BIOFORCETECH
CORPORATION

Biomass to Biochar Feasibility Study: PFAS Removal



Bioforcetech Biomass to Biochar Feasibility Study: PFAS Removal Testing Addendum



Dry Digested Biosolids



Biosolids Biochar - 650°C, 15 min

Overview

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals used in a variety of industries around the world. PFAS are persistent, accumulative, and leachable in the environment, and do not readily break down over time. Humans may introduce PFASs in their bodies via drinking contaminated water, and eating fish and meat as well as vegetables and fruits. The adverse effects of PFAS in humans may include, but are not limited to, increased cholesterol, hepatotoxicity and alterations in the immune system, as well as thyroid hormone disruption. Because PFAS may be released into the air, soil, and water (including drinking water sources), it's important to understand the level of exposure in both humans and the environment around us and to develop a reliable and cost-effective technological platform to minimize or eliminate PFAS compounds.

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PFAS compounds are thermally very stable and require high reaction energy/high temperatures to break down their chemical bonds. Thermal treatments such as pyrolysis, gasification, combustion and incineration may have the potential to fully/partially destruct PFASs due to their high temperature operation conditions.

EPA Testing Confirmed BFT Pyrolysis Removal of PFAS

In 2022, The US EPA published results from a pilot study conducted on Bioforcetech equipment that showed no PFAS compounds were detected in biochar produced from high temperature pyrolysis of biosolids that had confirmed PFAS, PFOA, and PFOS compounds in them prior to pyrolysis. It is hypothesized that the PFAS compounds from the biosolids when pyrolyzed at high temperatures enter the gas phase as volatile PFAS along with syngas. The volatile gasses along with syngas are then combusted in the combustion chamber. These findings show a promising pathway to management of contaminated organics and the removal of these 'forever chemicals.'

Bench Scale Testing

In 2024, Bioforcetech conducted an internal PFAS testing study with the bench scale unit and determined that pyrolysis of biosolids at standard temperature (650 °C) and residence time (15 minutes) produced biochar with no PFAS compounds detected that were originally present in the input biosolids (See **Table 2)**. Biochar was collected in a stainless steel collection bin, cooled to ambient temperatures, and carefully transferred into a PFAS free HDPE bottle and maintained at below 6 °C for PFAS testing. Samples were hand delivered to an accredited analytical laboratory for PFAS testing. PFAS testing was conducted following EPA Method 1633 - Analysis of Per- and Polyfluoroalkyl Substances (PFAS) in Aqueous, Solid, Biosolids, and Tissue Samples by LC-MS/MS. Quantitative determination of target analyte concentrations is made with respect to an isotopically labeled PFAS standard. Selection of target analytes in this study was based on the availability of standards for both unlabeled and isotopically labeled PFAS compounds.

In summary, fifteen PFAS compounds were detected in the Biosolids and zero PFAS compounds detected in the Biochar. From our internal study, we conclude that pyrolysis of input biosolids with the bench scale unit at standard temperature of 650 °C and residence time of 15 minutes resulted in processing conditions that effectively reduced the presence of PFAS in the output biochar.

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Table 2. Summary of PFAS Testing for Biosolids and Biochar using the Isotope Dilution Method via EPA Method 1633.

Analyte	Biosolids (ng/g)	Biochar (ng/g)
PFBA	Not Detected	Not Detected
3:3 FTCA	Not Detected	Not Detected
PFPeA	1.39	Not Detected
PFBS	9.71[1]	Not Detected
4:2 FTS	Not Detected	Not Detected
PFHxA	8.78	Not Detected
PFPeS	Not Detected	Not Detected
HFPO-DA	Not Detected	Not Detected
5:3 FTCA[2]	70.1	Not Detected
PFHpA	1.57	Not Detected
ADONA	Not Detected	Not Detected
PFHxS	Not Detected	Not Detected
6:2 FTS	Not Detected	Not Detected
PFOA	31.5	Not Detected
PFHpS	Not Detected	Not Detected
7:3 FTCA[3]	57.3	Not Detected
PFNA	1.30	Not Detected
PFOSA	Not Detected	Not Detected
PFOS	7.67	Not Detected
9Cl-PF3ONS	Not Detected	Not Detected
PFDA	10.3	Not Detected
8:2 FTS	Not Detected	Not Detected
PFNS	Not Detected	Not Detected
MeFOSAA	18.8	Not Detected
EtFOSAA	17.5	Not Detected
PFUnA	Not Detected	Not Detected
PFDS	Not Detected	Not Detected
11Cl-PF3OUdS	Not Detected	Not Detected
10:2 FTS	Not Detected	Not Detected
PFDoA	3.33	Not Detected
MeFOSA	Not Detected	Not Detected
PFTrDA	Not Detected	Not Detected
PFTeDA	Not Detected	Not Detected
EtFOSA	Not Detected	Not Detected
PFHxDA	Not Detected	Not Detected
PFODA	Not Detected	Not Detected

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MeFOSE	15.2	Not Detected
EtFOSE	9.39	Not Detected

[1] The ion transition ratio was outside of the acceptance criteria.

[2] 5:3 FTCA, or 5:3 fluorotelomer carboxylic acid, primarily comes from landfills, where it is released from products like carpets that contain PFAS (per- and polyfluoroalkyl substances), making it a common indicator of PFAS contamination originating from landfills; it is a breakdown product of other fluorotelomer compounds used in manufacturing various consumer goods.

[3] 7:3 FTCA (fluorotelomer carboxylic acid) primarily originates from the breakdown of fluorotelomer alcohols, which are used in various industrial and consumer products, and is considered a major byproduct of their biodegradation, meaning it is created when these chemicals are broken down by bacteria in the environment; essentially, it's a "breakdown product" of other PFAS chemicals, often detected in water, soil, and even wildlife due to its persistence in the environment.

Testing Your Biomass for PFAS Removal

Bioforcetech is pleased to offer PFAS testing of your input feedstock and output biochar. This testing will follow the same SOP detailed in the case study above. If there are specific compounds please let us know and we will work with our partner lab to understand if these can be covered and any costs associated with the addition of these compounds.

The timeline, sample amount, and biomass requirements do not change when adding PFAS testing to a biomass feasibility study. Please see the main Biomass Feasibility Study document for these details.

Ensuring Accurate Results

PFAS compounds are used across a variety of product categories and can be found in the open air ecosystem, drinking water, and more. When testing for the removal of PFAS compounds, it is absolutely critical that no exposure to PFAS occurs so as not to contaminate and disqualify a sample for testing. Bioforcetech has taken critical steps to ensure that all risks of sample contamination are eliminated/minimized. This includes the use of a PFAS free stainless steel production line and catchment system, PFAS free gloves, PFAS free quenching water (reagent water), PFAS free bottles and containers.

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Accurate testing requires that sample handling also follows the guidelines set out by the trusted third party lab, Enthalpy, that we work with and the EPA approved testing procedures that they follow. In order to ensure accurate results, samples of biochar produced for PFAS testing are cooled in their catchment chamber before opening, then transferred to certified PFAS free HDPE bottles which are immediately moved to a cold container to maintain required temperatures below 6°C. These samples are then hand delivered by BFT personnel at the required temperatures and within the required time limits to ensure the viability of the samples for testing are maintained.

If you have any questions regarding the steps Bioforcetech takes to ensure accurate results please do not hesitate to reach out to us at info@bioforcetech.com.

Process and Timeline

Stage 1: Sample Feasibility

Once received, a biomass that meets the requirements for conversion will be inspected and its ability to be conveyed through the pyrolysis unit will be determined. Upon receiving the biomass, a small sample will be sent to our lab for analysis to determine feasibility for a successful thermal conversion to biochar. If a material cannot be conveyed in its received state, further processing within reason will be done by Bioforcetech personnel at an added cost to the provider while awaiting results from the analysis. Once the material has reached a conveyable state and the results of analysis show feasibility for successful conversion, the testing can begin.

Stage 2: Biomass Conversion

During stage 2 the biomass is conveyed through the Bioforcetech bench scale system to be converted into a fixed carbon biochar. Like the full scale Bioforcetech system, this bench scale unit can control temperature and residence time +/- 1°C and to the second respectively. The airtight reactor ensures no extra oxygen reaches the material, and our oxidizing chamber ensures hydrocarbons are removed and spent so as not to condense onto the resulting biochar.

Stage 3: Analysis

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The biochar sample is analyzed and characterized by a trusted third party laboratory. Basic yet thorough characterization of the material will be completed to give an accurate picture of how this biochar compares to others. Characteristics include carbon content, carbon permanence through H:C ratio, biomass to biochar yield, ph, surface area, and more.

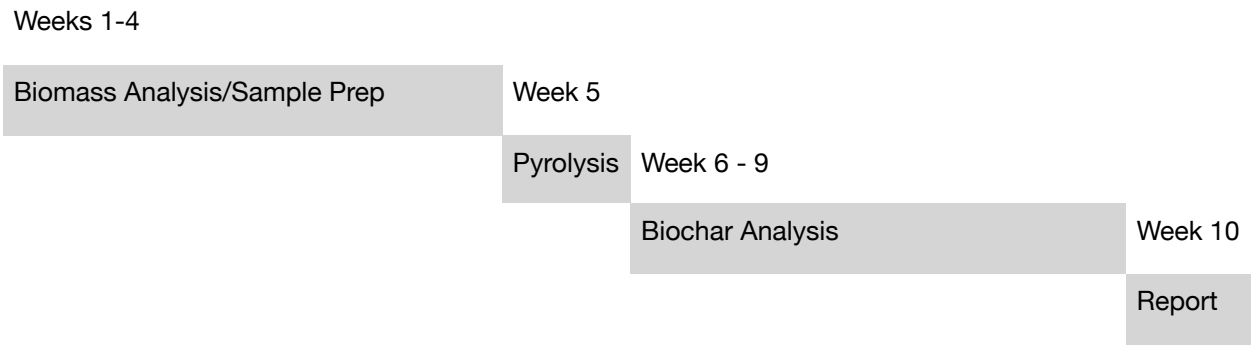
Stage 4: Results and Reporting

Once analyzed, a written report of the study will be shared with the biomass provider. More than pure data, this report includes a detailed review of the work done, notes on the physical and chemical analyses completed, and conclusions on the general feasibility of this material to produce a biochar at scale through a Bioforcetech system.

Timeline

Assuming no further processing is required to convert the biomass, that there is no delay at our lab or partner labs for analyses, and that the biomass is immediately able to move into production, Bioforcetech estimates results reported in 8 to 10 weeks.

Feasibility Study Timeline



Biomass Requirements

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In order to ensure quality and consistency during the feasibility study, a biomass sample must meet certain parameters. While some of the parameters listed below are the same for processing on a full scale Bioforcetech pyrolysis unit, a number of them are due to the conveyance requirements and size of the bench scale unit. To that end, processing required to procure a sample for a feasibility study may not be required for conveyance in a full scale BFT pyrolysis unit.

Biomass Requirements

Sample Size	6 dry kilograms
Particle Size Distribution	2-8 mm in all directions
Moisture Content	< 20%
Consistency	Homogenous
BTU	> 5,000 btu/lb

Pricing

Please see the below table for pricing reflective of this service.

Note that this is a complete study separate from a biomass to biochar feasibility study, which Bioforcetech also offers. The biochar created in this study cannot be analyzed for its general biochar characteristics due to the differing SOPs associated with production for each of these studies.

Biomass Feasibility and PFAS Destruction Testing Pricing

Testing Type	Sample 1	Sample 2+
Biomass PFAS Study	$8,900	$7,000

** Delivery of all samples for testing must be completed at the same time. If the project timeline requires that a sample be delivered independently than the cost of that sample will remain at $7,000.*

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