic carbon molar ratio - O:C_{org}

The oxygen to organic carbon molar ratio requires the determination of total oxygen as per section 8.7 or section 14.2 as deemed appropriate, and the determination of the organic carbon fraction as outlined in section 9. Once these two values have been generated O:C_{org} as follows:

$$O:C_{org} \text{ Molar Ratio} = \frac{\% \text{ Oxygen Dry Basis} / 15.999}{\% C_{org} \text{ Dry Basis} / 12.011}$$

where 15.999 is the atomic weight of oxygen and 12.011 is the atomic weight of carbon.

NOTE: See section 14 for a detailed description of issues related to testing high ash biochar, which includes an alternate approach to calculating oxygen content in section 14.2.

10.3 random reflectance

Random reflectance should be analyzed per ISO 7404-5 (white-light microscopy).

11 Physical Properties

Specifying test methods for biochar physical properties is challenging due to the diversity of end-use applications, many of which require specific physical testing procedures relevant to that application. It is acceptable to use the physical property test methods specified by a particular industry provided the test report references the applicable standard(s), and any deviations are clearly conveyed in the test report. In such cases, also be sure to review the sample preparation requirements to be sure the material being tested is prepared consistently with the intent of the standard being used.

When test methods are not otherwise specified, the following guidance is recommended.

11.1 bulk density

Bulk density should be determined per ISO 17828, using the specified 5-liter container as described in the method. Bulk density can be determined using other container sizes; however, altering the size and overall dimensions of the container will inherently result in different values, providing poor comparability. If alternate container sizes are used, the lab report should not reference ISO 17828. In such instances, the test report should specify the method used and any specific conditions, such as the container size. Per ISO 17828, a moisture determination is also to be conducted in conjunction with the bulk density determination so that the bulk density can be related to a specific moisture content. ISO 17828 also includes a calculation for expressing bulk density on a dry basis.

11.2 particle size distribution

There is no single preferred method for particle size distribution analysis of biochar. General guidance is to use progressive sieving with sieve sizes that bracket the particle sizes of the biochar sample being tested. The following sieves have been identified as common for the North American biochar industry and are recommended under this standard: 16, 8, 4, 2, 1, 0.5, 0.25, 0.125, and 0.063 mm. The frame of the sieves should have a height that enables the sieves to contain the sample and allows free movement of the sample during the sieving process. Test reports are to specify the test method as well as any variable parameters used to conduct the test (e.g. power settings, amplitudes, sieve times, etc.). Other techniques such as laser diffraction may also be used.

11.3 specific surface area (SSA) and pore sizing

For many biochar applications, SSA is considered to be a property of interest. Unfortunately, there is no one test procedure that can be conducted to definitively measure the actual surface area of biochar. By nature, biochar is porous, containing a mix of pore sizes ranging from ultra micropores (i.e. <1 nm) to relatively large macropores (i.e., >50 nm). SSA analysis uses a gas (e.g. N₂, CO₂, or others) to adsorb to biochar surfaces, however there is no gas that can adequately diffuse into all pore sizes. Nitrogen is the most commonly used gas for SSA analysis and does a good job of characterizing the surface areas of pores ranging from 0.45 - 50 nm; however, nitrogen is not able to readily diffuse into micropores <0.45 nm at the required experimental temperature (77 K). Carbon dioxide is better able to diffuse into micropores since the experiment can be run at a significantly higher temperature (273 K) but is not effective for characterizing pores larger than 1.5 nm because of the high saturation pressure of CO₂ at 273 K and 1 atmosphere of pressure. Other SSA techniques may extend the range of pore sizes that can be measured, and dual gas approaches may be used, however measurement techniques available are highly dependent on each laboratory's equipment/capabilities.

ISO 9277 is a general test procedure for conducting SSA according to the Brunauer, Emmet, and Teller (BET) method using nitrogen gas, and is recommended for laboratories performing this analysis. The following test conditions are recommended:

- Test materials should be dried at 105°C prior to the degassing step.
- For biochar materials produced at or above 350°C, it is recommended that degassing be conducted at 300°C (minimum) for at least 16 hours (overnight). For biochar materials produced below 350°C, it is recommended that degassing be conducted at least 50°C below the production temperature for at least 16 hours (overnight).
- It is important to perform degassing under vacuum pressure that is built slowly to prevent elutriation.
- Multi-point BET determinations are preferred.

Regarding pore sizing, techniques such as gas adsorption and Mercury Intrusion Porosimetry (MIP) can be used to evaluate pore size distribution and porosity from approximately 3nm to 900microns. If a full pore size distribution and/or porosity assessment is desired, then the following methods are considered standard:

- ISO 15901-1 (Mercury Intrusion porosimetry)
- ISO 15901-2 (Analysis of nanopores by gas adsorption).

Each technique described above provides relevant but incomplete information regarding the surface area and pore structure of biochar. A holistic approach that covers the entire pore size range is recommended. In general, combining multiple testing techniques will provide a more comprehensive SSA and/or pore size distribution analysis. Biochar producers should communicate with their laboratories to discuss analysis options/conditions to best determine a testing approach for their material. All test parameters should be provided on the test report.

12 Environmental Contaminants

The use of biochar may pose environmental risks in certain applications, such as soil amendments, fertilizer components, horticultural substrates, filtration media, or environmental remediation. In some cases, applicable regulations require the analysis of biochar for contaminants according to specific methods. To limit environmental risks, biochar used for these types of applications should be periodically analyzed for potential environmental pollutants.

Biochar samples intended for analysis of environmental pollutants should be tested using analytical methods that comply with the applicable regulatory framework in the jurisdiction where the material will be used. Accordingly, when biochar is used in the United States, samples should be analyzed according to US Environmental Protection Agency (EPA) methods. When biochar is used in Canada, samples may be analyzed according to US EPA or ISO methods but compared against the Canadian Council of Ministers of the Environment (CCME) regulatory limits. When biochar is used in Mexico, EPA methods are generally accepted, however it is wise to review the methods intended for use with Mexican authorities as Mexican regulations sometimes include modifications to EPA methods.

When conducting analysis for environmental contaminants, appropriate quality assurance measures, including the use of matrix spikes, blanks, and certified reference materials, are essential to validate results and ensure reliability. Any modifications to the standard EPA and/or ISO methods should be noted on laboratory test reports.

12.1 trace organics

The methods presented in this section were not developed specifically for biochar samples, and it is possible that some of the methods presented may not provide an assessment of the total concentration of that pollutant in a given sample of biochar. However, given that environmental analytical requirements are generally stipulated by regulatory authorities, biochar samples should be tested according to the methods presented below without modifications, except as approved and/or directed by relevant authorities.

12.1.1 polycyclic aromatic hydrocarbons (PAHs)

PAHs should be analyzed and reported according to Table 1.

Table – 1

Regulatory Framework	US EPA
Extraction Method(s)	EPA 3550C (Sonication) EPA 3540C (Soxhlet)
Analysis Method	EPA 8270E (GCMS)
Reporting Approach	Total PAHs and by compound
Individual Compounds	Acenaphthene Acenaphthylene Anthracene Benz(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Benzo(ghi)perylene Chrysene Dibenz(a,h)anthracene Fluoranthene Fluorene Indeno(1,2,3-cd)pyrene Naphthalene Phenanthrene Pyrene

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12.1.2 polychlorinated biphenyls (PCBs)

PCBs should be analyzed and reported according to Table 2.

Table – 2

Regulatory Framework	US EPA
Extraction Method(s)	EPA 3550C (Sonication) EPA 3540C (Soxhlet)
Analysis Method	EPA 8082A (GCMS)
Reporting Approach	Total PCBs and by Aroclor
Individual Compounds	Aroclor 1016 Aroclor 1221 Aroclor 1232 Aroclor 1242 Aroclor 1248 Aroclor 1254 Aroclor 1260

12.1.3 polychlorinated dibenzo-p-dioxins / furans (PCDD/Fs)

PCDD/Fs should be analyzed and reported according to Table 3.

Table – 3

Regulatory Framework	US EPA
Extraction Method(s)	EPA 3550C (Sonication) EPA 3540C (Soxhlet)
Analysis Method	EPA 8290A (GCMS) EPA 8290B (GCMS)
Reporting Approach	Total PCDD/Fs and by compound
Individual Compounds	2,3,7,8-Tetrachlorodibenzo-p-dioxin 1,2,3,7,8-Pentachlorodibenzo-p-dioxin 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin 1,2,3,4,5,6,7,8-Octachlorodibenzo-p-dioxin 2,3,7,8-Tetrachlorodibenzofuran 1,2,3,7,8-Pentachlorodibenzofuran 2,3,4,7,8-Pentachlorodibenzofuran 1,2,3,4,7,8-Hexachlorodibenzofuran 1,2,3,6,7,8-Hexachlorodibenzofuran 1,2,3,7,8,9-Hexachlorodibenzofuran 2,3,4,6,7,8-Hexachlorodibenzofuran 1,2,3,4,6,7,8-Heptachlorodibenzofuran 1,2,3,4,7,8,9-Heptachlorodibenzofuran 1,2,3,4,5,6,7,8-Octachlorodibenzofuran

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12.1.4 per- and polyfluoroalkyl substances (PFAS)

PFAS compounds are fairly ubiquitous in the environment and could be present in biochar. Their presence is more common in biochar made from feedstocks that contain high PFAS concentrations, such as wastewater treatment plant (WWTP) biosolids. While certain biochar production processing conditions can effectively destroy and/or volatilize PFAS, biochar produced from WWTP biosolids and/or other waste-derived feedstocks that could contain high PFAS concentrations should be periodically analyzed for PFAS.

When biochar is analyzed for PFAS, the analysis should be conducted per EPA Method 1633A. This standard does not establish pass/fail criteria for PFAS; users should refer to jurisdictional guidance (e.g., US EPA interim biosolids limits or state-specific soil screening levels).

Due to the complex and heterogeneous nature of biochar, thorough sample preparation and extraction are essential to ensure accurate PFAS analysis. Care must be taken to minimize matrix interferences, as the high organic carbon content and potential presence of inorganic compounds can affect extraction efficiency and analytical sensitivity. Additionally, precautions should be taken to prevent contamination during sampling and analysis, as even trace levels of PFAS can compromise data integrity.

Further, it should be noted that analysis of PFAS in biochar, and indeed in all materials, is an emerging science, so care should be taken to identify those operational conditions most suitable for accurate analysis of biochar.

12.2 trace metals

When analyzing biochar for trace metals EPA methods should be used when biochar is used in the United States. Biochar used in Canada and Mexico may be analyzed by either EPA or ISO methods depending on relevant environmental regulations. All applicable methods are outlined in Table 4 below.

Table – 4

Metal	EPA Methods		ISO Methods (Extraction and Analysis)
	Extraction	Analysis	
Arsenic	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Boron	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Cadmium	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Chromium	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Cobalt	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Copper	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Lead	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Manganese	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Mercury	EPA 7471B or EPA 7473		ISO 16967 or ISO 16968
Molybdenum	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Nickel	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Selenium	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Sodium	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968
Zinc	EPA 3050B/3051A	EPA 6010/6020	ISO 16967 or ISO 16968

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The EPA methods provided above require an acid digest of the raw biochar material, which may not fully digest all biochar material under the specified conditions. EPA methods provide a representation of metals extracted under certain conditions which are applied consistently across a variety of materials tested via the same EPA methods.

The ISO methods provided above are different in that hydrofluoric acid is used, which may result in a more complete digestion of the biochar material. Additionally, ISO 16967 provides an alternate procedure whereby biochar can be ashed at 550°C, and the ash is subsequently digested in acid. This technique provides a more complete digestion process; however, some inorganic materials may volatilize in the ashing stage.

For all metals analyses, care should be taken to ensure that method detection and reporting limits are sufficiently low to support regulatory compliance in a given jurisdiction. In some samples, concentrations of one metal may interfere with detection and increase reporting limits for other metals. Under such circumstances dilutions may be necessary to generate suitable data.

13 General Agricultural Analyses

Biochar is commonly used as an agricultural input, including applications as a soil amendment, a component of biochar-enhanced fertilizers, and as part of horticultural substrates. While typically considered to be an amendment, rather than a key nutrient source or fertilizer, some biochar does provide significant quantities of nutrients, particularly phosphorus, potassium, calcium, magnesium, and other trace nutrients. The following section presents recommended analysis methods for key parameters relevant to the agricultural use of biochar.

Because biochar is not typically marketed as a fertilizer, it is not necessary that all biochar samples be analyzed for available nutrients. For most biochar, analysis of total nutrients is sufficient for current agricultural uses of biochar, however, methods suitable for the analysis of extractable nutrients are provided in section 13.5.

If biochar is intended to be marketed as a fertilizer, analysis of available nutrients and certification of a guaranteed analysis is required in each US state and in each Canadian province. While such analyses can be completed for biochar following common Association of Official Analytical Collaboration International (AOAC) and ISO methods, additional regulatory steps are typically required for fertilizer registration, including potentially completing efficacy testing. Those wishing to market and sell biochar as a fertilizer and key source of nutrients should review relevant regulatory standards. In the United States and Canada, such standards are typically maintained by State or Provincial Departments of Agriculture or by the Association of American Plant Food Control Officials (AAPFCO).

13.1 total nitrogen

Testing for total nitrogen should be conducted per ISO 16948 as outlined in section 7.5 above.

13.2 total sulfur & chlorine

When total sulfur and/or chlorine are required, testing should be conducted per ISO 16994. The base method uses ion chromatography detection in conjunction with an oxygen bomb combustion vessel to prepare samples. This method is effective for biochar materials that combust readily in an oxygen bomb (e.g., low ash biochar). ISO 16994 also incorporates language for using other forms of instrumentation (e.g., combustion analyzers for sulfur content) provided the results can be validated against the base method. Combustion analyzers are considered acceptable for all biochar material types and are preferred for biochar samples that are high in ash content.

13.3 phosphorus, potassium, calcium, magnesium, iron, and sodium

It is recommended that *P, K, Ca, Mg, Fe, Na* be tested per ISO 16967 (9.1.2 Part B) by first ashing at 550°C and subsequent acid digestion. Ashing the materials first results in a breakdown of the organic carbon matrix, leaving the inorganic materials, which are subsequently easily digested in acid. It should be noted however that some inorganic materials may volatilize in the ashing stage.

There is strong evidence that direct digestion of biochar in acid as described within ISO 16967 (9.1.1 Part A) and as described within EPA methods 3050B and 3051A regularly result in incomplete digestion and could under report the true amount of the elements tested. It has been suggested that higher microwave temperature programs may be more effective at achieving complete digestion, but to date have not been confirmed. Laboratories wishing to develop a high temperature/high pressure microwave procedure are encouraged to evaluate each sample analyzed by this method for complete digestion and only make use of such procedures if it can be confirmed that digestion is complete. If such digestions are performed, then a description of the procedure should be noted on the test report.

ISO 16967 does specify the use of hydrofluoric acid (HF); however, this is specifically so that silica and other minerals bound within complex silicates can also be analyzed as part of the method. If silica and/or nutrients locked within silicates are not of concern, then HF can be omitted and replaced with additional nitric acid. If HF is omitted, then this should be stated on the test report.

13.4 boron, copper, molybdenum, nickel, and zinc

B, Cu, Mo, Ni, and Zn should be analyzed according to the methods presented in section 12.2 above.

13.5 extractable N, P, Mg, K, Ca & S

While there are currently no methods yet published for testing plant-available nutrients in biochar, there are extraction methods that attempt to better represent the nutrients that may be released into the soil by mimicking conditions of the soil near plant roots. For example, 1M HCl is a weak acid that may be used to extract *K, Mg, Ca, and S* from biochar to estimate the fraction of these nutrients that may be extracted by plant roots when they excrete H⁺ ions into the soil. Table 5 provides recommended methods for measuring extractable *N, P, K, Mg, Ca, and S*:

Table – 5

Nutrient	Extractant	Method	Reference
N	2M KCl	Colorimetry	Extract: Keeny and Nelson, 1982[2] NO ₃ - colorimetry: EPA 353.2 NH ₄ ⁺ colorimetry: EPA 350.1
P	2% Formic Acid	ICP-OES	Extract: EN 15919
K, Mg, Ca, S	1M HCl	ICP-OES	Extract: Rayment and Lyons, 2011[3]

Note: The extraction methods recommended in this section are intended to estimate the portion of certain nutrients that may be more readily mobilized in soil environments. However, the results obtained using these methods should not be interpreted as direct measures of plant-available nutrient content. Actual plant uptake is influenced by complex soil–plant interactions, including pH, cation exchange capacity, microbial activity, and other site-specific factors. These laboratory procedures do not replicate root exudation, microbial mineralization, or other dynamic processes that occur in the rhizosphere under field conditions.

For measurement of soluble salts (e.g., EC), see Clause 13.8.

13.6 pH

Testing for pH should be conducted per ISO 10390. This method allows for a choice between three different extraction solutions: 1.) DI water, 2.) 1M KCl, or 3.) 0.01 M CaCl₂, all of which are considered acceptable. pH results should state the extraction solution used (e.g. pH 1:5 vol/vol in DI or pH 1:5 vol/vol in CaCl₂). Because biochar can absorb significant amounts of solution, if the final slurry is too thick then more solution may be necessary. Lab reports should specify the ratio (vol:vol) used to perform the analysis.

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13.7 liming

Determination of neutralization value (liming) should be conducted per ISO 20978. This method provides a Method A option and a Method B option, both of which are considered acceptable. Reports should reference which option was chosen (A or B).

13.8 salinity

Determination of salinity (via electrical conductivity) should be conducted per ISO 11265. Biochar requires a modification to the method using a 1:10 dry weight to volume extraction ratio using DI water (instead of 1:5) due to biochar's ability to absorb water. Results are to be expressed as electrical conductivity in the units of dS/m or mmhos/cm.

14 Special Considerations Regarding High Ash Biochar

Not all materials that meet the definition of biochar (see section 4.1) will behave the same when conducting testing per the methods outlined in this standard. Behavioral differences are generally related to the amount of ash within the biochar and the composition of the ash. For example, material quantified as ash may contain carbonates (e.g. inorganic carbon) that are quantified as both ash and as part of the total carbon fraction resulting in an imbalance when calculating the oxygen value as part of an ultimate analysis. Similarly, some material quantified as ash may also become volatile when performing the volatile matter test, resulting in an imbalance when calculating the fixed carbon content as part of a proximate analysis. If ash concentrations are low, these effects may be minimal/not observable within the test data; however, as ash concentration increases the potential impacts can be greater and more likely observed. Regardless of whether the biochar ash content is high or low, it is important to understand these behavioral differences and to take them into consideration when evaluating biochar test results. See informative Annex A for example calculations using the scenarios described below.

14.1 fixed carbon

In high ash biochar materials, fixed carbon values may not be reported accurately and can even appear as negative values when using the standard methods outlined in section 8. This is due to some of the material quantified as ash also being lost during the volatile matter determination, (e.g. due to violent reactions during the heating process and/or volatilization of inorganic materials), causing it to be quantified as both ash and as volatile matter.

If your biochar application requires a more accurate determination of the fixed carbon, consider using the following approach. Using the general analysis sample, first perform the volatile matter test followed by conducting the ash test on the same material used in the volatile matter test. By this process the ash content is potentially under represented, however the fixed carbon would be more accurately quantified. A separate ash test can still be performed to generate accurate ash results.

Using this process the following calculation would apply:

$$\% \text{ Fixed Carbon} = 100 - \% \text{ Moisture} - \% \text{ Volatile Matter} - \% \text{ Ash (post volatile matter test)}$$

With this approach, fixed carbon is calculated on an as-determined or dry basis and converted to as-received and/or dry basis as appropriate (see section 8.8).

14.2 oxygen

With higher ash biochar, it has been observed that oxygen may not be reported accurately and may even be reported as a negative value when using the methods outlined in section 7. This is due to the potential presence of carbonates (inorganic carbon) in the ash fraction. If ash is determined at 550°C, it will include carbonates. The carbon incorporated within the carbonates will also be quantified as part of the total carbon analysis, causing it to be quantified both as ash and as total carbon.

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If your biochar application requires a more accurate determination of the oxygen concentration, consider using the following approach. Determine the inorganic carbon fraction using the methods outlined in section 9.1 or 9.2 as appropriate. Then calculate the organic carbon fraction (C_{org}) as per section 9.3. Substitute the C_{org} value in place of the total carbon value in the oxygen calculation as follows:

$$\%O(dry) = 100 - \%Ash(dry) - \%C_{org}(dry) - \%N(dry) - \%H(dry) - \%S(dry)$$

where O = Oxygen, C_{org} = organic carbon, N = Nitrogen, H = Hydrogen, and S = Sulfur.

The oxygen dry basis value can also be converted to the as-received basis (see section 7.8).

This improved oxygen value can be used to calculate the $O:C_{org}$ molar ratio, a common permanence indicator for biochar stability assessments.

14.3 TGA analysis

In thermogravimetric analysis (TGA), it is common practice to perform tests sequentially, beginning with moisture determination, followed by volatile matter measurement, and concluding with ash content determination. For high ash biochar, the total ash content may be reported lower than the test method outlined in section 8.2 due to some of the inorganic material being lost as volatile matter in advance of the ash test. If a more accurate analysis of the ash concentration is required for your biochar application, then ash testing should be performed on a separate aliquot of the sample for which a volatile matter test has not been conducted.

For high ash biochar, conducting the volatile matter test in advance of the ash test should produce a more accurate representation of fixed carbon as described in section 14.1

15 Next steps

While this standard outlines a comprehensive suite of methods for the measurement and testing of biochar, it is recognized that the field of biochar science and application is rapidly evolving. Numerous emerging and expanding uses for biochar are under active development across sectors ranging from agriculture and environmental remediation to industrial manufacturing and advanced materials.

As new applications mature and regulatory frameworks evolve, additional methods and performance metrics may become necessary to support biochar's safe, effective, and fit-for-purpose use. This standard is intended to be a living document, and it is anticipated that future revisions will incorporate new analytical approaches, sampling techniques, and application-specific guidance as the biochar industry continues to grow and diversify.

Future work may include development of methods to assess the net climate benefit of biochar use, including standardized approaches for estimating carbon permanence and GHG offsets under different land use and combustion scenarios.

References

- [1] Douek M. & ING, J. (1987). A new method for determining carbonate in samples from the pulp and paper industry. *Cellulose Chemistry and Technology*, 21, (315-327).
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Annex A

Example Calculations for High Ash Biochar

A.1 Fixed carbon example per section 14.1

A biochar sample was analyzed in accordance with the test methods outlined in section 8, which yielded the following test results. Note that fixed carbon is expressed as a negative value due to some of the inorganic materials being quantified as both ash and as volatile matter:

Table A1-1

Parameter	As-Received	Dry Basis
Total Moisture (%)	26.11	
Ash (%)	61.81	83.65
Volatiles (%)	20.8	28.15
Fixed Carbon (%)	-8.72	-11.80
Carbon (%)	6.36	8.61
Hydrogen (%)	0.2	0.27
Nitrogen (%)	0.19	0.25
Oxygen (%)	2.97	4.02
Sulfur (%)	2.37	3.20

To resolve this issue the volatile matter test was performed per section 8.4, however once complete the remaining material was ashed at 550°C per ISO 18122 (section 8.2), which yields the percent ash still remaining after the volatile matter test. For this example, the following results were achieved.

Table A1-2

Parameter	As-Received	Dry Basis
Total Moisture (%)	26.11	
Ash (%) - Post VM Test	48.47	65.60
Volatiles (%)	20.80	28.15

The % ash post volatile matter test is then used in the equation provided in 14.1 to yield a more representative fixed carbon content:

$$\% \text{ Fixed Carbon} = 100 - \% \text{ Moisture} - \% \text{ Volatile Matter} - \% \text{ Ash (post volatile matter test)}$$

Whereby % Fixed Carbon (as received) is calculated as follows:

$$\% \text{ Fixed Carbon (AR)} = 100 - 26.11 - 20.80 - 48.47$$

$$\% \text{ Fixed Carbon (AR)} = 4.62$$

Fixed carbon as received can then be converted to the dry basis per section 7

$$\% \text{ Fixed Carbon (DB)} = (4.62) * \left(\frac{100}{100 - 26.11} \right)$$

$$\% \text{ Fixed Carbon (DB)} = 6.25$$

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Since the ash content post volatile matter test does not represent all inorganic material contained within the sample. The proper display of the final results is to use the original ash value in conjunction with the adjusted fixed carbon content. For this example, the final expression of results is as follows:

Table A1-3

Parameter	As-Received	Dry Basis
Total Moisture (%)	26.11	
Ash (%)	61.81	83.65
Volatiles (%)	20.8	28.15
Fixed Carbon (%)	4.62	6.25
Carbon (%)	6.36	8.61
Hydrogen (%)	0.2	0.27
Nitrogen (%)	0.19	0.25
Oxygen (%)	2.97	4.02
Sulfur (%)	2.37	3.2

The final test report should include a description of the principles by which section 14.1 was applied (e.g., “Fixed carbon was recalculated per section 14.1 due to high ash content”).

A.2 Oxygen example per section 14.2

A biochar sample was analyzed in accordance with the test methods outlined in sections 8 & 9, which yielded the following test results. Note that oxygen is expressed as a negative value due to inorganic carbon being quantified as both ash and as part of the total carbon fraction:

Table A2-1

Parameter	As-Received	Dry Basis
Total Moisture (%)	62.98	
Ash (%)	23.06	62.28
Carbon (%)	13.54	36.57
Hydrogen (%)	0.42	1.14
Nitrogen (%)	0.12	0.32
Oxygen (%)	-0.16	-0.41
Sulfur (%)	0.04	0.10
Inorganic Carbon (%)		4.59
Organic Carbon (%)		31.98

To resolve this issue, use the equation provided in section 14.2.

$$\% O (dry) = 100 - \% Ash (dry) - \% C_{org} (dry) - \% N (dry) - \% H (dry) - \% S (dry)$$

where $\% Ash (dry) = 62.28$, $\% C_{org} (dry) = 31.98$, $\% N (dry) = 0.32$, $\% H (dry) = 1.14$, and $\% S (dry) = 0.10$

$$\% O (dry) = 100 - 62.28 - 31.98 - 0.32 - 1.14 - 0.10$$

$$\% O (dry) = 4.18$$

The $\% O$ dry basis can then be converted to the as received basis (see section 7).

The final expression of results would be as follows:

Table A2-2

Parameter	As-Received	Dry Basis
Total Moisture (%)	62.98	
Ash (%)	23.06	62.28
Carbon (%)	13.54	36.57
Hydrogen (%)	0.42	1.14
Nitrogen (%)	0.12	0.32
Oxygen (%)	1.55	4.18
Sulfur (%)	0.04	0.10
Inorganic Carbon (%)		4.59
Organic Carbon (%)		31.98

The final test report should include a description of the principles by which section 14.2 was applied.

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