A meeting of the Planning Board for the Town of Moreau, Saratoga County, State of New York was held at the Moreau Town Hall, 351 Reynolds Road, Moreau, NY 12828 on the 12nd day of May 2022 at 7:00 pm.

Town of Moreau

Special Planning Board Meeting

Thursday, May 12, 2022

Planning Board Members Present

John Arnold	Planning Board Member
Ann Purdue	Planning Board Member
Mike Shaver	Planning Board Member
Erik Bergman	Planning Board Member
Meredithe Mathias	Planning Board Member
Adam Seybolt	Planning Board Member

Also, present

Katrina Flexon	Meeting Secretary
Jim Martin	Zoning Administrator
Karla Buettner	Town Attorney
Ray Apy	Applicant
Bryce Meeker	Consultant for Applicant

The meeting was called to order at 7:01pm by Mr. Arnold he will be the acting Chairperson for the meeting this evening.

Chairperson Arnold addresses the room and makes known there will be rules in regard to the public hearing scheduled for this meeting. He reads the ground rules for the meeting; each speaker will be limited to 5 minutes, speakers may not concede their time to another speaker. Speakers must come to the podium and identify themselves; state their name and where they are from. All comments will be directed to the Board not the applicant or other members of the public. Attorneys speaking on behalf of their clients please identify the client. If the person is reading from a written statement please provide a copy of the statement to the Planning Board Clerk to be placed in the record. Only one person may speak at a time. No personal attacks on the applicant, consultants, representatives, town officials or any other members of the public. He announces to the room this is a public hearing for a site plan application only. SEQR has been determined. He asks the public comments to be focused on the site plan application aspects of the project. He states this is a time for the public to comment and for the Board to hear new information to help them make a deliberation on the application.

Chairperson Arnold opens the public hearing and reads individuals from the sign-in sheet who have identified they would like to make comments on the application from top to bottom.

The following is a list of individuals who spoke during the site plan review public hearing for Saratoga BioChar Solutions LLC project

Laurie LaFond	3 Oakwood Dr.	Against
Tom Mahoney	7 Sisson Rd.	Against
Mat Boucher	10 Sisson Rd.	Against
Melissa Chester	1662 Rt 9	Against
Ro Padron	19 Sisson Rd	Against
Sean Sheeran	297 Clark Rd	Against
Greg McCarty	201 Reservoir Rd	Against
Gina LeClair	37 Sisson Rd	Against
Holly Johnson	3 Deer Run	Against
Tori Riley	56 Duplainville Rd	For
Pat Bondzinski	49-53 Sisson Rd	Against
Samantha Fullerton	Argyle	For
Sandy Mahony	7 Sisson Rd	Against
Rebecca Smith	352 Reynolds Rd	Against
Chad Beatty	2254 Rt 50	Against
Mike Jarvis	2 Coby Dr	For
Tracy Frisch	1293 McClay Rd	Against
Jorge Padron	19 Sisson Rd	Against
Sherrie Murray	4 Thornapple Dr	Against
Erik Poust	9 Sisson Rd	Against
Emily Boucher	10 Sisson Rd	Against
Jordan Edens	29 Winterberry	Against
Bob LeClair	37 Sisson Rd	Against

Laurie Lafond speaks about not enough evidence according to EPA, air pollution, respiratory illness, cancer and shares a poem.

Tom Mahoney comments on odor, quality of life, Finch Paper LLC, and Hexion facilities; reads from the town codes stating waste can't be brough in from other towns.

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Mat Boucher speaks about air pollution, comments on the role of the applicant during the SEQR process, and methane levels.

Melissa Chester is concerned about kids, talks about noise, reads Town code noise section, speaks about the sewer capacity, PFAS, the facility run time, and the Hexion facility.

Ro Pedrone speaks about safety as a main concern, wants an updated EIS and outside review, also concerned about traffic, odors, noise, emissions, potential fires and whether there are protocols in place.

Sean Sheeran talks about chapter 92 of the Town Code to prohibit import of waste, brought up medical waste article 139-38 and 149.30 the Planning Board approval declined based on health and well-being of Town.

Greg McCarty comments on PFAS not removed by heat, bringing waste from elsewhere, and speaks about Maine moving to ban fertilizer with PFA.

Gina LaClair speaks about inconsistencies in SEQR and wants an independent review.

Holly Johnson speaks about needing an independent study to identify concerns, there was no sound study.

Tori Riley from SEDC is in support of the project.

Pat Bondzinski voices concerns about noise, smell, emissions, traffic.

Samantha Fullerton is a chemical engineer, her husband is a dairy farmer, she investigated the BioChar process, it has innovative technology, and she would welcome them in her backyard.

Sandy Mahoney has concerns about emergency services due to ladder truck, EMS, and Hazmat Team. She states the emergency services need to be informed and worries about chemical exposure.

Rebecca Smith wants an independent review, concerns about odors, air quality, and truck traffic on 197.

Chad Beatty spoke with friends in Moreau, doesn't think there is science behind the project.

Mike Jarvis member of 773 Plumbers and Steamfitters in Queensbury, with 500 members 10% of members in Moreau, agrees with testing, speaks in favor.

Tracy Frisch – says PFA will be everywhere, talks about the stats, total organic fluorine's, PFO, PFA, and 10 parts per billion limit, believes if left up to DEC its not being put in good hands.

Jorge Padron built house in 2021, talks about living within 1,200 feet of the facility and about quality of life.

Sherry Murray talks about systematic review from 2020 and BioChar sewage study, potential hazardous, leachability of metals. Doesn't believe there is enough research.

Erik Poust states he doesn't know enough about BioChar and doesn't want to be a guinea pig.

Emily Boucher talks about being a mom and the impact on kids.

Jordan Edens states he is new to the area, doesn't like that the facility is going to emit anything, concerned about developments.

Bob LaClair does not support the project, worked for other companies he has watched leave a mess.

Chairperson Arnold closes the public hearing at 8:43pm

Mr. Apy states he will comply with all monitoring, and they're going to test more than required. He will work with local fire and Saratoga Emergency Response. He adds that biosolids are not regulated as hazardous waste. They are modeling the facility after the Zion Illinois facility.

Ms. Purdue states there should be an independent review done, SEQR should be rescinded due to new information like excessive wastewater and water capacity.

Ms. Purdue makes a motion to rescind the Planning Boards prior negative declaration on SEQR for Saratoga BioChar Solutions LLC.

Attached to the meeting mins are reference documents associated with this motion.

Mr. Bergman seconds the motion.

Chairperson Arnold asks the Board if all in favor say Aye

Results as followed:

Mike Shaver	**No**
Ann Purdue	**Yes**
Erik Bergman	**Yes**

Adam Seybolt	**No**
Meredithe Mathias	**No**
John Arnold	**No**

2 in favor, 4 oppose, motion defeated

Ms. Purdue makes a motion to retain an independent consultant to assist with review of project, Saratoga BioChar Solutions LLC.

Mr. Bergman Seconded the motion.

Chairperson Arnold asks the Board if all in favor say Aye.

Results as followed:

John Arnold	**Aye**
Ann Purdue	**Aye**
Mike Shaver	**Aye**
Erik Bergman	**Aye**
Adam Seybolt	**Aye**
Meredithe Mathias	**Aye**

All in favor, none oppose, motion carries

A motion was made by Ms. Purdue and seconded by Mr. Bergman to retain an independent consultant to assist with review of Saratoga BioChar Solutions LLC project.

Ms. Purdue makes a motion to have Mr. Martin submit a scope of work to the Board, the Board will give him items they would like included in the scope of proposed work by close of business May 27, 2022.

Mr. Bergman Seconds the motion

Chairperson Arnold asks the Board if all in favor say aye

Results as followed:

John Arnold	**Aye**
Ann Purdue	**Aye**
Mike Shaver	**Aye**
Erik Bergman	**Aye**

Adam Seybolt	**Aye**
Meredithe Mathias	**Aye**

All in favor, none oppose, motion carries

A motion was made by Ms. Purdue to have Mr. Martin submit a scope of work to the Board, the Board will give him information of proposed work to include for the scope by close of business May 27, 2022 and seconded by Mr. Bergman.

Mr. Shaver makes a motion to adjourn the Planning Board meeting of May 12, 2022.

Mr. Seybolt seconds the motion.

Chairperson Arnold asks the Board all in favor say aye.

Results as followed:

John Arnold	**Aye**
Ann Purdue	**Aye**
Mike Shaver	**Aye**
Erik Bergman	**Aye**
Adam Seybolt	**Aye**
Meredithe Mathias	**Aye**

All in favor, none oppose motion carries

A motion was made by Mr. Shaver to adjourn the meeting and seconded by Mr. Seybolt.

Meeting was adjourned at 9:56 pm.

Respectfully submitted,
Katrina Flexon

A meeting of the Planning Board for the Town of Moreau, Saratoga County, State of New York was held at the Moreau Town Hall, 351 Reynolds Road, Moreau, NY 12828 on the 12nd day of May 2022 at 7:00 pm.

Attachment 1: written comments submitted by the public during the May 12 2022 meeting

Attachment 2: Reference Document submitted by Ms. Purdue

A meeting of the Planning Board for the Town of Moreau, Saratoga County, State of New York was held at the Moreau Town Hall, 351 Reynolds Road, Moreau, NY 12828 on the 12nd day of May 2022 at 7:00 pm.

Attachment 1

Pg ①

PUBLIC HEARING - MARCH 12, 2022 7:01PM - SARATOGA BIOCHAR SOLUTIONS LLC

SIGN-IN SHEET - PLEASE PRINT

NAME	ADDRESS	ARE YOU SPEAKING Y or N
Charles Dumas	For Applicant -	YES
Bryce Meeker	Applicant	Yes
Michael Nelson	Applicant	yes-
DAN SHIELDS	21 GLENMORE AVE SS 12866	NO
Laurie LaFond	Moreau 7 Oakwood Dr	Yes
Diane Collins	GF 33 Thornberry Dr	no
Roy Harden	3 Tina Ln Queensbury	NO
Tom MAHONEY	7 SISSON RD	YES
Marie Hughes	2 Winterberry Lane	NO
Mackenzie Johnson	3 Deer Run	NO
Jennette Hubinger	5 Deer Run	no
Matt Boucher	10 Sisson Road	Yes
Melissa Chester	1662 Rt 9 SGF	~~N~~ Yes
Ken Chester	1662 Rt 9 SGF	No
Mary Clear	35 Sisson Rd.	N
Chris [illegible]	15 McHugh St	NO
Christine Jarvis	2 Coby Dr. Queensbury	NO
Ro Padron	19 Sisson Rd Moreau	yes
SEAN SHEEHAN	292 Clark Rd	YES
Ashley Albrecht	5 Winterberry Ln	NO
Jeremy Jensen		Yes
Greg McCARTY	201 RESERVOIR RD	YES
Caitlin McIntyre	35 Winterberry	NO
MIKE MUNTER	909 MURRAY RD [illegible]	NO
[illegible]	20 Lupine Ln	No
Ronald Quinn	9 OAK VIEW DRIVE	NO

PERSONS CHOOSING TO SPEAK WILL HAVE 5 MINUTES TO DO SO AND CANNOT CEDE TIME TO OTHERS. MORE INSTRUCTIONS TO FOLLOW.

Pg 2

PUBLIC HEARING - MARCH 12, 2022 7:01PM - SARATOGA BIOCHAR SOLUTIONS LLC
SIGN-IN SHEET - PLEASE PRINT

NAME	ADDRESS	ARE YOU SPEAKING Y or N
Lorraine Ropati	36 Stewart Ave SGF	N
Karen LeOvier	24 Lupine La Qby	?
Gina LeClair	37 Sisson Rd	Yes
Bob LeClair	37 Sisson Rd	
Holly Johnson	3 Deer Runs	yes
Colleen McCoy	182 Ft Edward Rd	No
Bill McCoy	"	No
Shauna McCoy	"	NO
[illegible]	19 [illegible] Dr.	N
[illegible]	12&P Saratoga Rd	NO
Peg Kittle	6 Robertson SGF	NO
Roy Apy	Greenfield Ct.	Applicant
Fran Apy	"	NO
Lee Wulfekuhle	Missouri	No Applicant
Patrick Ellis	New Hampshire	APPLicant
Kurt Bedell	68 Fish House Rd	NO
Justin Jetten	75 Knight Street	No
Lori JE Riley	56 Duplainville Rd S. Springs	Y
Andrew Millspaugh	STERLING ENVIRONMENTAL W/ APPLICANT	N
Pat Bandzinski Frederick	49-53 Sisson Rd	might have a question
Samantha B Fullerton	Argyle	Y
Matthew Fullerton	Argyle	N
[illegible] Smith Sandy Mahoney	9 B 7 Sisson Road	? Yes,
John Smith	26 Sisson Rd	No
Virginia Livsey	289 Burt Rd	NO
BRUCE FLAYER	"	No

PERSONS CHOOSING TO SPEAK WILL HAVE 5 MINUTES TO DO SO AND CANNOT CEDE TIME TO OTHERS. MORE INSTRUCTIONS TO FOLLOW.

Pg ③

PUBLIC HEARING - MARCH 12, 2022 7:01PM - SARATOGA BIOCHAR SOLUTIONS LLC
SIGN-IN SHEET - PLEASE PRINT

NAME	ADDRESS	ARE YOU SPEAKING Y or N
Jordan Corey	87 Harrison Avenue	~~No~~ Yes
Emily Boucher	10 Sisson Rd	NO
Melissa Rayno	350 Reynolds Rd	NO
REBECCA SMITH	352 REYNOLDS RD	YES
Chad Beatty	2254 Rt. 50 S. S.S.	Yes
MIKE JARVIS	2 Coby Dr. QBY	Yes
Dana Charpentier	348 Reynolds Rd SGF	NO
Suzy Chhin-Paris	20 Lupine Lane, QBY	No
Maria + Eric Poust	9 Sisson Rd.	NO
JARON EDENS	24 WINTERBERRY LN	NO
Tracy Frisch	1293 McClay Rd, Greenwich	Yes
(George) Jorge Padron	19 Sisson RD Ft Edward	yes
JOHN MUNN	500 SOD-[illegible] Rd [illegible]	NO
Sherrie Murray	4 Thornapple Dr Gansevoort N.Y.	~~No~~ Yes
Carolyn Maxam	30 Winterberry Ln. Moreau, NY 12828	No
Andrew Dirga	557 Gansevoort Rd, SGF	No
Joscelyn Hadden	27 Sisson Rd	NO
Jared Hadden	27 Sisson Rd	No
[illegible] Thurston	Saratoga	NO
JOHN HADDEN	165 REDMOND Rd	NO
Chris Baxter	21 Charles St.	No
Mary & Steve Weeks	15 Thomas Ave	NO

PERSONS CHOOSING TO SPEAK WILL HAVE 5 MINUTES TO DO SO AND CANNOT CEDE TIME TO OTHERS. MORE INSTRUCTIONS TO FOLLOW.

f. Does the project include new residential uses? ☐Yes ☑No
If Yes, show numbers of units proposed.

	One Family	Two Family	Three Family	Multiple Family (four or more)
Initial Phase				
At completion of all phases				

g. Does the proposed action include new non-residential construction (including expansions)? ☑Yes ☐No
If Yes,
i. Total number of structures 1
ii. Dimensions (in feet) of largest proposed structure: 50 height; 303 width; and 222 length
iii. Approximate extent of building space to be heated or cooled: 7,560 ~~8,000~~ square feet

h. Does the proposed action include construction or other activities that will result in the impoundment of any liquids, such as creation of a water supply, reservoir, pond, lake, waste lagoon or other storage? ☐Yes ☑No
If Yes,
i. Purpose of the impoundment: ________
ii. If a water impoundment, the principal source of the water: ☐ Ground water ☐ Surface water streams ☐ Other specify:
iii. If other than water, identify the type of impounded/contained liquids and their source.
iv. Approximate size of the proposed impoundment. Volume: ________ million gallons; surface area: ________ acres
v. Dimensions of the proposed dam or impounding structure: ________ height; ________ length
vi. Construction method/materials for the proposed dam or impounding structure (e.g., earth fill, rock, wood, concrete):

D.2. Project Operations

a. Does the proposed action include any excavation, mining, or dredging, during construction, operations, or both? ☐Yes ☑No
(Not including general site preparation, grading or installation of utilities or foundations where all excavated materials will remain onsite)
If Yes:
i. What is the purpose of the excavation or dredging? ________
ii. How much material (including rock, earth, sediments, etc.) is proposed to be removed from the site?
- Volume (specify tons or cubic yards): ________
- Over what duration of time? ________

iii. Describe nature and characteristics of materials to be excavated or dredged, and plans to use, manage or dispose of them.
iv. Will there be onsite dewatering or processing of excavated materials? ☐Yes ☐No
If yes, describe. ________
v. What is the total area to be dredged or excavated? ________ acres
vi. What is the maximum area to be worked at any one time? ________ acres
vii. What would be the maximum depth of excavation or dredging? ________ feet
viii. Will the excavation require blasting? ☐Yes ☐No
ix. Summarize site reclamation goals and plan: ________

b. Would the proposed action cause or result in alteration of, increase or decrease in size of, or encroachment into any existing wetland, waterbody, shoreline, beach or adjacent area? ☐Yes ☑No
If Yes:
i. Identify the wetland or waterbody which would be affected (by name, water index number, wetland map number or geographic description): ________

C.3. Zoning

a. Is the site of the proposed action located in a municipality with an adopted zoning law or ordinance? ☑ Yes ☐ No

If Yes, what is the zoning classification(s) including any applicable overlay district?

M1 - Manufacturing 1

b. Is the use permitted or allowed by a special or conditional use permit? ☑ Yes ☐ No

c. Is a zoning change requested as part of the proposed action? ☐ Yes ☑ No

If Yes,

i. What is the proposed new zoning for the site? ________

C.4. Existing community services.

a. In what school district is the project site located? South Glens Falls

b. What police or other public protection forces serve the project site?

South Glens Falls Police Department

c. Which fire protection and emergency medical services serve the project site?

Moreau Fire Protection (FD026)

d. What parks serve the project site?

None

D. Project Details

D.1. Proposed and Potential Development

a. What is the general nature of the proposed action (e.g., residential, industrial, commercial, recreational; if mixed, include all components)? Industrial - Manufacturing

b. a. Total acreage of the site of the proposed action? 5.89 acres

b. Total acreage to be physically disturbed? 4.84 acres

c. Total acreage (project site and any contiguous properties) owned or controlled by the applicant or project sponsor? 5.89 acres

c. Is the proposed action an expansion of an existing project or use? ☐ Yes ☑ No

i. If Yes, what is the approximate percentage of the proposed expansion and identify the units (e.g., acres, miles, housing units, square feet)? % ________ Units: ________

d. Is the proposed action a subdivision, or does it include a subdivision? ☐ Yes ☑ No

If Yes,

i. Purpose or type of subdivision? (e.g., residential, industrial, commercial; if mixed, specify types) ________

ii. Is a cluster/conservation layout proposed? ☐ Yes ☐ No

iii. Number of lots proposed? ________

iv. Minimum and maximum proposed lot sizes? Minimum ________ Maximum ________

e. Will the proposed action be constructed in multiple phases? ☑ Yes ☐ No

i. If No, anticipated period of construction: ____ months

ii. If Yes:

- Total number of phases anticipated 3
- Anticipated commencement date of phase 1 (including demolition) Dec month 2022 year
- Anticipated completion date of final phase Dec month 2028 year
- Generally describe connections or relationships among phases, including any contingencies where progress of one phase may determine timing or duration of future phases:

Following approval, Phase 1 will be constructed to achieve 240 tons per day capacity of received biosolids. Phase 2 and 3 will be constructed over the first 5 years of operation to bring the facility to the target manufacturing capacity of 720 tons per day of received biosolids.

B. Government Approvals

B. Government Approvals, Funding, or Sponsorship. ("Funding" *includes* grants, loans, tax relief, and any other forms of financial assistance.)

Government Entity		If Yes: Identify Agency and Approval(s) Required	Application Date (Actual or projected)
a. City Counsel, Town Board, or Village Board of Trustees	☐Yes☑No		
b. City, Town or Village Planning Board or Commission	☑Yes☐No	Town of Moreau Planning Board - Site Plan Application	August 2021
c. City, Town or Village Zoning Board of Appeals	☐Yes☑No		
d. Other local agencies	☑Yes☐No	City of Glens Falls Wastewater Discharge Permit	September 2021
e. County agencies	☐Yes☑No		
f. Regional agencies	☐Yes☑No		
g. State agencies	☑Yes☐No	NYSDEC Region 5 - Part 360 SWMF Permit, Air State Facility Permit, Construction SPDES	October 2021
h. Federal agencies	☐Yes☑No		

i. Coastal Resources.

i. Is the project site within a Coastal Area, or the waterfront area of a Designated Inland Waterway? ☐Yes☑No

ii. Is the project site located in a community with an approved Local Waterfront Revitalization Program? ☐Yes☑No

iii. Is the project site within a Coastal Erosion Hazard Area? ☐Yes☑No

C. Planning and Zoning

C.1. Planning and zoning actions.

Will administrative or legislative adoption, or amendment of a plan, local law, ordinance, rule or regulation be the only approval(s) which must be granted to enable the proposed action to proceed? ☐Yes☑No

- If Yes, complete sections C, F and G.
- If No, proceed to question C.2 and complete all remaining sections and questions in Part 1

C.2. Adopted land use plans.

a. Do any municipally- adopted (city, town, village or county) comprehensive land use plan(s) include the site where the proposed action would be located? ☑Yes☐No

If Yes, does the comprehensive plan include specific recommendations for the site where the proposed action would be located? ☑Yes☐No

b. Is the site of the proposed action within any local or regional special planning district (for example: Greenway; Brownfield Opportunity Area (BOA); designated State or Federal heritage area; watershed management plan; or other?) ☑Yes☐No

If Yes, identify the plan(s):

NYS Heritage Areas:Mohawk Valley Heritage Corridor

c. Is the proposed action located wholly or partially within an area listed in an adopted municipal open space plan, or an adopted municipal farmland protection plan? ☐Yes☑No

If Yes, identify the plan(s):

Full Environmental Assessment Form

Part 1 - Project and Setting

5/12 Providing facts to potentially concerned citizens who been totally neglected until just the last days.

Instructions for Completing Part 1

Part 1 is to be completed by the applicant or project sponsor. Responses become part of the application for approval or funding, are subject to public review, and may be subject to further verification.

Complete Part 1 based on information currently available. If additional research or investigation would be needed to fully respond to any item, please answer as thoroughly as possible based on current information; indicate whether missing information does not exist, or is not reasonably available to the sponsor; and, when possible, generally describe work or studies which would be necessary to update or fully develop that information.

Applicants/sponsors must complete all items in Sections A & B. In Sections C, D & E, most items contain an initial question that must be answered either "Yes" or "No". If the answer to the initial question is "Yes", complete the sub-questions that follow. If the answer to the initial question is "No", proceed to the next question. Section F allows the project sponsor to identify and attach any additional information. Section G requires the name and signature of the applicant or project sponsor to verify that the information contained in Part 1 is accurate and complete.

A. Project and Applicant/Sponsor Information.

Name of Action or Project:
Saratoga Biochar Solutions, LLC. - Carbon Fertilizer Manufacturing Facility - Moreau Industrial Park

Project Location (describe, and attach a general location map):
Moreau Industrial Park (Parcels 60.-4-16 and 60.-4-22) , Moreau, NY (Map Attached)

Brief Description of Proposed Action (include purpose or need):
The Applicant is proposing to construct and operate a Carbon Fertilizer Manufacturing Facility (the "Facility") within the Moreau Industrial Park (Parcels 60.-4-16 and 60.-4-22) that will manufacture carbon fertilizer (a form of biochar) from biosolids at a rate of 720 tons of received biosolids per day. Construction is proposed in three phases over five years. Each phase will be capable of processing 240 tons of received biosolids per day. The Facility includes a fully enclosed building for receiving and handling biosolids as the feedstock for the carbon fertilizer manufacturing process. The Facility requires Site Plan approval by the Town of Moreau Planning Board and issuance of a Solid Waste Management Facility Permit and Air State Facility Permit from the New York State Department of Environmental Conservation (NYSDEC). The development proposes to merge parcels 60.-4-16 and 60.4-22 into a single parcel with access directly from Farnan Road.

Name of Applicant/Sponsor: Saratoga Biochar Solutions, LLC.
Telephone: 518-391-0586
E-Mail: ray@northeasternbiochar.com
Address: 26F Congress Street #346
City/PO: Saratoga Springs
State: NY
Zip Code: 12866

Project Contact (if not same as sponsor; give name and title/role): Raymond Apy, CEO Northeastern Biochar Solutions, LLC
Telephone: 518-391-0586
E-Mail: ray@northeasternbiochar.com
Address: 26F Congress Street #346
City/PO: Saratoga Springs
State: NY
Zip Code: 12866

Property Owner (if not same as sponsor): Moreau Industrial Park, LLC
Telephone:
E-Mail:
Address: 268 Ballard Road
City/PO: Wilton
State: NY
Zip Code: 12831

Gina LeClair

From: Trish Johnson <btrayde@hotmail.com>
Sent: Thursday, May 12, 2022 8:30 PM
To: Katrina Flexon
Subject: Wastewater Effluent Spreading Prion Contamination

https://greenercities.org/cities-spreading-alzheimers-disease-with-sewage-sludge/
I thought I should send you this documented info. Hopefully people become aware of why companies like biochar are banned in other states.

Good Evening. Matt Boucher 10 Sisson Road.

I attended the March 7 SEQR hearing for this project. I was surprised to hear members of our planning board discussing how they didn't know much about the science particulars in the plan and that they would need the company to help them understand it.

1. This immediately struck me as to why didn't the town hire an INDEPENDENT ANALYST (not one recommended by an applicant) for this project(with the cost being paid for by the applicant).
2. The SEQR impacts answers should never come from the applicant-as a few of the questions did.
3. A question was posed about sewer line capability and nobody had an answer to which I interjected that I did. I discussed the previous situation of # of taps by Schermerhorn apartments and the capacity percentage left of the line originally meant for the industrial park. Someone suggested reaching out to Mr. Fishbeck who had some previous knowledge of line. This was given a declaration that night. Should not have, as there was no definitive answer to the amount of proposed sewage discharge and capacity levels. The Supervisor wants to expand line to exit 16 (no doubt with cost being born by residents).

15-30 ~~amount of~~ sewage trucks passing down Ft. Edward road within 180 yards of the Village of Ft. Edward Reservoir plant property.

1. Have we considered an accident where a **spill** may take place? The ditch/culvert runs directly down to stream by Reservoir.
2. Would we be a ~~party~~ co-defendent in a legal proceeding by the Village of FE should any contamination of their water take place?
3. Officials there are concerned, I have spoken with multiple village board members. Is this a good project to consider based on the unknown legal possibility as well as the town-town relationship?
4. But most importantly: Why would a Town that has about 90% of residents on septic systems, that WE have to pay to maintain, consider hauling into our town, 720 tons per day of other towns ~~[illegible]~~ Sewage ,

May 12, 2022
To: Town of Moreau Planning board
zoningadministrator@townofmoreau.org
Bclerk@townofmoreau.org

Rojana Padron
19 Sisson Rd
Moreau, NY 12828

I stand before the planning board today to discuss the Saratoga Biochar proposal that has been brought to my attention recently. As I mentioned in my previous email to the Planning board on 04/18/22, there are many concerns that I have for me, my family and my surrounding neighbors if this proposal passes.

The ulitmate concern that I have of course is our safety. How safe is this facility if built? What kind of odors, what kind of air emissions or what kind of traffic will there be? Will the odors make us choke? Will the air emmissions make us sick? Will there be major traffic, truck accidents or sewage spills that can hurt my family or anyone? What about the noise levels? What if there is a fire or an explosion at the facility? What safety protocols are in place? Who is going to enforce that these safety procedures are being followed? Or will you allow SB to monitor themselves?

Why is the town considering adding another plant, that has no history to a town that already has had a very negative history with other plants? Do you want another repeat? There is high concentration of cancer in this county? Why is that?

According to SB company, they will be the 1st of its kind and potentially the biggest in the country if built. According to SB, it is safe. If it is safe, why do they have the need to state that the facility is in an area that is less populated? Why should that matter if they are safe? Should we believe they are telling the truth because they said so in a few articles that the newspaper media wrote and on their own website? Their facility will be safe because Saratoga Biochar Solutions said so themselves and they wrote a letter to the board that states that the planning board did do their due dilegence to ensure that the information provided by Saratoga Solutions themselves is true and accurate. What has been done?

The Moreau planning board decided that a full environmental impact study was not warranted. Why? This facility is the first of its kind, right? How can the planning board rely on a review given by SB themselves? That is my question. Is there supporting evidence to corroborate their predictions from an outside party? Does the town really want to take SB at face value?

There is no proof to prove or disprove their statements. Again, do we just rely on their words or your words?

I request the board to turn the applicant's proposal down based on the fact that we just don't have enough suppporting information independent from what Saratoga Biochar Solution says. Can I trust the planning board to do the right thing?

Respectfully,

Ro Padron

The fact that an takes time for the review should be irrelevant. Developers know this may be a normal part of their review process and they are required to pay the cost for the Towns independent experts to verify facts and protect our community.

An Article 78 proceeding could be avoided if a full Environmental Impact Study is ordered.

Please get that study done for this proposal.

I'd like to finish with a few texted comments from Preston [illegible]

Thank you

Thank you for holding this Public Hearing.

I am concerned with the inconsistencies throughout the SEQR workbook.

The lack of Saratoga Biochar's responses in their section of the State Environmental Review workbook and the fact that the Planning Board seemed to be relying on Saratoga Biochar for assistance with answers to the SEQR questions in their section of the report concerns me greatly.

I started out making notes to share with you tonight but there are too many items of concern to share in the allotted time. I have printed copies of part 1 and part two with my comments for your review. I will give it to your clerk in a minute. I would like a copy recorded in the minutes and also provided to each of you.

Without the Planning Board requiring a complete Environmental Impact Study to provide confirmation of accuracy and transparency to the answers in the SEQR workbook, we have no assurance that our fears of possible health and quality of life issues will not happen.

ii. Describe how the proposed action would affect that waterbody or wetland, e.g. excavation, fill, placement of structures, or alteration of channels, banks and shorelines. Indicate extent of activities, alterations and additions in square feet or acres:

iii. Will the proposed action cause or result in disturbance to bottom sediments? ☐Yes☐No
If Yes, describe:

iv. Will the proposed action cause or result in the destruction or removal of aquatic vegetation? ☐Yes☐No
If Yes:

- acres of aquatic vegetation proposed to be removed:
- expected acreage of aquatic vegetation remaining after project completion:
- purpose of proposed removal (e.g. beach clearing, invasive species control, boat access):
- proposed method of plant removal:
- if chemical/herbicide treatment will be used, specify product(s):

v. Describe any proposed reclamation/mitigation following disturbance:

c. Will the proposed action use, or create a new demand for water? ☑Yes☐No
If Yes:

i. Total anticipated water usage/demand per day: 30,079 gallons/day

ii. Will the proposed action obtain water from an existing public water supply? ☑Yes☐No
If Yes:

- Name of district or service area: Moreau Water District #3
- Does the existing public water supply have capacity to serve the proposal? ☑Yes☐No
- Is the project site in the existing district? ☑Yes☐No
- Is expansion of the district needed? ☐Yes☑No
- Do existing lines serve the project site? ☑Yes☐No

iii. Will line extension within an existing district be necessary to supply the project? ☐Yes☑No
If Yes:

- Describe extensions or capacity expansions proposed to serve this project:
- Source(s) of supply for the district:

iv. Is a new water supply district or service area proposed to be formed to serve the project site? ☐Yes☑No
If, Yes:

- Applicant/sponsor for new district:
- Date application submitted or anticipated:
- Proposed source(s) of supply for new district:

v. If a public water supply will not be used, describe plans to provide water supply for the project:

vi. If water supply will be from wells (public or private), what is the maximum pumping capacity: _______ gallons/minute.

d. Will the proposed action generate liquid wastes? ☑Yes☐No
If Yes:

i. Total anticipated liquid waste generation per day: 29,456 gallons/day

ii. Nature of liquid wastes to be generated (e.g., sanitary wastewater, industrial; if combination, describe all components and approximate volumes or proportions of each):
Sanitary Wastewater - 35 gph, Truck Wash - 75 gph, and Processing - 1,284 gph

iii. Will the proposed action use any existing public wastewater treatment facilities? ☑Yes☐No
If Yes:

- Name of wastewater treatment plant to be used: City of Glens Falls Wastewater Treatment Plant
- Name of district: Sewer District #1
- Does the existing wastewater treatment plant have capacity to serve the project? ☑Yes☐No
- Is the project site in the existing district? ☑Yes☐No
- Is expansion of the district needed? ☐Yes☑No

- Do existing sewer lines serve the project site? ☑ Yes ☐ No
- Will a line extension within an existing district be necessary to serve the project? ☐ Yes ☑ No

  If Yes:
  - Describe extensions or capacity expansions proposed to serve this project: ______

iv. Will a new wastewater (sewage) treatment district be formed to serve the project site? ☐ Yes ☑ No

If Yes:
- Applicant/sponsor for new district: ______
- Date application submitted or anticipated: ______
- What is the receiving water for the wastewater discharge? ______

v. If public facilities will not be used, describe plans to provide wastewater treatment for the project, including specifying proposed receiving water (name and classification if surface discharge or describe subsurface disposal plans): ______

vi. Describe any plans or designs to capture, recycle or reuse liquid waste: ______

e. Will the proposed action disturb more than one acre and create stormwater runoff, either from new point sources (i.e. ditches, pipes, swales, curbs, gutters or other concentrated flows of stormwater) or non-point source (i.e. sheet flow) during construction or post construction? ☑ Yes ☐ No

If Yes:

i. How much impervious surface will the project create in relation to total size of project parcel?

______ Square feet or 3.07 acres (impervious surface)
______ Square feet or 5.89 acres (parcel size)

ii. Describe types of new point sources. N/A

iii. Where will the stormwater runoff be directed (i.e. on-site stormwater management facility/structures, adjacent properties, groundwater, on-site surface water or off-site surface waters)?

on-site stormwater management facility/structure and groundwater

- If to surface waters, identify receiving water bodies or wetlands: ______
- Will stormwater runoff flow to adjacent properties? ☐ Yes ☑ No

iv. Does the proposed plan minimize impervious surfaces, use pervious materials or collect and re-use stormwater? ☑ Yes ☐ No

f. Does the proposed action include, or will it use on-site, one or more sources of air emissions, including fuel combustion, waste incineration, or other processes or operations? ☑ Yes ☐ No

If Yes, identify:

i. Mobile sources during project operations (e.g., heavy equipment, fleet or delivery vehicles)

Delivery vehicles during operation.

ii. Stationary sources during construction (e.g., power generation, structural heating, batch plant, crushers)

None.

iii. Stationary sources during operations (e.g., process emissions, large boilers, electric generation)

Process Emissions from manufacturing process requiring air permit.

g. Will any air emission sources named in D.2.f (above), require a NY State Air Registration, Air Facility Permit, or Federal Clean Air Act Title IV or Title V Permit? ☑ Yes ☐ No

If Yes:

i. Is the project site located in an Air quality non-attainment area? (Area routinely or periodically fails to meet ambient air quality standards for all or some parts of the year) ☐ Yes ☑ No

NEEDS INDEPENDANT REVIEW

ii. In addition to emissions as calculated in the application, the project will generate:

- 98,232 Tons/year (short tons) of Carbon Dioxide (CO_2) Less than 5% variance before EPA review + permit needed
- 0 Tons/year (short tons) of Nitrous Oxide (N_2O)
- 0 Tons/year (short tons) of Perfluorocarbons (PFCs)
- 0 Tons/year (short tons) of Sulfur Hexafluoride (SF_6)
- 0 Tons/year (short tons) of Carbon Dioxide equivalent of Hydroflourocarbons (HFCs)
- 12.7 Tons/year (short tons) of Hazardous Air Pollutants (HAPs) NEEDS independant review

h. Will the proposed action generate or emit methane (including, but not limited to, sewage treatment plants, landfills, composting facilities)? ☑ Yes ☐ No

If Yes:

i. Estimate methane generation in tons/year (metric): 0

ii. Describe any methane capture, control or elimination measures included in project design (e.g., combustion to generate heat or electricity, flaring): Methane generation eliminated through thermal oxidizer

i. Will the proposed action result in the release of air pollutants from open-air operations or processes, such as quarry or landfill operations? ☐ Yes ☑ No

If Yes: Describe operations and nature of emissions (e.g., diesel exhaust, rock particulates/dust):

j. Will the proposed action result in a substantial increase in traffic above present levels or generate substantial new demand for transportation facilities or services? ☑ Yes ☐ No

Is there a current traffic study

If Yes:

i. When is the peak traffic expected (Check all that apply): ☑ Morning ☑ Evening ☐ Weekend

☐ Randomly between hours of ________ to ________.

ii. For commercial activities only, projected number of truck trips/day and type (e.g., semi trailers and dump trucks): Up to 50 truck trips per day (90% rear dump semi trailers; <5% roll-off trucks; <5% single unit box truck)

iii. Parking spaces: Existing 0 Proposed 22 Net increase/decrease 22

iv. Does the proposed action include any shared use parking? ☐ Yes ☑ No

v. If the proposed action includes any modification of existing roads, creation of new roads or change in existing access, describe:

No new roads proposed.

vi. Are public/private transportation service(s) or facilities available within ¼ mile of the proposed site? ☐ Yes ☑ No

vii Will the proposed action include access to public transportation or accommodations for use of hybrid, electric or other alternative fueled vehicles? ☐ Yes ☑ No

viii. Will the proposed action include plans for pedestrian or bicycle accommodations for connections to existing pedestrian or bicycle routes? ☐ Yes ☑ No

k. Will the proposed action (for commercial or industrial projects only) generate new or additional demand for energy? ☑ Yes ☐ No

If Yes:

i. Estimate annual electricity demand during operation of the proposed action: 1,500 kWh/hr (500 kWh/hr per phase)

ii. Anticipated sources/suppliers of electricity for the project (e.g., on-site combustion, on-site renewable, via grid/local utility, or other):

Local Utility Provider.

iii. Will the proposed action require a new, or an upgrade, to an existing substation? ☐ Yes ☑ No

can these increase?

l. Hours of operation. Answer all items which apply.

i. During Construction:

- Monday - Friday: 7 AM - 5 PM
- Saturday: 7 AM - 5 PM
- Sunday: NA
- Holidays: NA

ii. During Operations:

- Monday - Friday: 24/7 Ops, Deliveries 6 AM-6PM
- Saturday: 24/7 Ops, Deliveries 6 AM-6PM
- Sunday: 24/7 Ops, No Deliveries
- Holidays: 24/7 Ops, No Deliveries

Are you relying on a 20 yr old traffic study?
over 2,000 new families and individual households have
been built since then. This includes Home of the Good Shepherd
and Senior Apartments.

m. Will the proposed action produce noise that will exceed existing ambient noise levels during construction, operation, or both? ☑ Yes ☐ No

Indp. SOUND Analysis ? Please

If yes:

i. Provide details including sources, time of day and duration:

Construction equipment during weekday hours will temporarily exceed ambient noise levels during construction. Noise sources during operations will be indoors and operations are not expected to result in offsite exceedances of ambient noise levels.

ii. Will the proposed action remove existing natural barriers that could act as a noise barrier or screen? ☐ Yes ☑ No

Describe: ______

n. Will the proposed action have outdoor lighting? ☑ Yes ☐ No

If yes:

i. Describe source(s), location(s), height of fixture(s), direction/aim, and proximity to nearest occupied structures:

Lighting will be used to to illuminate onsite driving areas consisting of LED wallpack and pole mounted fixtures. Lights will be shielded and directed to prevent offsite dispersion. The nearest building is located approximately 225 feet east of parcel 60.-4-18 across Farnan Road.

ii. Will proposed action remove existing natural barriers that could act as a light barrier or screen? ☐ Yes ☑ No

Describe: ______

o. Does the proposed action have the potential to produce odors for more than one hour per day? ☑ Yes ☐ No

If Yes, describe possible sources, potential frequency and duration of odor emissions, and proximity to nearest occupied structures: Independent Report - Mitigation? Not Neighbors Trees

Biosolids deliveries (6 days/week) during receiving hours (6 AM-3 PM). Manufacturing operations occur 24/7. All biosolids receipt and manufacturing operations occur indoors with advanced odor control systems. The nearest occupied structure is located approximately 225 feet east of parcel 60.-4-18.

p. Will the proposed action include any bulk storage of petroleum (combined capacity of over 1,100 gallons) or chemical products 185 gallons in above ground storage or any amount in underground storage? ☑ Yes ☐ No

If Yes:

i. Product(s) to be stored Sulfuric Acid

ii. Volume(s) 218 Gal per unit time day (e.g., month, year)

iii. Generally, describe the proposed storage facilities:

5,000 gallon sulfuric acid tank located within secondary containment and accessible for truck loading. Requires NYSDEC CBS Registration.

q. Will the proposed action (commercial, industrial and recreational projects only) use pesticides (i.e., herbicides, insecticides) during construction or operation? ☐ Yes ☑ No

If Yes:

i. Describe proposed treatment(s):

______

ii. Will the proposed action use Integrated Pest Management Practices? ☐ Yes ☐ No

r. Will the proposed action (commercial or industrial projects only) involve or require the management or disposal of solid waste (excluding hazardous materials)? ☑ Yes ☐ No

If Yes:

i. Describe any solid waste(s) to be generated during construction or operation of the facility: Not acceptable answer.

- Construction: TBD tons per Week (unit of time)
- Operation : TBD tons per Week (unit of time)

ii. Describe any proposals for on-site minimization, recycling or reuse of materials to avoid disposal as solid waste:

- Construction: Recycling containers will be maintained during construction to collect recyclables for recycling.
- Operation: Recycling containers will be maintained during operations to collect recyclables for recycling.

iii. Proposed disposal methods/facilities for solid waste generated on-site:

- Construction: Waste containers will be maintained onsite during construction that will be serviced weekly by a local hauling company for landfill disposal.
- Operation: Waste containers will be maintained onsite during operations that will be serviced weekly by a local hauling company for landfill disposal.

What is the traffic impact? How much? Noise?, What is being transported?

s. Does the proposed action include construction or modification of a solid waste management facility? ☑ Yes ☐ No

If Yes:

i. Type of management or handling of waste proposed for the site (e.g., recycling or transfer station, composting, landfill, or other disposal activities): Receiving and thermally treating biosolids to manufacture a "beneficial use" carbon fertilizer.

ii. Anticipated rate of disposal/processing:

- N/A Tons/month, if transfer or other non-combustion/thermal treatment, or
- 30 Tons/hour, if combustion or thermal treatment

iii. If landfill, anticipated site life: N/A years

is only sewage sludge burned
720 tons a day delivered =
30 he

t. Will the proposed action at the site involve the commercial generation, treatment, storage, or disposal of hazardous waste? ☐ Yes ☑ No

where is the Science backing this up

If Yes:

what about the wood chips

i. Name(s) of all hazardous wastes or constituents to be generated, handled or managed at facility:

Sulfork Acid?

ii. Generally describe processes or activities involving hazardous wastes or constituents:

Heavy metals?
Sludge?

iii. Specify amount to be handled or generated ____ tons/month

iv. Describe any proposals for on-site minimization, recycling or reuse of hazardous constituents:

What are trucks transporting-

v. Will any hazardous wastes be disposed at an existing offsite hazardous waste facility? ☐ Yes ☐ No

If Yes: provide name and location of facility:

If No: describe proposed management of any hazardous wastes which will not be sent to a hazardous waste facility:

E. Site and Setting of Proposed Action

E.1. Land uses on and surrounding the project site

a. Existing land uses.

i. Check all uses that occur on, adjoining and near the project site.

☐ Urban ☑ Industrial ☐ Commercial ☐ Residential (suburban) ☐ Rural (non-farm)
☑ Forest ☐ Agriculture ☐ Aquatic ☐ Other (specify):

Moreau Residents 1/3 mile away
Hudson falls 1/5 mile away

ii. If mix of uses, generally describe:

The proposed development is located within the Moreau Industrial Park consisting of industrial use. Undeveloped land within the industrial park and immediate surrounding area is predominantly forest.

b. Land uses and covertypes on the project site.

Land use or Covertype	Current Acreage	Acreage After Project Completion	Change (Acres +/-)
• Roads, buildings, and other paved or impervious surfaces	0	3.07	+3.07
• Forested	2.6	0.38	-2.22
• Meadows, grasslands or brushlands (non-agricultural, including abandoned agricultural)	3.29	2.44	-0.85
• Agricultural (includes active orchards, field, greenhouse etc.)	0	0	0
• Surface water features (lakes, ponds, streams, rivers, etc.)	0	0	0
• Wetlands (freshwater or tidal)	0	0	0
• Non-vegetated (bare rock, earth or fill)	0	0	0
• Other Describe: ________			

c. Is the project site presently used by members of the community for public recreation? ☐ Yes ☑ No

i. If Yes: explain: ______________________

d. Are there any facilities serving children, the elderly, people with disabilities (e.g., schools, hospitals, licensed day care centers, or group homes) within 1500 feet of the project site? ☐ Yes ☑ No

If Yes,

i. Identify Facilities:

____

____

e. Does the project site contain an existing dam? ☐ Yes ☑ No

If Yes:

i. Dimensions of the dam and impoundment:

- Dam height: ______________________ feet
- Dam length: ______________________ feet
- Surface area: ______________________ acres
- Volume impounded: ______________________ gallons OR acre-feet

ii. Dam's existing hazard classification: ______________________

iii. Provide date and summarize results of last inspection:

____

____

f. Has the project site ever been used as a municipal, commercial or industrial solid waste management facility, or does the project site adjoin property which is now, or was at one time, used as a solid waste management facility? ☐ Yes ☑ No

If Yes:

i. Has the facility been formally closed? ☐ Yes ☐ No

- If yes, cite sources/documentation: ______________________

ii. Describe the location of the project site relative to the boundaries of the solid waste management facility:

____

iii. Describe any development constraints due to the prior solid waste activities: ______________________

____

g. Have hazardous wastes been generated, treated and/or disposed of at the site, or does the project site adjoin property which is now or was at one time used to commercially treat, store and/or dispose of hazardous waste? ☐ Yes ☑ No

If Yes:

i. Describe waste(s) handled and waste management activities, including approximate time when activities occurred:

____

____

h. Potential contamination history. Has there been a reported spill at the proposed project site, or have any remedial actions been conducted at or adjacent to the proposed site? ☐ Yes ☑ No

If Yes:

i. Is any portion of the site listed on the NYSDEC Spills Incidents database or Environmental Site Remediation database? Check all that apply: ☐ Yes ☐ No

☐ Yes – Spills Incidents database Provide DEC ID number(s): ______________________

☐ Yes – Environmental Site Remediation database Provide DEC ID number(s): ______________________

☐ Neither database

ii. If site has been subject of RCRA corrective activities, describe control measures: ______________________

____

iii. Is the project within 2000 feet of any site in the NYSDEC Environmental Site Remediation database? ☑ Yes ☐ No

If yes, provide DEC ID number(s): 546031

iv. If yes to (i), (ii) or (iii) above, describe current status of site(s):

Site 546031 is the Hudson River PCB Sediments, a Class 2 State Superfund Site. The Hudson River is located approximately 1,900 feet east of parcel 50.-4-16.

v. Is the project site subject to an institutional control limiting property uses? ☐Yes ☑No
- If yes, DEC site ID number:
- Describe the type of institutional control (e.g., deed restriction or easement):
- Describe any use limitations:
- Describe any engineering controls:
- Will the project affect the institutional or engineering controls in place? ☐Yes ☐No
- Explain:

E.2. Natural Resources On or Near Project Site

a. What is the average depth to bedrock on the project site? >6.5 feet

Ground Water Reports

b. Are there bedrock outcroppings on the project site? ☐Yes ☑No
If Yes, what proportion of the site is comprised of bedrock outcroppings? ___ %

c. Predominant soil type(s) present on project site: Loamy Sand (WnB) 100 %
___ %
___ %

d. What is the average depth to the water table on the project site? Average: >6.5 feet

Potential high impact - engineers report

e. Drainage status of project site soils:
☐ Well Drained: 100 % of site
☐ Moderately Well Drained: ___ % of site
☐ Poorly Drained ___ % of site

f. Approximate proportion of proposed action site with slopes:
☑ 0-10%: 100 % of site
☐ 10-15%: ___ % of site
☐ 15% or greater: ___ % of site

g. Are there any unique geologic features on the project site? ☐Yes ☑No
If Yes, describe:

h. Surface water features.
i. Does any portion of the project site contain wetlands or other waterbodies (including streams, rivers, ponds or lakes)? ☐Yes ☑No
ii. Do any wetlands or other waterbodies adjoin the project site? ☐Yes ☑No

1/4 mile from Hudson River

If Yes to either *i* or *ii*, continue. If No, skip to E.2.i.
iii. Are any of the wetlands or waterbodies within or adjoining the project site regulated by any federal, state or local agency? ☐Yes ☑No
iv. For each identified regulated wetland and waterbody on the project site, provide the following information:
- Streams: Name ___ Classification ___
- Lakes or Ponds: Name ___ Classification ___
- Wetlands: Name ___ Approximate Size ___
- Wetland No. (if regulated by DEC) ___

v. Are any of the above water bodies listed in the most recent compilation of NYS water quality-impaired waterbodies? ☐Yes ☑No
If yes, name of impaired water body/bodies and basis for listing as impaired:

i. Is the project site in a designated Floodway? ☐Yes ☑No

j. Is the project site in the 100-year Floodplain? ☐Yes ☑No

k. Is the project site in the 500-year Floodplain? ☐Yes ☑No

l. Is the project site located over, or immediately adjoining, a primary, principal or sole source aquifer? ☑Yes ☐No
If Yes:
i. Name of aquifer: Principal Aquifer

what is this?

m. Identify the predominant wildlife species that occupy or use the project site:

Typical suburban wildlife

☐ Yes ☑ No

n. Does the project site contain a designated significant natural community?

If Yes:

i. Describe the habitat/community (composition, function, and basis for designation):

ii. **Source(s) of description or evaluation:**

iii. **Extent of community/habitat:**

- **Currently:** acres
- **Following completion of project as proposed:** acres
- **Gain or loss (indicate + or -):** acres

☐ Yes ☑ No

o. Does project site contain any species of plant or animal that is listed by the federal government or NYS as endangered or threatened, or does it contain any areas identified as habitat for an endangered or threatened species?

If Yes:

i. Species and listing (endangered or threatened):

☐ Yes ☑ No

p. Does the project site contain any species of plant or animal that is listed by NYS as rare, or as a species of special concern?

If Yes:

i. Species and listing:

☐ Yes ☑ No

q. Is the project site or adjoining area currently used for hunting, trapping, fishing or shell fishing?

If yes, give a brief description of how the proposed action may affect that use:

E.3. Designated Public Resources On or Near Project Site

☐ Yes ☑ No

a. Is the project site, or any portion of it, located in a designated agricultural district certified pursuant to Agriculture and Markets Law, Article 25-AA, Section 303 and 304?

If Yes, provide county plus district name/number:

☐ Yes ☑ No

b. Are agricultural lands consisting of highly productive soils present?

i. If Yes: acreage(s) on project site?

ii. Source(s) of soil rating(s):

☐ Yes ☑ No

c. Does the project site contain all or part of, or is it substantially contiguous to, a registered National Natural Landmark?

If Yes:

i. **Nature of the natural landmark:** ☐ Biological Community ☐ Geological Feature

ii. **Provide brief description of landmark, including values behind designation and approximate size/extent:**

☐ Yes ☑ No

d. Is the project site located in or does it adjoin a state listed Critical Environmental Area?

If Yes:

i. CEA name:

ii. Basis for designation:

iii. Designating agency and date:

e. Does the project site contain, or is it substantially contiguous to, a building, archaeological site, or district which is listed on the National or State Register of Historic Places, or that has been determined by the Commissioner of the NYS Office of Parks, Recreation and Historic Preservation to be eligible for listing on the State Register of Historic Places? ☐ Yes ☑ No

If Yes:

i. Nature of historic/archaeological resource: ☐ Archaeological Site ☐ Historic Building or District

ii. Name:

iii. Brief description of attributes on which listing is based: Indian Burial Site

f. Is the project site, or any portion of it, located in or adjacent to an area designated as sensitive for archaeological sites on the NY State Historic Preservation Office (SHPO) archaeological site inventory? ☑ Yes ☐ No

g. Have additional archaeological or historic site(s) or resources been identified on the project site? ☐ Yes ☑ No

If Yes:

i. Describe possible resource(s): Archaelogical Society –

ii. Basis for identification: Old fort Ruins

h. Is the project site within fives miles of any officially designated and publicly accessible federal, state, or local scenic or aesthetic resource? ☑ Yes ☐ No

If Yes:

i. Identify resource: Mohawk Valley Corridor

ii. Nature of, or basis for, designation (e.g., established highway overlook, state or local park, state historic trail or scenic byway, etc.): NYS Designated Heritage Area

iii. Distance between project and resource: 0 (includes entire county) miles.

i. Is the project site located within a designated river corridor under the Wild, Scenic and Recreational Rivers Program 6 NYCRR 666? ☐ Yes ☑ No

1/4 mile from River

If Yes:

i. Identify the name of the river and its designation:

ii. Is the activity consistent with development restrictions contained in 6NYCRR Part 666? ☐ Yes ☐ No

F. Additional Information

Attach any additional information which may be needed to clarify your project.

If you have identified any adverse impacts which could be associated with your proposal, please describe those impacts plus any measures which you propose to avoid or minimize them.

G. Verification

I certify that the information provided is true to the best of my knowledge.

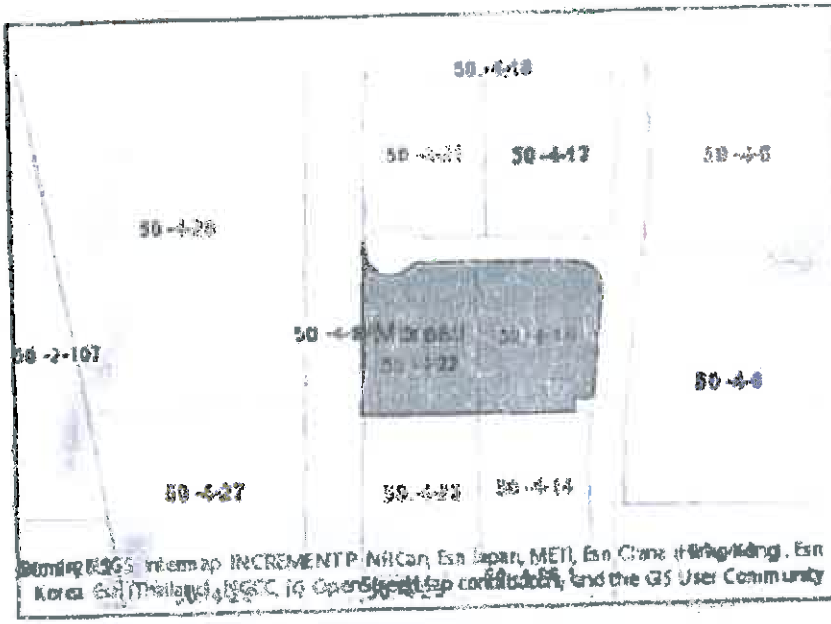
Applicant/Sponsor Name: RAYMOND APY Date: 2-22-2022

Signature: Title: CEO

PRINT FORM

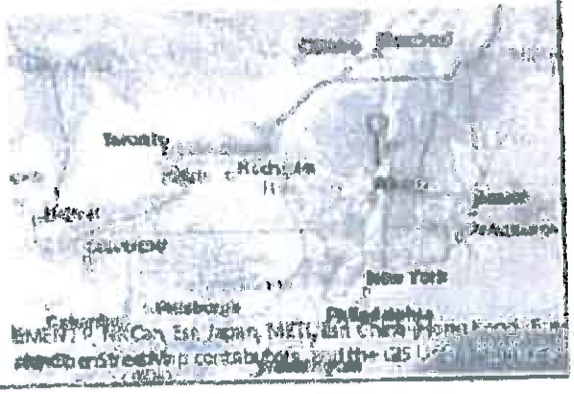
EAF Mapper Summary Report

Monday, June 28, 2021 3:54 PM



Sources: USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Disclaimer: The EAF Mapper is a screening tool intended to assist project sponsors and reviewing agencies in preparing an environmental assessment form (EAF). Not all questions asked in the EAF are answered by the EAF Mapper. Additional information on any EAF question can be obtained by consulting the EAF Workbooks. Although the EAF Mapper provides the most up-to-date digital data available to DEC, you may also need to contact local or other data sources in order to obtain data not provided by the Mapper. Digital data is not a substitute for agency determinations.



EMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri ... (c) OpenStreetMap contributors, and the GIS User

B.i.i [Coastal or Waterfront Area]	No
B.i.ii [Local Waterfront Revitalization Area]	No
C.2.b. [Special Planning District]	Yes - Digital mapping data are not available for all Special Planning Districts. Refer to EAF Workbook.
C.2.b. [Special Planning District - Name]	NYS Heritage Areas:Mohawk Valley Heritage Corridor
E.1.h [DEC Spills or Remediation Site - Potential Contamination History]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
E.1.h.i [DEC Spills or Remediation Site - Listed]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
E.1.h.i [DEC Spills or Remediation Site - Environmental Site Remediation Database]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
E.1.h.iii [Within 2,000' of DEC Remediation Site]	Yes
E.1.h.iii [Within 2,000' of DEC Remediation Site - DEC ID]	546031
E.2.g [Unique Geologic Features]	No
E.2.h.i [Surface Water Features]	No
E.2.h.ii [Surface Water Features]	No
E.2.h.iii [Surface Water Features]	No
E.2.h.v [Impaired Water Bodies]	No
E.2.i. [Floodway]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
E.2.j. [100 Year Floodplain]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
E.2.k. [500 Year Floodplain]	Digital mapping data are not available or are incomplete. Refer to EAF Workbook.
E.2.l. [Aquifers]	Yes

Full Environmental Assessment Form
Part 2 - Identification of Potential Project Impacts

Agency Use Only [If applicab
Project :
Date :

Part 2 is to be completed by the lead agency. Part 2 is designed to help the lead agency inventory all potential resources that could be affected by a proposed project or action. We recognize that the lead agency's reviewer(s) will not necessarily be environmental professionals. So, the questions are designed to walk a reviewer through the assessment process by providing a series of questions that can be answered using the information found in Part 1. To further assist the lead agency in completing Part 2, the form identifies the most relevant questions in Part 1 that will provide the information needed to answer the Part 2 question. When Part 2 is completed, the lead agency will have identified the relevant environmental areas that may be impacted by the proposed activity.

If the lead agency is a state agency and the action is in any Coastal Area, complete the Coastal Assessment Form before proceeding with this assessment.

Tips for completing Part 2:

- Review all of the information provided in Part 1.
- Review any application, maps, supporting materials and the Full EAF Workbook.
- Answer each of the 18 questions in Part 2.
- If you answer "Yes" to a numbered question, please complete all the questions that follow in that section.
- If you answer "No" to a numbered question, move on to the next numbered question.
- Check appropriate column to indicate the anticipated size of the impact.
- Proposed projects that would exceed a numeric threshold contained in a question should result in the reviewing agency checking the box "Moderate to large impact may occur."
- The reviewer is not expected to be an expert in environmental analysis.
- If you are not sure or undecided about the size of an impact, it may help to review the sub-questions for the general question and consult the workbook.
- When answering a question consider all components of the proposed activity, that is, the "whole action".
- Consider the possibility for long-term and cumulative impacts as well as direct impacts.
- Answer the question in a reasonable manner considering the scale and context of the project.

why was this changed

1. Impact on Land
Proposed action may involve construction on, or physical alteration of, the land surface of the proposed site. (See Part 1. D.1)
If "Yes", answer questions a - j. If "No", move on to Section 2.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may involve construction on land where depth to water table is less than 3 feet.	E2d	☐	☐
b. The proposed action may involve construction on slopes of 15% or greater.	E2f	☐	☐
c. The proposed action may involve construction on land where bedrock is exposed, or generally within 5 feet of existing ground surface.	E2a	☐	☐
d. The proposed action may involve the excavation and removal of more than 1,000 tons of natural material.	D2a	☐	☐
e. The proposed action may involve construction that continues for more than one year or in multiple phases.	D1e	☐	☐ ?
f. The proposed action may result in increased erosion, whether from physical disturbance or vegetation removal (including from treatment by herbicides).	D2e, D2q	☐	☐
g. The proposed action is, or may be, located within a Coastal Erosion hazard area.	B1i	☐	☐
h. Other impacts: ______________________________		☐	☐
______________________________		☐	☐

Indipendant Engineering, traffic, Ground Water, Storm water & Emissions Analysis NeeDeD to verify Applicant claims

Provide Data for an exhisting facilities operations based on proposed application

Gina LeClair

2. Impact on Geological Features

The proposed action may result in the modification or destruction of, or inhibit access to, any unique or unusual land forms on the site (e.g., cliffs, dunes, minerals, fossils, caves). (See Part 1. E.2.g)

If "Yes", answer questions a - c. If "No", move on to Section 3.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. Identify the specific land form(s) attached: ______	E2g	☐	☐
b. The proposed action may affect or is adjacent to a geological feature listed as a registered National Natural Landmark. Specific feature: ______	E3c	☐	☐
c. Other impacts: ______		☐	☐

3. Impacts on Surface Water

The proposed action may affect one or more wetlands or other surface water bodies (e.g., streams, rivers, ponds or lakes). (See Part 1. D.2, E.2.h)

If "Yes", answer questions a - l. If "No", move on to Section 4.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may create a new water body.	D2b, D1h	☐	☐
b. The proposed action may result in an increase or decrease of over 10% or more than a 10 acre increase or decrease in the surface area of any body of water.	D2b	☐	☐
c. The proposed action may involve dredging more than 100 cubic yards of material from a wetland or water body.	D2a	☐	☐
d. The proposed action may involve construction within or adjoining a freshwater or tidal wetland, or in the bed or banks of any other water body.	E2h	☐	☐
e. The proposed action may create turbidity in a waterbody, either from upland erosion, runoff or by disturbing bottom sediments.	D2a, D2h	☐	☐
f. The proposed action may include construction of one or more intake(s) for withdrawal of water from surface water.	D2c	☐	☐
g. The proposed action may include construction of one or more outfall(s) for discharge of wastewater to surface water(s).	D2d	☐	☐
h. The proposed action may cause soil erosion, or otherwise create a source of stormwater discharge that may lead to siltation or other degradation of receiving water bodies.	D2e	☐	☐
i. The proposed action may affect the water quality of any water bodies within or downstream of the site of the proposed action.	E2h	☐	☐
j. The proposed action may involve the application of pesticides or herbicides in or around any water body.	D2q, E2h	☐	☐
k. The proposed action may require the construction of new, or expansion of existing, wastewater treatment facilities.	D1a, D2d	☐	☐

l. Other impacts: ______________________________		☐	☐

4. Impact on groundwater

The proposed action may result in new or additional use of ground water, or may have the potential to introduce contaminants to ground water or an aquifer. (See Part 1. D.2.a, D.2.c, D.2.d, D.2.p, D.2.q, D.2.t)
If "Yes", answer questions a - h. If "No", move on to Section 5.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may require new water supply wells, or create additional demand on supplies from existing water supply wells.	D2c	☐	☐
b. Water supply demand from the proposed action may exceed safe and sustainable withdrawal capacity rate of the local supply or aquifer. Cite Source: ______________________________	D2c	☐	☐
c. The proposed action may allow or result in residential uses in areas without water and sewer services.	D1a, D2c	☐	☐
d. The proposed action may include or require wastewater discharged to groundwater.	D2d, E2l	☐	☐
e. The proposed action may result in the construction of water supply wells in locations where groundwater is, or is suspected to be, contaminated.	D2c, E1f, E1g, E1h	☐	☐
f. The proposed action may require the bulk storage of petroleum or chemical products over ground water or an aquifer.	D2p, E2l	☐	☐
g. The proposed action may involve the commercial application of pesticides within 100 feet of potable drinking water or irrigation sources.	E2h, D2q, E2l, D2c	☐	☐
h. Other impacts: ______________________________		☐	☐

5. Impact on Flooding

The proposed action may result in development on lands subject to flooding. (See Part 1. E.2)
If "Yes", answer questions a - g. If "No", move on to Section 6.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may result in development in a designated floodway.	E2i	☐	☐
b. The proposed action may result in development within a 100 year floodplain.	E2j	☐	☐
c. The proposed action may result in development within a 500 year floodplain.	E2k	☐	☐
d. The proposed action may result in, or require, modification of existing drainage patterns.	D2b, D2e	☐	☐
e. The proposed action may change flood water flows that contribute to flooding.	D2b, E2i, E2j, E2k	☐	☐
f. If there is a dam located on the site of the proposed action, is the dam in need of repair, or upgrade?	E1e	☐	☐

g. Other impacts: ______________________		☐	☐

6. Impact on Air

The proposed action may include a state regulated air emission source. (See Part 1. D.2.f., D.2.h, D.2.g) ☐ NO ☒ YES

If "Yes", answer questions a - f. If "No", move on to Section 7.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. If the proposed action requires federal or state air emission permits, the action may also emit one or more greenhouse gases at or above the following levels:			
i. More than 1000 tons/year of carbon dioxide (CO_2) Y	D2g	☒ no	~~☒~~
ii. More than 3.5 tons/year of nitrous oxide (N_2O)	D2g	☒	☐
iii. More than 1000 tons/year of carbon equivalent of perfluorocarbons (PFCs)	D2g	☒	☐
iv. More than .045 tons/year of sulfur hexafluoride (SF_6)	D2g	☒	☐
v. More than 1000 tons/year of carbon dioxide equivalent of hydrochloroflourocarbons (HFCs) emissions	D2g	☒	☐
vi. 43 tons/year or more of methane	D2h	☒	☐
b. The proposed action may generate 10 tons/year or more of any one designated hazardous air pollutant, or 25 tons/year or more of any combination of such hazardous air pollutants.	D2g	☒	☐
c. The proposed action may require a state air registration, or may produce an emissions rate of total contaminants that may exceed 5 lbs. per hour, or may include a heat source capable of producing more than 10 million BTU's per hour. changed - Stack Verification ?	D2f, D2g	☐	☒
d. The proposed action may reach 50% of any of the thresholds in "a" through "c", above.	D2g	☐	☒
e. The proposed action may result in the combustion or thermal treatment of more than 1 ton of refuse per hour.	D2s	☐	■
f. Other impacts: ______________________		☐	☐

7. Impact on Plants and Animals

The proposed action may result in a loss of flora or fauna. (See Part 1. E.2. m.-q.) ☒ NO ☐ YES

If "Yes", answer questions a - j. If "No", move on to Section 8.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may cause reduction in population or loss of individuals of any threatened or endangered species, as listed by New York State or the Federal government, that use the site, or are found on, over, or near the site.	E2o	☐	☐
b. The proposed action may result in a reduction or degradation of any habitat used by any rare, threatened or endangered species, as listed by New York State or the federal government.	E2o	☐	☐
c. The proposed action may cause reduction in population, or loss of individuals, of any species of special concern or conservation need, as listed by New York State or the Federal government, that use the site, or are found on, over, or near the site.	E2p	☐	☐
d. The proposed action may result in a reduction or degradation of any habitat used by any species of special concern and conservation need, as listed by New York State or the Federal government.	E2p	☐	☐

e. The proposed action may diminish the capacity of a registered National Natural Landmark to support the biological community it was established to protect.	E3c	☐	☐
f. The proposed action may result in the removal of, or ground disturbance in, any portion of a designated significant natural community. Source: ______	E2n	☐	☐
g. The proposed action may substantially interfere with nesting/breeding, foraging, or over-wintering habitat for the predominant species that occupy or use the project site.	E2m	☐	☐
h. The proposed action requires the conversion of more than 10 acres of forest, grassland or any other regionally or locally important habitat. Habitat type & information source: ______	E1b	☐	☐
i. Proposed action (commercial, industrial or recreational projects, only) involves use of herbicides or pesticides.	D2q	☐	☐
j. Other impacts: ______		☐	☐

8. Impact on Agricultural Resources

The proposed action may impact agricultural resources. (See Part 1. E.3.a. and b.)
If "Yes", answer questions a - h. If "No", move on to Section 9. ☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may impact soil classified within soil group 1 through 4 of the NYS Land Classification System.	E2c, E3b	☐	☐
b. The proposed action may sever, cross or otherwise limit access to agricultural land (includes cropland, hayfields, pasture, vineyard, orchard, etc).	E1a, Elb	☐	☐
c. The proposed action may result in the excavation or compaction of the soil profile of active agricultural land.	E3b	☐	☐
d. The proposed action may irreversibly convert agricultural land to non-agricultural uses, either more than 2.5 acres if located in an Agricultural District, or more than 10 acres if not within an Agricultural District.	E1b, E3a	☐	☐
e. The proposed action may disrupt or prevent installation of an agricultural land management system.	El a, E1b	☐	☐
f. The proposed action may result, directly or indirectly, in increased development potential or pressure on farmland.	C2c, C3, D2c, D2d	☐	☐
g. The proposed project is not consistent with the adopted municipal Farmland Protection Plan.	C2c	☐	☐
h. Other impacts: ______		☐	☐

9. **Impact on Aesthetic Resources**
The land use of the proposed action are obviously different from, or are in sharp contrast to, current land use patterns between the proposed project and a scenic or aesthetic resource. *(Part 1. E.1.a, E.1.b, E.3.h.)*
If "Yes", answer questions a - g. If "No", go to Section 10.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. Proposed action may be visible from any officially designated federal, state, or local scenic or aesthetic resource.	E3h	☐	☐
b. The proposed action may result in the obstruction, elimination or significant screening of one or more officially designated scenic views.	E3h, C2b	☐	☐
c. The proposed action may be visible from publicly accessible vantage points: i. Seasonally (e.g., screened by summer foliage, but visible during other seasons) ii. Year round	E3h	☐ ☐	☐ ☐
d. The situation or activity in which viewers are engaged while viewing the proposed action is: i. Routine travel by residents, including travel to and from work ii. Recreational or tourism based activities	E3h E2q, E1c	☐ ☐	☐ ☐
e. The proposed action may cause a diminishment of the public enjoyment and appreciation of the designated aesthetic resource.	E3h	☐	☐
f. **There are similar projects visible within the following distance of the proposed project:** **0-1/2 mile** **½ -3 mile** **3-5 mile** 5+ mile	D1a, E1a, D1f, D1g	☐	☐
g. Other impacts: ______		☐	☐

10. **Impact on Historic and Archeological Resources**
The proposed action may occur in or adjacent to a historic or archaeological resource. *(Part 1. E.3.e, f. and g.)*
If "Yes", answer questions a - e. If "No", go to Section 11.

☒ NO ☐ YES

Study ?

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may occur wholly or partially within, or substantially contiguous to, any buildings, archaeological site or district which is listed on the National or State Register of Historical Places, or that has been determined by the Commissioner of the NYS Office of Parks, Recreation and Historic Preservation to be eligible for listing on the State Register of Historic Places.	E3e	☐	☐
b. The proposed action may occur wholly or partially within, or substantially contiguous to, an area designated as sensitive for archaeological sites on the NY State Historic Preservation Office (SHPO) archaeological site inventory.	E3f	☐	☐
c. The proposed action may occur wholly or partially within, or substantially contiguous to, an archaeological site not included on the NY SHPO inventory. Source: ______	E3g	☐	☐

d. Other impacts: ______________________________		☐	☐
e. If any of the above (a-d) are answered "Moderate to large impact may occur", continue with the following questions to help support conclusions in Part 3:			
i. The proposed action may result in the destruction or alteration of all or part of the site or property.	E3e, E3g, E3f	☐	☐
ii. The proposed action may result in the alteration of the property's setting or integrity.	E3e, E3f, E3g, E1a, E1b	☐	☐
iii. The proposed action may result in the introduction of visual elements which are out of character with the site or property, or may alter its setting.	E3e, E3f, E3g, E3h, C2, C3	☐	☐

11. Impact on Open Space and Recreation

The proposed action may result in a loss of recreational opportunities or a reduction of an open space resource as designated in any adopted municipal open space plan.
(See Part 1. C.2.c, E.1.c., E.2.q.)

☒ NO ☐ YES

If "Yes", answer questions a - e. If "No", go to Section 12.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may result in an impairment of natural functions, or "ecosystem services", provided by an undeveloped area, including but not limited to stormwater storage, nutrient cycling, wildlife habitat.	D2e, E1b E2h, E2m, E2o, E2n, E2p	☐	☐
b. The proposed action may result in the loss of a current or future recreational resource.	C2a, E1c, C2c, E2q	☐	☐
c. The proposed action may eliminate open space or recreational resource in an area with few such resources.	C2a, C2c E1c, E2q	☐	☐
d. The proposed action may result in loss of an area now used informally by the community as an open space resource.	C2c, E1c	☐	☐
e. Other impacts: ______________________________		☐	☐

12. Impact on Critical Environmental Areas

The proposed action may be located within or adjacent to a critical environmental area (CEA). (See Part 1. E.3.d)

☒ NO ☐ YES

If "Yes", answer questions a - c. If "No", go to Section 13.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may result in a reduction in the quantity of the resource or characteristic which was the basis for designation of the CEA.	E3d	☐	☐
b. The proposed action may result in a reduction in the quality of the resource or characteristic which was the basis for designation of the CEA.	E3d	☐	☐
c. Other impacts: ______________________________		☐	☐

13. Impact on Transportation
The proposed action may result in a change to existing transportation systems. ☒ NO ☐ YES
(See Part 1. D.2.j)
If "Yes", answer questions a - f. If "No", go to Section 14.

over 2000 new residents since old study we need a new study

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. Projected traffic increase may exceed capacity of existing road network.	D2j	☐	☐
b. The proposed action may result in the construction of paved parking area for 500 or more vehicles.	D2j	☐	☐
c. The proposed action will degrade existing transit access.	D2j	☐	☐
d. The proposed action will degrade existing pedestrian or bicycle accommodations.	D2j	☐	☐
e. The proposed action may alter the present pattern of movement of people or goods.	D2j	☐	☐
f. Other impacts: ______		☐	☐

14. Impact on Energy
The proposed action may cause an increase in the use of any form of energy. ☒ NO ☒ YES
(See Part 1. D.2.k)
If "Yes", answer questions a - e. If "No", go to Section 15.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action will require a new, or an upgrade to an existing, substation.	D2k	☒	☐
b. The proposed action will require the creation or extension of an energy transmission or supply system to serve more than 50 single or two-family residences or to serve a commercial or industrial use.	D1f, D1q, D2k	☒	☐
c. The proposed action may utilize more than 2,500 MWhrs per year of electricity.	D2k	☒	☐
d. The proposed action may involve heating and/or cooling of more than 100,000 square feet of building area when completed.	D1g	☒	☐
e. Other Impacts: ______		☒	☐

15. Impact on Noise, Odor, and Light
The proposed action may result in an increase in noise, odors, or outdoor lighting. ☐ NO ☒ YES
(See Part 1. D.2.m., n., and o.)
If "Yes", answer questions a - f. If "No", go to Section 16.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may produce sound above noise levels established by local regulation.	D2m	☒	☐
b. The proposed action may result in blasting within 1,500 feet of any residence, hospital, school, licensed day care center, or nursing home.	D2m, D1d	☒	☐
c. The proposed action may result in routine odors for more than one hour per day.	D2o	☒	☒

mitigation? Not neighbors trees!

24 hrs a day

NEW

SCREENING BUILDING INC. OPERATING UNDER NEG. PRESSURE

d. The proposed action may result in light shining onto adjoining properties.	D2n	☒	☐
e. The proposed action may result in lighting creating sky-glow brighter than existing area conditions.	D2n, E1a	☒	☐
f. Other impacts: ______________________________		☒	☐

16. Impact on Human Health

The proposed action may have an impact on human health from exposure to new or existing sources of contaminants. (See Part 1.D.2.q., E.1. d. f. g. and h.) ☐ NO ☒ YES

If "Yes", answer questions a - m. If "No", go to Section 17.

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action is located within 1500 feet of a school, hospital, licensed day care center, group home, nursing home or retirement community.	E1d	☒	☐
b. The site of the proposed action is currently undergoing remediation.	E1g, E1h	☒	☐
c. There is a completed emergency spill remediation, or a completed environmental site remediation on, or adjacent to, the site of the proposed action.	E1g, E1h	☒	☐
d. The site of the action is subject to an institutional control limiting the use of the property (e.g., easement or deed restriction).	E1g, E1h	☒	☐
e. The proposed action may affect institutional control measures that were put in place to ensure that the site remains protective of the environment and human health.	E1g, E1h	☒	☐
f. The proposed action has adequate control measures in place to ensure that future generation, treatment and/or disposal of hazardous wastes will be protective of the environment and human health.	D2t	☐	☒
g. The proposed action involves construction or modification of a solid waste management facility.	D2q, E1f	☒	☐
h. The proposed action may result in the unearthing of solid or hazardous waste.	D2q, E1f	☒	☐
i. The proposed action may result in an increase in the rate of disposal, or processing, of solid waste.	D2r, D2s	☒	☐
j. The proposed action may result in excavation or other disturbance within 2000 feet of a site used for the disposal of solid or hazardous waste.	E1f, E1g E1h	☒	☐
k. The proposed action may result in the migration of explosive gases from a landfill site to adjacent off site structures.	E1f, E1g	☒	☐
l. The proposed action may result in the release of contaminated leachate from the project site. what will be in this ?	D2s, E1f, D2r	☒	☐
m. Other impacts: Scientific Review ?		☒	☐

Independent Review Requested,!

It is their science making the claims It needs to be indepently verified Please !

17. Consistency with Community Plans
The proposed action is not consistent with adopted land use plans.
(See Part 1. C.1, C.2. and C.3.)
If "Yes", answer questions a - h. If "No", go to Section 18.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action's land use components may be different from, or in sharp contrast to, current surrounding land use pattern(s).	C2, C3, D1a E1a, E1b	☐	☐
b. The proposed action will cause the permanent population of the city, town or village in which the project is located to grow by more than 5%.	C2	☐	☐
c. The proposed action is inconsistent with local land use plans or zoning regulations.	C2, C2, C3	☐	☐
d. The proposed action is inconsistent with any County plans, or other regional land use plans.	C2, C2	☐	☐
e. The proposed action may cause a change in the density of development that is not supported by existing infrastructure or is distant from existing infrastructure.	C3, D1c, D1d, D1f, D1d, E1b	☐	☐
f. The proposed action is located in an area characterized by low density development that will require new or expanded public infrastructure.	C4, D2c, D2d D2j	☐	☐
g. The proposed action may induce secondary development impacts (e.g., residential or commercial development not included in the proposed action)	C2a	☐	☐
h. Other: ______		☐	☐

18. Consistency with Community Character
The proposed project is inconsistent with the existing community character.
(See Part 1. C.2, C.3, D.2, E.3)
If "Yes", answer questions a - g. If "No", proceed to Part 3.

☒ NO ☐ YES

	Relevant Part I Question(s)	No, or small impact may occur	Moderate to large impact may occur
a. The proposed action may replace or eliminate existing facilities, structures, or areas of historic importance to the community.	E3e, E3f, E3g	☐	☐
b. The proposed action may create a demand for additional community services (e.g. schools, police and fire)	C4	☐	☐
c. The proposed action may displace affordable or low-income housing in an area where there is a shortage of such housing.	C2, C3, D1f D1g, E1a	☐	☐
d. The proposed action may interfere with the use or enjoyment of officially recognized or designated public resources.	C2, E3	☐	☐
e. The proposed action is inconsistent with the predominant architectural scale and character.	C2, C3	☐	☐
f. Proposed action is inconsistent with the character of the existing natural landscape.	C2, C3 E1a, E1b E2g, E2h	☐	☐
g. Other impacts: ______		☐	☐

PRINT FULL FORM

Environmental
Science
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Removal of PFASs from biosolids using a semi pilot scale pyrolysis reactor and the application of biosolids derived biochar for the removal of PFASs from contaminated water†

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This study focuses on the conversion of biosolids to biochar and its further use in adsorbing per- and polyfluoroalkyl substances (PFASs) from contaminated water. In particular, this study aims to (a) investigate the performance of a semi-pilot fluidised bed pyrolysis unit in converting biosolids into biochar, (b) examine the ability of the pyrolysis–combustion integrated process to destruct PFASs present in biosolids and (c) study the application of biosolids derived biochar for removing PFASs from contaminated water. The semi-pilot fluidised bed pyrolysis unit demonstrated stable temperature and oxygen profiles in the reactor. The yield of biochar was found to be 36–45% at studied temperatures (500–600 °C). The produced biosolids derived biochar samples, due to their lower H/C and O/C ratio, were found to be extremely stable with an expected long (millennia) residence time in soil. It was concluded that >90% removal of perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA) from biosolids derived biochar could be achieved in the pyrolysis–combustion integrated process. The biosolids derived biochar demonstrated >80% adsorption of long-chain PFASs and 19–27% adsorption of short-chain PFASs from PFAS contaminated water.

Water impact

The effectiveness of a fluidised bed pyrolysis for reducing biosolids volume and producing biochar material was demonstrated. Over 90% of PFOS and PFOA was safely removed from the resultant biochar during pyrolysis. The produced biochar was able to adsorb PFASs from contaminated water in the range of 20 to over 95%, depending on the individual PFAS considered.

1. Introduction

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~~Stabilised sewage sludge, produced by wastewater treatment~~ plants (WWTPs), is known as biosolids. This material is an unavoidable by-product that originates from households and many industries.[1] The rapid increase in population as well as urbanisation contributes to a continued increase in the production of biosolids.[2,3] Biosolids contain many macronutrients such as nitrogen, phosphorus, sulphur, potassium, calcium and magnesium as well as micronutrients such as zinc, copper, boron, molybdenum, manganese and iron.[4] Therefore, biosolids are attractive for agricultural applications, and the majority of this material is currently utilised for this purpose in many countries including Australia.[5,6] However, biosolids may contain harmful pathogens and current regulations (particularly in Victoria, Australia) require biosolids to be stockpiled onsite for 1–3 years to reduce pathogen levels to the highest possible treatment grade for soil amendment. Also, heavy metals, micro-plastics, pesticides, chemicals, herbicides and pharmaceutical ingredients are present in biosolids.[2,3,7] Recently, biosolids have been recognised as a potential source of PFAS contamination in soil and groundwater which may restrict their land application in the near future.[8,9]

PFASs are anthropogenic compounds and, historically, have been used in a wide range of applications including fire-fighting foams, non-stick cookware, stain- and water repellent fabrics, polishes, waxes, paints and cleaning products.[10,11] To date, more than 3000 PFASs and their potential precursors have been identified[12] and their numbers increase with time as research progresses. Consequently, PFASs have become ubiquitous in terrestrial and aquatic environments. These chemicals are persistent, accumulative and leachable. PFOA and PFOS are the most studied PFASs. 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 human bodies may include, but are not limited to, increased cholesterol,[13] hepatotoxicity and alterations in the immune system[14] as well as thyroid hormone disruption.[15] Besides, these chemicals may cause low infant birth weights,[16] and they are also suspected of causing cancer.[17] PFASs have been detected in WWTP influent, effluent and biosolids globally.[18] Hydrophobic partitioning in WWTPs is expected to result in the retention of long-chain PFASs in the sludge/biosolids.[19] The major PFASs in biosolids, reported in a study on US biosolids, were PFOS (403 ± 127 ng g^{-1} dry weight) and PFOA (34 ± 22 ng g^{-1} dry weight).[19] The other PFAS values were lower and in the range of 2 and 26 ng g^{-1} dry weight. Similar results were obtained in Australian studies.[8,20] PFAS management guidelines have become available in several Australian states, for example, in Victoria (regulated by EPA Victoria).[6] These may potentially impact the wider land application of biosolids in the near future. Therefore, a reliable and cost-effective technological platform is warranted that minimises/eliminates the PFAS risks of biosolids for land application.

PFASs have strong chemical structures, are thermally very stable and require high reaction energy/high temperatures to break down their chemical bonds. The available literature suggests that immobilisation could be the most cost-effective method for remediation of PFASs in biosolids and biosolids amended soils.[21] However, keeping PFASs immobilised in a solid matrix for a long time still needs to be verified by further investigation. 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. Most of the studies in the literature have focused on investigating PFAS destruction through incineration.[22–26] Studies on the potential of pyrolysis and gasification technologies to destruct PFASs are very limited.

The pyrolysis process decomposes carbonaceous materials, such as biosolids, in the absence of oxygen.[2] Usually, a sweeping gas flow is provided in the pyrolysis process (except vacuum pyrolysis). In the case of fluidised bed pyrolysis, the flow-rate of the sweeping gas is high and it may be economically feasible to recycle the CO_2 containing hot pyrolysis/flue gas as the sweeping gas rather than using a high purity and expensive inert sweeping gas such as N_2. Biochar (solid), bio-oil (liquid) and bio-gas are the three products that are generated from the pyrolysis of biosolids. The yield distribution of these products depends on a number of parameters including the composition of biosolids, pyrolysis temperature, heating/energy transfer rate, and flow rate of the sweeping gas as well as the catalyst/additive if used. Bio-oil and bio-gas could be used as fuel[24,27] while biochar could be used as a soil amendment material,[24,27] as a catalyst in the production of carbon nanomaterials[28] or as an adsorbent for removing micropollutants.[29,30] If there is a priority between biochar and bio-oil, the heating/energy transfer rate is usually considered to be tweaked. When bio-oil is considered to be the primary product, a high heating rate is applied while a slow heating rate is applied when biochar is considered to be the primary product. Previous studies suggested that pyrolysis can successfully destroy impurities such as pathogens, micro plastics, pesticides and pharmaceutical ingredients and the products from this process can be free from these nuisances.[31–34] If the destruction of PFASs from biosolids can be safely performed by a pyrolysis process, it can assist water industries in reducing biosolids volume and creating an indisputable application of biosolids derived biochar as a soil amendment material as well as its other applications in chemical processing.

Pyrolysis can be carried out in both fixed bed and fluidised bed reactors. The poor gas–solid contact in fixed bed reactors may compromise the quality of biochar. Biochar with uniform characteristics is beneficial and desired, particularly if the considered end use is being a catalyst or an adsorbent. Fluidised bed reactors ensure uniform heating even at high heating rates leading to the production of high quality biochar with uniform characteristics. This opens up the possibility of extending the application of biosolids derived biochar, produced from fluidised bed reactors, in the adsorption of PFASs from contaminated water.

Several reactor designs have been evaluated in a large scale for the pyrolysis of biosolids. For instance, a microwave heating system was applied aiming to produce bio-oil as a primary product from the transformation of sewage sludge using several additives such as KOH, H_2SO_4, H_3BO_3, $ZnCl_2$ and $FeSO_4$.[35] The technological feasibility was found to be dependent on the optimisation of process parameters and selection of appropriate additives. In a different study, sewage sludge was blended with other feedstock such as manure and studied in a fixed bed pilot-scale reactor with positive findings.[36] A few other pilot-scale studies were carried out using a fixed bed reactor in non-catalytic, autocatalytic or catalytic mode. However, the application of

fluidised bed pyrolysis reactors is found to be rare for pyrolysis of biosolids. In addition, pyrolysis is an endothermic process and the optimisation of energy is vital for the commercial viability of any technology. Therefore, a fluidised bed pilot scale reactor integrated with a combustion chamber, which aims to run pyrolysis in autothermal mode (i.e. no need for external energy), is in demand in the search for sustainable uses of biosolids.

Typically, pyrolysis of carbonaceous materials is carried out between 300 to 1000 °C.[37] Lower pyrolysis temperature generates biochar with a lower surface area and high oxygen containing functional groups. As the pyrolysis temperature increases, the surface area of biochar increases at the expense of functional groups. Therefore, low temperature pyrolysis is generally preferred for producing biochar for soil application while high temperature is desired when biochar with a high surface area needs to be produced. Choosing a pyrolysis temperature is challenging and a few aspects could be taken into consideration.

(a) This work aims to produce biochar to be used as an adsorbent; therefore, a high surface area and an improved morphology is critical. Our previous work suggests that the

pyrolysis temperature has a tremendous impact on the morphology of biochar and a pyrolysis temperature between 500 and 700 °C can generate biochar with a high porosity and surface area from biosolids.[28] (b) The second aspect may be the destruction of pollutants, particularly PFASs which are inherently present in biosolids. The devolatilisation and destruction of PFASs at high temperature during combustion have been established.[38,39] However, biosolids contain a reasonable concentration of metals and minerals that are expected to function as catalysts for the destruction of PFASs at relatively low temperature in an integrated pyrolysis–combustion process which has not been studied in the literature. (c) The third aspect may be the formation of polycyclic hydrocarbons (PAHs). Below 500 °C pyrolysis temperature, PAHs are formed via carbonisation and aromatisation.[40,41] Above 500 °C, a free radical pathway, followed by pyrosynthesis, dominates the formation of PAHs.[40–42] When investigating PAH formation in the pyrolysis temperature range of 100–700 °C, researchers found that the formation of PAHs is the highest in the temperature range of 400–500 °C.[43,44] Applying a pyrolysis temperature ≥500 °C is often suggested to minimise extractable PAHs in biochar.[43,45] Accounting for all these aspects, a moderate temperature range of 500–600 °C could be considered which is a trade-off between minimising PAHs and obtaining high quality biochar while assisting in the investigation of destruction of PFASs in biosolids at relatively low temperature.

Table 1 Proximate and ultimate analyses of biosolids

Proximate analysis[a] (%)				Ultimate analysis[a] (%)				
Moisture	Volatiles	Ash	Fixed carbon	C	H	N	S	O[b]
11.0	60.6	29.0	10.4	38.3	4.7	6.02	0.96	21.02

[a] Values on a dry weight basis. [b] Value determined by difference.

Proximate and ultimate analyses of biosolids

PFAS contamination in ground water and industrial wastewater is a serious problem and their concentrations often reach above those set by the regulatory guidelines.[46] So far, granular activated carbon (GAC) from various sources (e.g., coconut shell and coal) has been extensively studied for the adsorption of PFASs.[46–50] Biomass derived biochar has also been used in PFAS adsorption studies.[51,52] However, biosolids derived biochar has been rarely used in adsorption studies of PFASs.

The aim of the current study is to (a) investigate the performance of a semi-pilot fluidised bed pyrolysis unit in converting biosolids into biochar, (b) examine the ability of the pyrolysis–combustion integrated process to destruct PFASs present in biosolids and (c) study the application of biosolids derived biochar for removing PFASs from contaminated water.

2. Methodology

2.1. Pyrolysis of biosolids

2.1.1. Biosolids sample. The biosolids sample employed in this study was sourced from the Mount Martha Water Recycling Plant (38°16′06″S and 145°03′31″E) of South East Water Corporation, Victoria, Australia. This plant predominantly receives domestic and trade sewage, and treats sewage sludge through an activated sludge process followed by anaerobic digestion. After digestion, the solids are processed through a dewatering plant (i.e., centrifuge) and solar drying facility before they are sent to stockpiling. Thus, the samples used in this study were processed through a solar dryer shed.

The biosolids sample was initially ground using a pin mill (Chenwei Machinery CW-20B) and then segregated using a vibrating screen (Sanfeng Machinery, SF-600) at FA Maker Pty. Ltd., Victoria, Australia. The pin mill and vibrating screen employed in this study are shown in Fig. S1.† The biosolids, used in the trials, were 0.5–2 mm in particle size. The detailed proximate and ultimate analyses of biosolids are presented in Table 1.

2.1.2. Description of the semi-pilot unit employed for the pyrolysis of biosolids. The process block diagram is shown in Fig. 1 (actual image of the semi-pilot pyrolysis plant can be found in ESI† Fig. S2). Each pyrolysis trial was conducted for 5 hours. Trials were performed in triplicate (n = 3 for each trial) to ensure consistency of the data and the average values are presented in this manuscript. The run mode of this system is considered as semi-continuous since the biosolids

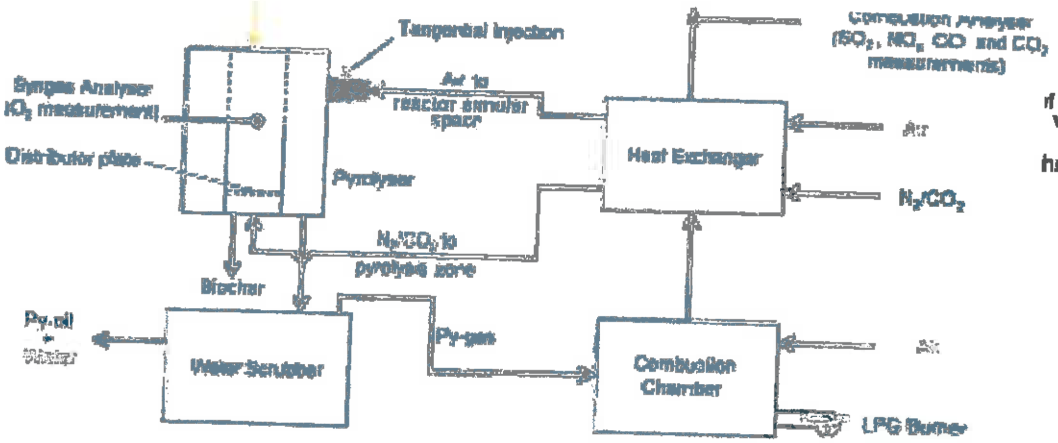

Fig. 1 Process block diagram for the semi-pilot plant setup.

were fed continuously throughout the trial period while char was collected only after the 5-hour period at the end of each trial.

During start-up, the semi-pilot plant was heated via a liquefied petroleum gas (LPG) burner. The hot flue gas leaving the LPG burner was used to pre-heat the gases (i.e. air and N$_2$/CO$_2$) entering the semi-pilot plant via a heat exchanger. The pre-heated air and N$_2$/CO$_2$ gases were then circulated in the reactor to heat the reactor to a desired temperature. The hopper was filled with the biosolids sample at the beginning of each trial (Fig. S2†). The hopper was charged with N$_2$ via a N$_2$ purging line. Once the desired temperature of the reactor was attained, biosolids were continuously charged at 0.25 kg h^{-1} from the hopper to the reactor via a pre-calibrated screw-feeder with continuous N$_2$ purging. The screw-feeder was calibrated for each trial.

The reactor, employed in this study, was constructed from stainless steel 253MA and insulated with ceramic fibre insulation to minimise heat losses. It was of concentric geometry, where the inner tube functioned as the pyrolyser. The bottom half of the inner tube was made of pipe, while the top half of the inner tube consisted of a wedge-wire screen. Biosolids were pyrolysed under bubbling fluidised conditions using a pre-heated N$_2$/CO$_2$ mixed stream

containing 85% N_2 and 15% CO_2, v/v. The reason for using a N_2/CO_2 mixed stream (85% N_2, 15% CO_2, v/v) in the pyrolyser was to mimic the scenario of pyrolysis in the presence of recycled flue gas. The produced gas and oil vapours from the inner pyrolyser tube were then transferred to the annular space via the wedge-wire screen from the top half of the reactor while the biochar produced remained at the bottom of the inner pyrolyser tube. At the end of each trial, biochar was kept further in that inner tube with an inert environment for cooling and then collected further for analysis. The annular space acted as a partial combustor for py-gas and py oil vapours. The temperature in the annular space was controlled by adjusting the air inlet rate. The temperature at the annular space was purposefully kept lower or equal to the pyrolysis temperature to find out whether or not PFASs are destroyed at lower temperatures in thermal systems.

By employing pre-heated air tangentially at a >10 m s^{-1} velocity in the annular space, the py-gas and py-oil vapours were partially combusted and PFASs, if they survived in the pyrolyser, were destructed in this annular space. The remaining py-gas and py-oil vapours were rapidly transported from the annular space to a water scrubber, where they were immediately quenched. The reason for using tangential entry and high-velocity air was to ensure that the pyrolysis reaction environment is not affected and the py-gas and py-oil vapours are immediately quenched without any secondary reactions. The py-oil was condensed in the scrubber water, while non condensable py-gas was sent to the combustion chamber of the LPG burner to ensure that it was combusted before releasing to the environment. The energy required for pyrolysis was provided by the hot air and N_2/CO_2 gases, which were pre-heated using the combustion of LPG and py gas (once produced). At the end of each trial, the sample from the water scrubber was collected for oil and PFAS analysis. Any PFAS species carried by the gas stream, if they survive in the pyrolysis–combustion system, should be trapped in the water scrubber. The reason is that the boiling points of PFASs, even for short chain PFASs (e.g., the boiling point of pentafluorobenzoic acid (PFBA) is 220 °C), are higher than the water boiling point.

An online gas monitor (combustion analyser, MRU Optima 7) was employed to measure the concentrations of various gaseous species (CO, CO_2, NO_x and SO_x) in the stack. The reactor was equipped with four thermocouples and they measured the following temperatures: 1) pyrolyser temperature, 2) annular space temperature, 3) reactor inlet N_2/CO_2 stream temperature and 4) reactor inlet N_2 temperature. The pyrolysis trials were carried out at three different temperatures: 500, 550 and 600 °C. The average temperature at the pyrolyser thermocouple was considered as the pyrolysis temperature. The concentration of O_2 in the pyrolyser was continuously monitored by an online gas monitor (syngas analyser, Madur Aqua GA40T Plus). Biochar produced from biosolids in the semi-pilot trials at 500, 550 and 600 °C are labelled as BSBC 500, BSBC-550 and BSBC-600, respectively.

Biochar produced during the trial was characterised by surface imaging using a scanning electron microscope (SEM) of the Philips XL30 model and a Brunauer–Emmett–Teller (BET) analyser (Micromeritics 2000/2400). The particle size distributions of both biosolids and biochar were determined using a Malvern particle size analyser (Mastersizer 3000). Analyses related to PFAS, py-oil and heavy metals were performed externally (by ALS Limited, Australia). ALS laboratories are NATA (National Association of Testing Authorities, Australia) accredited laboratories. They have applied their WP045B, WP075A and WP0125A methods for py-oil analysis, EP231 method for PFAS analysis and WG020B for heavy metal analysis.

2.2. PFAS adsorption

2.2.1. Biochar preparation for PFAS adsorption. Biomass biochar was produced at 600 °C pyrolysis temperature to make a comparison with biosolids biochar produced at the same temperature (BSBC-600) mainly for exploring its potential to adsorb PFASs from PFAS contaminated water. The biomass biochar produced at 600 °C in this study is

referred to as BMBC-600. Sawdust (predominantly Australian pine wood, sourced from a mechanical workshop at RMIT University) of the same initial particle size as the biosolids (i.e., 0.5–2 mm) was used in the production of biomass biochar. Instead of a semi-pilot plant, a muffle furnace (Barnstead Thermolyne 30400) was employed for the production of biomass biochar, where the furnace was operated at 600 °C for 1 hour. The furnace was then kept closed until it was cooled down naturally to room temperature. Afterwards, the biochar sample was taken out and stored in a desiccator. Both BMBC-600 and BSBC-600 were sieved to obtain a particle size of 0.3–0.5 mm and further employed in the PFAS adsorption study. The BET surface areas of these samples were measured and found to

Table 2 Concentrations of various PFASs in contaminated water

Chemical

be 79.87 $m^2 g^{-1}$ and 55.29 $m^2 g^{-1}$ for BMBC-600 and BSBC 600, respectively.

2.2.2. Procedure for PFAS adsorption. Two PFAS contaminated water samples (sources can't be revealed) were used in this study. The PFAS content in sample 1 was significantly higher than that in sample 2 (Table 2). In addition, several PFAS species in sample 2 were below the detection limit of the analytical instrument, and therefore, they were excluded from the adsorption study. The pH values of sample 1 and sample 2 were 4.3 and 7.85, respectively. In this study, we have not adjusted the pH level for the adsorption tests.

Initially, PFAS contaminated water samples were filtered through 6-micron polyethersulfone (PES) membrane filter paper to remove any suspended solids. Two adsorbents were

employed to remove PFASs from these samples as detailed earlier: 1) biosolids biochar (BSBC-600) and 2) biomass biochar (BMBC-600). For each study, one gram of adsorbent was taken in a conical flask, and 50 mL of PFAS contaminated water was introduced into the conical flask. For each set of adsorption study, there was a repeat test. The tops of the conical flasks were wrapped with aluminium foil, and they were placed in an orbital shaker (Thermoline TS 400) set at 180 rpm. The samples were shaken for 48 hours. After the completion of trials, solid adsorbents were separated using 0.45-micron polyethersulfone (PES) membrane filter paper. The filtrates as well as raw samples were then sent to ALS Limited, Australia for analysis. The adsorption of PFASs by various adsorbent materials was determined using the ALS generated data.

3. Results and discussion

3.1. Process stability

Process stability with respect to important process parameters such as temperature and O_2 concentration is vital in obtaining products of desired quality as well as maintaining the energy balance of the semi-pilot pyrolysis unit. The integration and operation of pyrolysis–combustion has been demonstrated in fixed bed and Auger type reactor designs in the literature.[53] However, an integrated fluidised bed pyrolysis–combustion process has not been demonstrated yet in the literature. The present work demonstrated a stable

Species	formula	Concentration ($\mu g\ L^{-1}$) Sample 1	Sample 2
Perfluorooctanesulfonic acid (PFOS)	$F(CF_2)_8SO_3H$	480	0.08
Perfluorooctanoic acid (PFOA)	$F(CF_2)_7COOH$	24	0.36
Perfluorohexanesulfonic acid (PFHxS)	$F(CF_2)_6SO_3H$	210	0.61
Perfluorobutanesulfonic acid (PFBS)	$F(CF_2)_4SO_3H$	80	0.05
Perfluoropentanesulfonic acid (PFPeS)	$F(CF_2)_5SO_3H$	56	—
Perfluoroheptanesulfonic acid (PFHpS)	$F(CF_2)_7SO_3H$	20	—
Perfluorododecanoic acid (PFDoA)	$F(CF_2)_{11}COOH$	0.22	—
Perfluorotridecanoic acid (PFTrDA)	$F(CF_2)_{12}COOH$	0.07	—
Perfluorotetradecanoic acid (PFTeDA)	$F(CF_2)_{13}COOH$	0.07	—

integrated fluidised bed pyrolysis–combustion system that can achieve highly stable temperature and oxygen concentration profiles. The advantage of such an integrated process is the compact design which can help reduce the capital and operating costs as well as improve the product quality.

Fig. 2 shows an illustrative presentation of the temperature profiles of various thermocouples as well as the O_2 concentration profile during a trial performed at 600 °C.

Temperature fluctuation was found to be minimal. In addition, the O_2 concentration was far below 1% during the entire trial and, consequently, the process atmosphere was nearly inert. This demonstrates that this technology offers a stable process for biochar production.

The monitoring of major components of flue gas during the trial is shown in Fig. 3. The concentration of CO_2 ranged

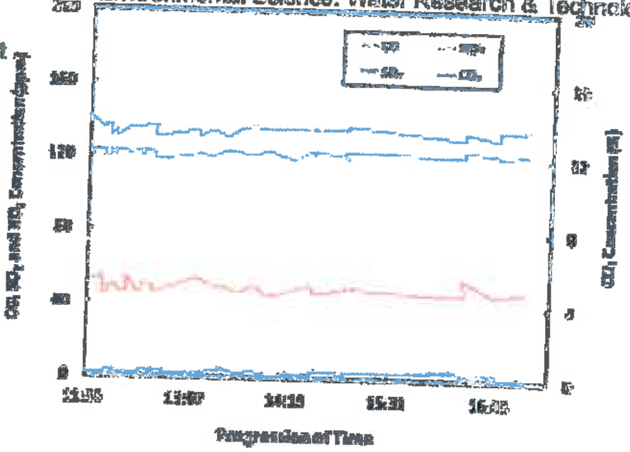

Fig. 3 Analysis of flue gas using an online IR analyser for the 600 °C

definitive]. These efforts, in cooperation with states and industries, is aimed at proper disposal of PFAS-laden wastes without media-to-media transfer or environmental release [i.e., we don't know yet that this is a safe method for preventing media-to-media release]

Incineration is probably better at destroying PFAS than most disposal methods; BUT, there are few (no?) studies that comprehensively assess what happens to PFAS when it's incinerated.
This one looks specifically at PFTE incineration and finds that incinerated PFTE pellets and wood pellets were statistically comparable in terms of PFAS detected (they tested 31 PFAS compounds, including a number of low molectular weight ones). They were still able to detect 11/31 of them in the incinerated samples. **Also worth noting that the study was commissioned by a company that manufactures fluoropolymers...**
They also note that one of the biproducts is **hydrofluoric acid**, a highly corrosive acid that is very likely to pose a significant hazard to workers.
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On Wed, May 4, 2022 at 1:03 PM Sarah Woodbury <swoodbury@defendourhealth.org> wrote:
This is all I have.

---------- Forwarded message ---------
From: **Matthew Boucher** <matthew.boucher@putnamcsd.org>
Date: Wed, Apr 27, 2022 at 3:26 PM
Subject: Saratoga Bio Char in Moreau NY
To: <swoodbury@defendourhealth.org>

Hello Ms. Woodbury. We were given your contact from senator Richard Bennett when we reached out to him regarding his work in banning sewage sludge on Maine lands due to PFAS contamination.
Currently, our town officials have seemingly fast- tracked a proposed facility in our town industrial park that proposes to burn/gassify sewage sludge and wood chips to create bio char to spread on farm fields. We met with the company who proposes this facility and asked many questions including PFAS in sewage sludge and monitoring its disposal(to which there is very little evidence that it breaks down completely).
The industrial park where this is proposed borders a residential community and its residents are adamantly opposed to this project. We are teaching out to any resource to help in our fight and your name was prominent in our search.
If there is anything you can add to our opposition to our town planning board vote on this project on May 12 at 7:00pm we would appreciate more than we can express.
Thank you,
Matthew Boucher

--
Sarah Woodbury (she/her)
Director of Advocacy
Defend Our Health
Office 207-699-5791 | **Mobile** 503-913-2484

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trial.

between 13 and 15%. This range of CO_2 values provides a justification for choosing a mixture of 85% N_2 and 15% CO_2 as the fluidising gas. The concept applied here is that the flue gas may be recycled and utilised as the fluidising gas.

The gas analysis was performed at the stack. The level of SO_2 was observed to be very low (4–10 ppm) in all of our trials. NO_x was also low and in the range of 120 to 125 ppm while CO was between 40 and 50 ppm (Fig. 3). The concentrations of hydrocarbons were also measured; however, the values were not detectable and therefore, not reported here. These values were found to be well below the emission limits recommended by the Industrial Emissions Directive (IED) 2010/75/EU.

3.2. Product distribution of py-oil

The analysis of the scrubber water sample (i.e., product distribution of py-oil) is shown in Fig. 4. The Py-oil components were divided into six major groups, which include polyaromatic hydrocarbons (PAHs), monoaromatic hydrocarbons (MAHs), alcohols, phenols, and C10–C14 and C15–C28 liquid hydrocarbons. This grouping was done following previous studies.[54,55] It was found that the production of PAHs and MAHs were minimal in the py-oil sample. The major components of py-oil were hydrocarbons followed by alcohols and phenols. This product distribution is favourable if py-oil is considered for combustion to provide energy to the pyrolysis system.

While the py-oil product distribution is favourable in the context of combustibility, it will still require pre-treatment before it can be used as a fuel in traditional power generators.[24] A better approach could be combusting py-oil to provide energy to the pyrolysis process. In the current semi pilot plant, a lower combustion temperature was applied with the intention to investigate PFAS destruction. In the real world, a higher combustion temperature could be applied which would combust py-oil and py-gas and provide the required energy to the system.

3.3. Yield and stability of biochar

The biochar yield against pyrolysis temperature is shown in Fig. 5. In this study, py-gas and py-oil were partially

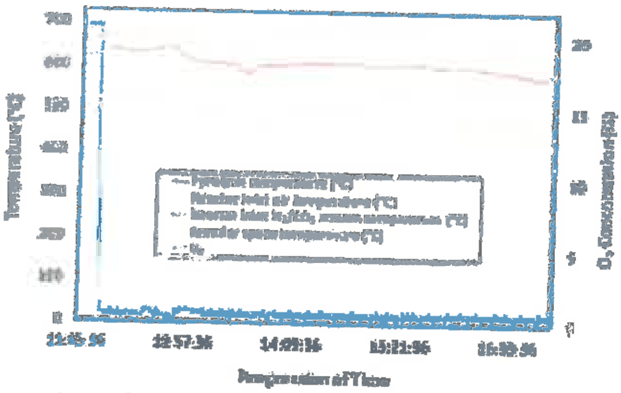

Fig. 2 Temperature profiles and oxygen concentration (in the pyrolysis zone) for the 600 °C trial.

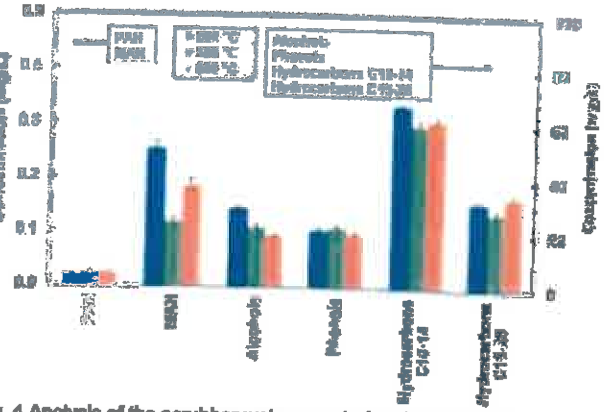

Fig. 4 Analysis of the scrubber water sample (product distribution of py-oil).

Fig. 5 Biochar yield against pyrolysis temperature.

combusted. The uncombusted py-oil was captured in the water scrubber while uncombusted py-gas was detected in the flue gas. As the combusted portion was not measured, the determination of yields of py-gas and py-oil was not possible. Therefore, biochar yield data are only obtained and presented. Pyrolysis of biosolids results in the decomposition of carbohydrates, proteins, lipids, polyphenols and other macromolecular humic substances as well as microorganisms.[56,57] The level of decomposition of these

Table 4 H/C and O/C mole ratios of biosolids and biochar

	Biosolids	BSBC-500	BSBC-550	BSBC-600
H/C mole ratio	1.4726	0.6800	0.6761	0.6087
O/C mole ratio	0.4116	0.0125	0.0111	0.0095

BSBC-500: biochar produced at 500 °C, BSBC-550: biochar produced at 550 °C, BSBC-600: biochar produced at 600 °C.

CH_3) and decarboxylation (loss of CO_2) reactions are enhanced with the increase of pyrolysis temperature. The increase of demethylation reactions decreases the H/C ratio while the increase in decarboxylation reactions reduces the O/C ratio.[59]

species increases with pyrolysis temperature, leading to lower biochar yield.

The effects of pyrolysis temperature on biochar formation is further reflected by the proximate and ultimate analyses of the biochar samples (Table 3). As expected, with the increase of temperature, the volatile matter and fixed carbon decreased while the ash content increased. According to the ultimate analysis, C, H and N decreased with the increase of

temperature. However, the variation of S was found to be minimal in the investigated temperature regime. This suggests that the sulphur containing species do not degrade significantly within the temperature regime investigated. The proximate and ultimate analyses of biosolids and biochar were also used to construct a Van Krevelen diagram (Fig. S3†). This diagram is an illustration of the maturity/stability of biochar materials.[58] Both H/C and O/C ratios decreased significantly from biosolids to biochar as confirmed in Fig. S3.†

The detailed transition of H/C and O/C values from biosolids to biochar is shown in Table 4. It was found that both ratios decreased with the increase of pyrolysis temperature. A similar result was reported by Fryda and Visser.[58] This was possible because demethylation (loss of

Table 3 Proximate and ultimate analyses of biochar

Sample	Proximate analysis[a] (%)				Ultimate analysis[a] (%)				
	Moisture	Volatiles	Ash	Fixed carbon	C	H	N	S	O[b]
BSBC-500	1.7	13.2	64.88	19.1	29.27	1.66	3.25	0.46	0.49
BSBC-550	1.3	12.1	66.77	21.4	28.01	1.58	2.78	0.44	0.41
BSBC-600	2.0	10.9	68.03	10.9	27.21	1.38	2.60	0.43	0.35

[a] Values on a dry weig

and similar definitions

emperature of 500 °C

The highest H/C mole ratio was found to be 0.68 for the biochar produced at 500 °C and this value was lower than that from the International Biochar Initiative guidelines (the suggested maximum H/C mole ratio by the guidelines is 0.7).[60] The highest O/C mole ratio was 0.0125 for the biochar produced at 500 °C. This O/C ratio value is in the lower range when compared to that of other biochar samples, and this seems indicative of a very long half-life (more than 1000 years) when added to soil.[61] Therefore, it is worth noting that the produced biochar samples are very stable carbon materials and suitable for soil carbon sequestration.

3.4. Biochar morphology and surface area

The morphological analyses of biochar produced at 500, 550 and 600 °C were performed using a scanning electron microscope (SEM) (Fig. 5). It can be seen that a porous structure was evident at all temperatures and the porosity was found to increase slightly with the increase in temperature from 500 to 600 °C. The BET surface area of the biochar samples was measured and the values obtained are in the range of 26 to 55 $m^2 g^{-1}$ (mean values were 26.45, 44.06 and 55.29 $m^2 g^{-1}$ for the 500, 550 and 600 °C trials, respectively). These values are well aligned with the SEM findings.

The particle size distributions of biosolids and biochar particles are shown in Fig. 7. It was found that the particle size decreases from biosolids to biochar. The median value (for a volume distribution value), $D_v(50)$, decreased from 829 to 587 μm. $D_v(50)$ represents the median value for a volume distribution. As shown in Fig. 6, the biochar yield was in the range of 36–45%, depending on temperature. This huge

Fig. 6 SEM images of the biochar samples: (A) BSBC-500, (B) BSBC-550 and (C) BSBC-600.

percentage reduction of mass leads to a decrease in solid particle size as confirmed by the particle size distribution results. The bulk densities of solid particles were also reduced. The bulk density of 0.5–2 mm biosolids was found to be 660 kg m^{-3}, while the biochar obtained from the pyrolysis of these biosolids at 500 °C exhibited a bulk density of 620 kg m^{-3}.

3.5. Heavy metal composition

The concentrations of various heavy metals in the biosolids employed and biochar samples produced from the trials are presented in Table 5. Also, the allowable concentrations of heavy metals for land application suggested by EPA Victoria (for biosolids)[62] and the International Biochar Initiative[60] are also provided for comparison. Contamination grade 1 (C1) biosolids, as per the EPA Victoria guidelines, correspond to the highest quality biosolids consisting of the lowest level of heavy metal contamination, and therefore, they are allowed to be used in land application without any specific control measures. In contrast, contamination grade 2 (C2) biosolids are allowed with controlled application.

The mass and volume reduction from biosolids to biochar during the pyrolysis process increased the concentrations of heavy metals. The only exception observed was Hg. This is because of the lower boiling point of Hg, leading to vapourisation of this element at the studied pyrolysis temperatures. While the heavy metal concentrations increased in biosolids biochar, the values were still below the threshold values of the C2 grade suggested by the EPA Victoria and International Biochar Initiative guidelines.

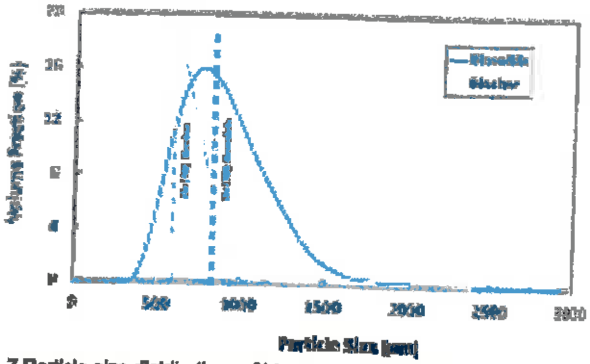

Fig. 7 Particle size distributions of biosolids and biochar.

3.6. Destruction of biosolids PFASs

Fig. 8 highlights the PFAS analysis data for biosolids, biochar and scrubber water. While the concentrations of a majority of PFAS species in the biosolids were found to have definite values, all PFAS species were extremely low (less than detectable values) in both biochar and scrubber water. This confirmed that PFASs were vapourised from biosolids at pyrolysis temperature leading to the production of nearly PFAS free biochar. Similar findings were published by Bioforcetech.[63,64] The extremely low concentrations of PFAS species in both biochar and scrubber water suggest that several PFAS species might have been partially or completely destroyed in the integrated pyrolysis–combustion environment maintained in the pyrolysis reactor and its adjacent annular space. Temperature, gas residence time, oxygen, water vapour and the gas phase chemistry of alkali and alkaline earth minerals (i.e. K, Na, Ca, and Mg) might have played critical roles in PFAS destruction followed by mineralisation. The roles of temperature and residence time are well-known as higher temperature and residence times can improve the destruction kinetics.[65] The literature has demonstrated that oxygen and water vapour can play critical roles in the destruction of fluorinated hydrocarbons.[66,67] In a similar way, oxygen and water vapour (generated from combustion of pyrolysis gas vapours) can play important roles in PFAS destruction. The release of alkali and alkaline earth minerals into the vapour phase and their gas phase chemistry with PFASs and destructed fluorine can also enhance PFAS destruction and mineralisation efficiency.[66,68] There is also a possibility that PFASs might have converted into some unknown organofluorine compounds which might not be in the analytical range.[28,69] Such compounds could be gaseous organofluorocarbons such as CF_4 and C_2F_6. Unfortunately, the nature of the semi-pilot scale trials presented in this work did not allow the authors to investigate the role of each of these parameters in detail.

Mass balance for PFASs could not be developed for the semi-pilot trials as several PFAS concentration values in the

Table 5 Total metal concentrations (mg kg^{-1}) of the biosolids and corresponding biochar samples

Metals	BS	BSBC-500	BSBC-550	BSBC-600	C1 grade[a]	C2 grade[a]	Biochar guidelines[b]
As	<5	5	5	<5	20	60	13–100
Cd	1.4	1.9	1.6	1.6	1	10	1.4–39
Cr	24	44	50	78	400	3000	93–1200
Cu	660	1100	1200	1100	100	2000	143–6000
Pb	19	40	42	39	300	500	121–300
Hg	0.79	<0.05	<0.05	<0.05	1	5	1–17
Ni	18	37	68	180	60	270	47–420
Se	6	6	6	5	3	50	2–200
Zn	870	1600	1700	1700	200	2500	416–7400

BS: biosolids. [a] EPA Victoria Biosolids guidelines.[62] [b] International Biochar Initiative guidelines.[80]

liquid and biochar samples were not specific. However, attempts were made to gain some understanding on PFAS removal efficiency (Table S2†). In this estimation, the concentration values, shown with the '<' sign in Table S1† (also presented in Fig. 8 with a marker), were considered as the final concentration values for PFASs. For instance, the concentration of PFOS in biochar was <0.0002 mg kg^{-1} (Table S1†). In the estimation, the concentration of PFOS was considered as 0.0002 mg kg^{-1}. This estimation provides the removal values of PFBS, PFOS, PFPeA, PFHxA, PFHpA and PFOA as follows: 74, 98, 75, 84, 54 and 96%, respectively. While this is a very rough estimation, this still tells that several PFASs were removed in the pyrolysis process. The removal of other PFAS compounds was either low or they were forming during the process.

To confirm this as well as to explore the mechanism of PFAS destruction, more scientific experiments would be required in the future. As described previously, closing the mass balance for all PFASs was extremely difficult due to the low values of PFASs in the initial biosolids samples. A practical method for the way forward could be performing systematic spiking experiments (i.e. spike different PFASs into biosolids) in a lab-environment in a more controlled manner as spiking at a semi-pilot or pilot scale can be very

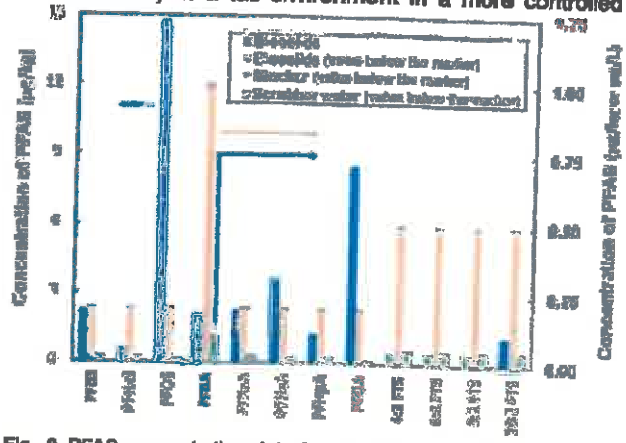

Fig. 8 PFAS concentration data for biosolids (µg kg^{-1}), biochar (µg kg^{-1}) and scrubber water (µg L^{-1}). Columns with markers represent values less than the marker values (see detailed data in Table S1†).

challenging. Lab-scale spiking experiments in a controlled environment may help not only in closing the mass balance but also in exploring the reaction mechanism of PFAS destruction in biosolids pyrolysis, where the feed material is highly heterogeneous, including organic and inorganic materials.

From this study, the authors would like to highlight that PFASs in biosolids, when compared with pure PFASs, might not require higher temperatures (i.e. ~1000 °C for pure PFASs[70]) for their destruction due to the different gas-phase chemistry and potential catalytic effects of minerals/heavy metals present in the biosolids. More scientific work will be required to investigate this fundamentally. Specifically, spiking experiments with particular PFAS compounds at the lab scale in a controlled environment are desirable to evaluate the destruction and mineralisation efficiency and mechanism.

3.7. PFAS adsorption

The adsorption efficiency (% adsorption) of char materials for PFASs of contaminated water samples (i.e., sample 1 and sample 2) is shown in Fig. 9. For this study, BSBC-600 and BMBC-600 were used. It is well known that pH has a great impact on the adsorption of PFASs.[22,71] This has also been reflected in the present study. For example, there was a higher PFOS adsorption efficiency for sample 1 compared to that for sample 2. This was due to the lower pH of sample 1 than that of sample 2 (4.3 vs. 7.85), and this is consistent with the literature.[71] At low pH of the contaminated water sample, electrostatic attraction between the positively charged adsorbent surface and the negatively charged PFOS molecules is strong,[72] and this assists in enhanced adsorption of PFOS molecules.

The length of PFAS chains has significant impacts on PFAS adsorption. Short-chain PFASs are difficult to adsorb by many adsorbents, including commercially available granular activated carbon (GAC). For example, perfluorobutanesulfonic acid (PFBS) is a C4 PFAS. The adsorption efficiency of these species by both BSBC and BMBC is low with a range of 19– 27% (Fig. 9a). However, the adsorption efficiency of PFBS was

water as a hydrophilic functional group with a hydrophobic tail is present in PFASs.[74,75] Briefly, the hydrophobic surface of adsorbents enhances PFAS adsorption.[76,77] The metal content was higher in BSBC compared to BMBC. Therefore, it may be possible that the metals in BSBC reduce surface hydrophobicity and decrease the adsorption of PFASs.[78] This may be the reason for the higher PFAS adsorption on BMBC compared to that on BSBC. While BSBC did not perform as

effectively as BMBC for adsorption of some PFASs, its production is expected to be comparatively less expensive. Therefore, a higher amount of BSBC can be applied solely or in combination with BMBC and high performing PFAS adsorbents such as GAC and resins. Also, selective application of BSBC for the adsorption of some PFASs such as PFOS and PFBS can also be considered.

4. Conclusions

A semi-pilot pyrolysis unit was employed for the transformation of biosolids into biochar. The semi-pilot unit achieved highly stable thermal and oxygen profiles in the pyrolysis zone. It was observed that with the increase of pyrolysis temperature, the biochar yield and fixed carbon in biochar decreased. It could be noted that the development of pores increased with the pyrolysis temperature. The produced biochar samples were stable and are expected to present a long half-life if used as soil additives. The heavy metal concentration in biochar increased, but it was within the EPA Victoria C2 biosolids grading and the found to increase for the low concentration sample with both adsorbents (Fig. 9b). Using the BSBC adsorbent, the effect of concentration on the adsorptions of PFOS, PFOA and PFHxS was found to be the opposite of that for PFBS. With the decrease of concentration, the adsorption of the three PFASs decreased when BSBC was applied. The impact of concentration on PFAS adsorption with BMBC was found

Fig. 9 PFAS adsorption efficiency by various char samples: (a) contaminated water sample with high concentration (i.e., sample 1) and (b) contaminated water sample with low concentration (i.e., sample 2). Note that BSBC represents biosolids biochar, and BMBC represents biomass biochar.

to be relatively low. This is most likely due to the higher surface area of BMBC (BET surface area, BMBC-600: 79.87 m^2 g^{-1}; BSBC-600: 55.29 m^2 g^{-1}). This finding is aligned with a previous study conducted by Bentley et al. who investigated micropollutant adsorption using biosolids biochar and pine biochar.[73]

The terminal functional groups may have an impact on PFAS adsorption. Regardless of concentration, BSBC underperformed in PFOA adsorption when compared to BMBC. It appears that PFASs with carboxylic acids as functional groups have lower adsorption affinity to BSBC. However, the difference of adsorption affinity between BSBC and BMBC becomes very low for PFASs with sulphonic acids as a terminal functional group.

The hydrophobic interactions between PFASs and the adsorbent can assist in PFAS removal from contaminated guidelines provided by the International Biochar Initiative. The trials also demonstrated that integrated low-temperature pyrolysis–combustion might be an effective method for removing PFASs from biosolids by converting them into biochar. More scientific experiments in a controlled lab environment are needed to confirm this.

Biosolids biochar was found to be an excellent adsorbent for removing PFASs from contaminated water. The benchmarking with biomass biochar suggested that the biomass biochar performed better in adsorbing PFASs when compared to the biosolids biochar. Despite this, the lower production cost of biosolids biochar might still make it attractive to be used at a commercial scale.

Conflicts of interest

There are no conflicts of interest to declare.

Acknowledgements

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It was mentioned by a member of the application team that there would be "less methane produced in this project than a landfill". Being that there is currently NOT a landfill in the Industrial Park, I am comfortable with the Zero amount we have.

Which brings me to my next and largest point. To their credit, The applicants team met with myself, Tracy Frisch from Clean Air Action Network, Mike Ewall, attorney for Environmental justice. Two major things that stood out:

1. When asked if the company applied to Wilton Industrial Park(near where the CEO resides), the answer was no. Why ? Because the zoning would be an issue and take time. Interesting as we are currently doing a rezoning for a P&H company who would be a far better fit for this park.

2. When asked if the company would consider continuous emissions monitoring based on concerns from residents, the applicant defaulted to DEC numerous times until forced to commit. The answer was no, they would not do any type of continuous emissions monitoring. The planning board on March 7 discussed that the DEC only monitors once a year for six hours, and that the DEC does not even report findings to the town.
   IS THIS REALLY SOMETHING THIS BOARD SHOULD EVEN CONSIDER. A company can simply just use their wood chips when DEC is coming.
   IF they fail, our town may not even know.

Fort Edward was the first GE host around here as well.

WHY take this dangerous chance? So we can be the ""first"" to have this plant in NY. So what! The possible dangers far outweigh the project benefit. School taxes don't even go to SGF schools. Shame on our Supervisor for conspiring to bring this here. There has been a ton of evidence presented as the to the possible dangers and unproven scientific data ~~presented~~ put forth. Does this planning board want to vote to approve an unknown science and have to live with the knowledge that THEY supported it against the wishes of their residents? If you consider the potential harm to your residents, you should vote no.

- Supt. 12 yrs - Trust/Children - No Way

We know that in addition to containing bacteria, municipal waste also contains PFOAs. After reading and listening to previous meetings on this, it seems that at this facility the waste will be heated to remove water and the steam produced will be used to power the kiln used in the drying process. While I can't speak to if the other contaminants would be effectively removed, I can say that research has shown that PFOAs are not effectively removed with heat. In addition to the effectiveness being in question, the EPA also suggests that high heat needs to be used to destroy the PFOAs showing promising results at heats of over 1000 degrees Celsius(1832F) up to 1400 degrees Celsius (2552F). The proposed facility will be using low heat to produce the biochar as stated in their application.

While PFAs are found in waste in almost all communities, this facility will be trucking in additional waste from other communities that could have a higher concentration of PFAs. This proposal includes the need for a discharge pipe to go back into the sewar system for treatment. The research shows that treatment plants are often ineffective at removal of PFAs in waste water and therefore could be introducing additional PFOAs into our system.[2]

Last year the Sierra Club published a report showing that in the 30 brands of fertilizer, for sale today in 8 states and Washington DC, that are produced using biosolids (treated municipal waste), there were 24 identifiable PFOAs. In fact, they contained both short and long chain PFOAs.[3] As of today, the state of Maine has passed a bill in the house and senate putting a ban on all biosolid fertilizers that are produced using waste that contains PFOAs. In case you are not aware of it I am referring to LD 1911.[4] In fact, some PFOAs may become classified as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act which we know all too well about considering that we have a superfund site already in our town.

While I have additional concerns over the frequency of the DEC auditing process, I also understand that to be out of your control but should still be something that we look at in terms of if we want this facility in our town or not. The DEC will only be auditing this facility every 5 years and from the way they responded to that question at the meeting it did seem like it could be longer. I have read the questions and answers between one of the board members and Saratoga Biochar and I would like to echo her call for an independent review

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Incineration may spread, not break down PFAS

Preliminary data show soil and water near New York facility are contaminated

Cheryl Hogue

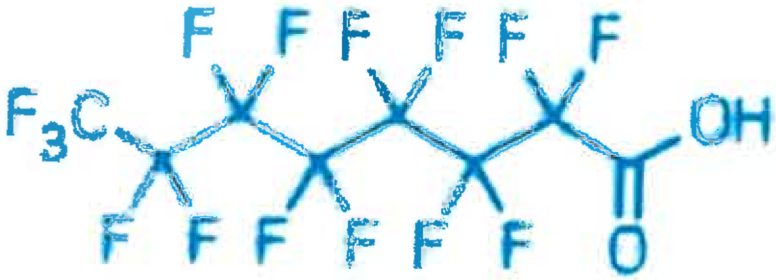
Credit: David Bond/Bennington College

The Norlite facility, which incinerates hazardous waste, abuts a public housing complex in Cohoes, New York.

New data suggest that commercial incineration of per- and polyfluoroalkyl substances (PFAS) doesn't break down these hardy chemicals. Instead, it spreads them into surrounding areas.

Soil and surface water near a commercial facility in Cohoes, New York, that has burned firefighting foam containing PFAS are tainted with these

persistent substances, preliminary data released April 27 by Bennington College show.



PFOA

In early March, a team of professors and students from the Vermont college traveled about 50 km (31 miles) from their campus to Cohoes, where they collected soil and surface water samples near the facility. A commercial laboratory analyzed the samples for the presence of PFAS. The PFAS found in the samples are the same chemicals that were formerly used in firefighting foams, notably perfluorooctanoic acid (PFOA), says David Bond, a professor at Bennington College.

The new data suggest that incineration of the PFAS-containing foam at the Cohoes facility is not breaking down the persistent chemicals but is "redistributing them into nearby poor and working-class neighborhoods," Bond says.

"It's the very definition of foolhardy to try to keep burning these things," Bond says of PFAS. "By design, they resist thermal degradation."

The sampling was part of research that the COVID-19 pandemic interrupted, Bond says. Investigators found the early results alarming and significant for public health so they opted to release them before publication. "It's not ethical to sit on data like that," Bond adds.

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Norlite, a company that makes a ceramic aggregate material, operates the Cohoes facility, burning hazardous waste to fire two kilns. Norlite has voluntarily stopped accepting and processing firefighting foam, pending research by the US Environmental Protection Agency, says a statement from Tradebe an environmental services company of which Norlite is a subsidiary. Tradebe points out that Norlite burned the PFAS-containing foam in accordance with permits from the EPA and the New York

Department of Environmental Conservation.

The US military and nearby states have sent PFAS-containing firefighting foam to the Norlite plant. This facility is one of several across the US that environmental activists are asking a federal judge to shut down. A federal law enacted in December requires the Department of Defense to ensure that the hazardous waste destruction facilities it sends its PFAS materials to actually break down these persistent compounds.

CORRECTION

This article was revised on May 26, 2020, to reflect that the Norlite facility is not an incinerator. Instead, it burns hazardous waste to fire aggregate kilns.

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Per- and Polyfluoroalkyl Substances (PFAS): Incineration to Manage PFAS Waste Streams

Background

Per- and polyfluoroalkyl substances (PFAS) are a very large class of man-made chemicals that include PFOA, PFOS and GenX chemicals. Since the 1940s, PFAS have been manufactured and used in a variety of industries in the United States and around the globe. PFAS are found in everyday items such as food packaging, non-stick stain repellent, and waterproof products, including clothes and other products used by outdoor enthusiasts. PFAS are also widely used in industrial applications and for firefighting. PFAS can enter the environment through production or waste streams and can be very persistent in the environment and the human body. PFAS have many and varied pathways into waste streams, presenting challenges for ultimate disposal. Determining the appropriate method for ultimate disposal of PFAS wastes is a complex issue due to their volatility, solubility, and environmental mobility and persistence. EPA is currently considering multiple disposal techniques, including incineration, to effectively treat and dispose of PFAS waste.

Options and Considerations for the Disposal of PFAS Waste via Incineration

One potential disposal method for PFAS waste is through high temperature chemical breakdown, or incineration. Incineration has been used as a method of destroying related halogenated organic chemicals such as polychlorinated biphenyls (PCBs) and ozone-depleting substances (ODSs), where sufficiently high temperatures and long residence times break the carbon-halogen bond, after which the halogen can be scrubbed from the flue gas, typically as an alkali-halogen. PFAS compounds are difficult to break down due to fluorine's electronegativity and the chemical stability of fluorinated compounds. Incomplete destruction of PFAS compounds can result in the formation of smaller PFAS products, or products of incomplete combustion (PICs), which may not have been researched and thus could be a potential chemical of concern.

Incineration of halogenated organic compounds occurs via unimolecular decomposition and radical reaction. For unimolecular decomposition, fluorinated organic compounds likely require higher temperatures to achieve 99.99% destruction in 1 second residence time than do their chlorinated counterparts. Unimolecular decomposition of highly fluorinated organics most likely occurs through breakage of C-C or C-F bonds (Tsang et al., 1998). The most difficult fluorinated organic compound to decompose is CF_4, requiring temperatures over 1,400°C, but is easily monitored, making it a potential candidate for destructibility trials.

Fluorinated organic compounds can also be degraded via incineration by free radical initiation, propagation, and branching mechanisms. Although hydroxyl radical reaction with hydrocarbons is a common combustion flame-propagating mechanism, the strength of the C-F bond makes this pathway unlikely and would instead leave atomic hydrogen, formed at high temperatures, as the likely radical reacting with the carbon-bonded fluorine.

Radical reactions are more likely for chloroalkanes than fluoroalkanes, due to the lower bond energy of C-Cl (Tsang et al., 1998). If formed, the extremely high electronegativity of fluorine radicals results in their quick combination with other radical species, preventing flame-sustaining free radical propagation and branching processes. This propensity to terminate free radical chemistry make PFAS effective fire suppressants.

The stability of perfluorinated radicals leads to higher concentrations and correspondingly increased propensity to recombine, creating larger molecules that are products of incomplete combustion (PIC) and distinctive from the original fluorinated organics. These reactions are promoted by partial organic combustion resulting from insufficient temperatures, time, and mixing. In addition, the presence of catalytic surfaces, often metals, promotes further reaction and PIC formation in post-combustion regions. This scenario has been most studied related to the formation of polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDDs/PCDFs) in the cool-down regions of waste incinerators.

The effectiveness of incineration to destroy PFAS compounds and the tendency for formation of fluorinated or mixed halogenated organic byproducts is not well understood. Few experiments have been conducted under oxidative and temperature conditions representative of field-scale incineration. Limited studies on the thermal destructibility of fluorotelomer-based polymers found no detectable levels of perfluorooctanoic acid after 2 second residence time and 1,000°C (Yamada et al., 2005; Taylor et al., 2014). Emission studies, particularly for PICs, have been incomplete due to lack of necessary measurement methods suitable for the comprehensive characterization of fluorinated and mixed halogenated organic compounds.

Addressing Gaps in Research for PFAS Waste

The extent to which PFAS-containing waste material in the United States is incinerated is not fully documented or understood. PFAS compounds are not listed as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) nor as hazardous air pollutants under Clean Air Act regulations, so they are not subject to the tracking systems associated with these regulations.

EPA is currently considering multiple disposal techniques, including incineration, to effectively treat and dispose of PFAS wastes. EPA researchers are currently studying PFAS incineration, sampling and analytical methods development, and industrial field sampling. Research on thermal stability of PFAS compounds, the ability to fully capture and identify PFAS compounds and their thermal decomposition byproducts, and the efficacy of emission control technologies are areas of targeted research. These efforts, in cooperation with states and industries, is aimed at proper disposal of PFAS-laden wastes without media-to-media transfer or environmental release.

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Note: This technical brief is a summary of the science and does not necessarily reflect EPA policy.

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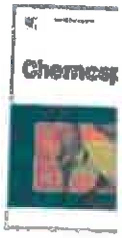

Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas

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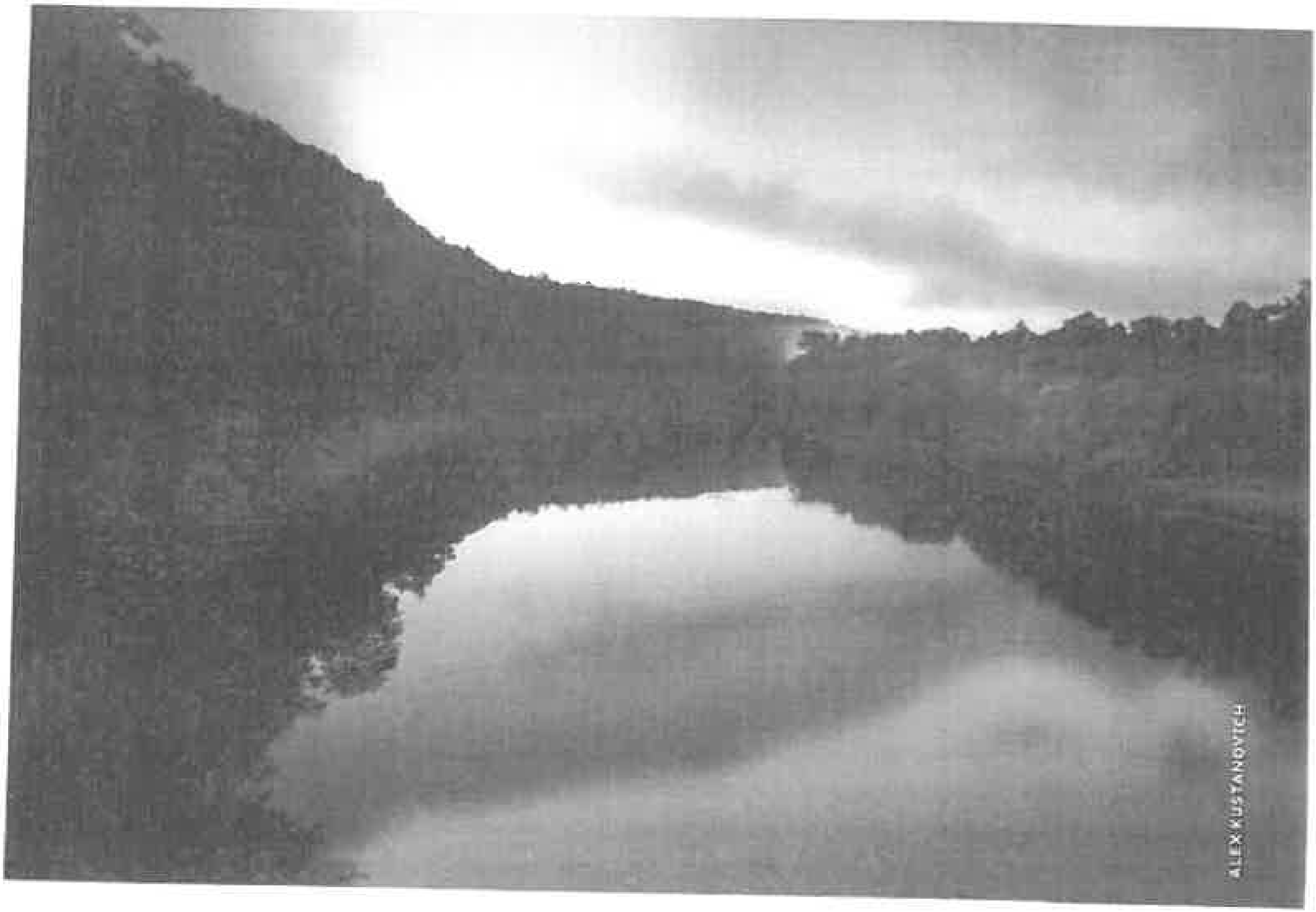

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SOMETHING IN THE WATER

ROBERT BILOTT ON CORPORATE GREED AND CHEMICAL CONTAMINATION

TRACY FRISCH

Robert Bilott is an unlikely environmental hero. As a lawyer in the 1990s he worked extensively on behalf of chemical companies. Then, in 1998, a West Virginia cattle farmer named Wilbur Earl Tennant contacted Bilott looking for legal representation. Tennant's cattle were inexplicably dying and bearing deformed and stillborn calves, and the farmer suspected that industrial chemicals leaking from a DuPont landfill were to blame. DuPont operated the world's largest Teflon factory in Parkersburg, West Virginia, just seven miles from Tennant's farm. Though Tennant's request fell outside of Bilott's normal work, the lawyer agreed to look into it, mostly because the farmer knew his grandmother.

As a child growing up in a military family, Bilott had spent many holidays and summer vacations visiting his grandmother in West Virginia. In college he majored in political science and urban studies at New College of Florida. After graduation he considered going to grad school to study urban planning, but his father persuaded him to attend law school instead. He obtained his law degree from The Ohio State University in 1990 and subsequently landed a position at the corporate environmental law firm Taft Stettinius & Hollister LLP in Cincinnati, where he became a partner and still practices.

Bilott thought the Tennant case would be easy: just get the landfill permit, figure out the identity of the toxic chemical, and let the U.S. Environmental Protection Agency (EPA) do the rest. He did not anticipate that the culprit would turn out to be a group of hazardous chemicals for which the EPA had no regulations. Unknown to most Americans, yet found in hundreds of consumer products, PFAS compounds were being used to make resistant coatings on products such as Teflon and Scotchgard, as well as firefighting foam. PFAS stands for "per- and polyfluoroalkyl substances." The compounds are what are commonly referred to as "forever chemicals," meaning they don't break down in the environment or in the human body, and they have contaminated the drinking water of about 110 million people in the U.S.

Though it put him at odds with his law firm and threatened his career, Bilott brought lawsuits against DuPont and called wide attention to these carcinogenic compounds. He settled his first case with the chemical giant in 2001 and went on to negotiate a unique settlement of a class-action suit on behalf of tens of thousands of people exposed to PFAS compounds through drinking water in the Ohio River watershed. Bilott's investigation and litigation inspired the 2019 Hollywood legal thriller Dark Waters *and are the subject of the 2018 documentary* The Devil We Know. *He recounts his story in his memoir,* Exposure: Poisoned Water, Corporate Greed, and One Lawyer's Twenty-Year Battle against DuPont.

Without Bilott's groundbreaking work, we might still be in the dark about the dangers and prevalence of PFAS chemicals, which have been in use since 1947 and have spread throughout the environment. Though the EPA forced DuPont and other companies to phase out production of the specific chemical that had poisoned Tennant's cattle, thousands of other PFAS compounds remain unregulated. Bilott continues to use his expertise on these chemicals to inform the public about the dangers. He has received the international Right Livelihood Award (also known as the Alternative Nobel Prize) for his work on PFAS contamination.

I first encountered Bilott in 2017 at a small conference on PFAS held at Northeastern University in Boston, where he gave an account of the litigation against DuPont and the huge epidemiology study and medical-monitoring project that had resulted from it. Despite my many years of involvement in the environmental movement, this case was a revelation to me. I was able to have a wide-ranging Zoom conversation with Bilott from our respective offices last year.

Frisch: How did you figure out that a chemical released by DuPont was killing cattle?

Bilott: Cattle farmer Earl Tennant first contacted me more than twenty years ago, in October 1998. He called me at my office and started talking about his cows dying. I was about to tell him I couldn't help him when he mentioned that he had received my name from my grandmother. So I paused and paid closer attention.

He explained that he was raising animals outside of Parkersburg, West Virginia, a town I knew well. It was where my mom had grown up. My dad was in the Air Force, and we moved around a lot, but we always came back to Parkersburg for holidays and birthdays. Mr. Tennant said he had been trying for a couple of years to find a lawyer to help him figure out why his cows were getting sick and wasting away. They were developing tumors. Their teeth were turning black. Calves were stillborn or born with cloudy or deformed eyes. And it wasn't just the cows. He saw this happening with the wildlife in the area, the deer and the fish, and he was concerned that it could be affecting him and his wife and children as well, because he would have difficulty breathing when vapor clouds from a nearby landfill would come over his property.

The landfill was owned by the DuPont chemical company. Tennant could see white, foaming water coming out of the landfill, through a discharge pipe, and right into a creek that ran through his property and that the cows and the wildlife drank from. For quite some time he had been trying to get answers from DuPont about what was in that

water, but he wasn't getting anywhere. He had called the state environmental protection agency and the federal EPA. He had tried local lawyers, but they weren't willing to dig into it, because DuPont was one of the town's biggest employers.

So he was looking for somebody outside of the community who could help him, and he knew my grandmother had been bragging about my being an environmental lawyer in Cincinnati. This was definitely not the kind of case I was taking at the time. I had spent eight years or so helping corporate clients get permits to run landfills just like this DuPont one. But I told him I'd see if there was something we could do.


ROBERT BILOTT

At the time I thought this would be fairly straightforward: We could pull the landfill permits, which would identify all the regulated chemicals being monitored at the site. There was probably something exceeding the permit limits. But when I looked, I really didn't see anything on those permits that could be the cause.

We ended up filing a lawsuit against DuPont, whose attorneys called and told us there was already an investigation underway with the federal EPA, which was specifically looking at the cattle. No need to get into a bunch of expensive discovery, they said, because they would probably have an answer from the EPA soon.

When the EPA's report came back, it suggested that the farmer just didn't know how to raise his cattle. That's when I started to get suspicious. This farmer did know how to raise cattle, and there was obviously something in that water that was causing it to foam. Since we weren't seeing anything in the permit information, I asked DuPont for all files relating to that landfill — in particular, what they were making at the plant down the river that was generating the waste. That's when they began to fight us. We had to get a court order to make them turn over the documents — hundreds of thousands of pages.

I was surprised to learn that the landfill contained a massive quantity of a highly toxic chemical that didn't break down in the environment, accumulated in the bodies of people and animals, and was possibly carcinogenic. Yet this chemical was completely unregulated. State and federal agencies knew nothing about it. This was going on outside of the regulatory system that I thought I understood.

Frisch: That's extremely important. What is the name of the chemical?

Bilott: DuPont called it C8, because of the chemical structure. Its scientific name is perfluorooctanoic acid, or PFOA for short.

Frisch: What was DuPont's factory on the Ohio River in Parkersburg making?

Bilott: One of its main products was Teflon.

Frisch: And what's the relationship between PFOA and Teflon?

Bilott: PFOA was used in the production of Teflon. It was not an ingredient in Teflon. DuPont had originally purchased PFOA from the multinational conglomerate 3M, which had shipped it to West Virginia. Later DuPont had started making PFOA itself.

DuPont had been using PFOA since around 1951. It was used in a lot of consumer products, like waterproof clothing, stain-resistant carpeting, and fast-food wrappers and packaging.

Besides PFOA, 3M manufactured another closely related chemical called PFOS, which stands for perfluorooctane sulfonate. It was used in firefighting foam. As a class, these fluorine-related carbon compounds are called PFAS chemicals.

Frisch: You learned that DuPont knew about the effects of PFOA, because its toxicology department had studied it for decades. What did the company know, exactly?

Bilott: You have to keep in mind that the federal EPA wasn't established until 1970, and the first laws regulating new toxic chemicals coming onto the market weren't passed until 1976. Here you had a chemical that had been developed right after World War II, long before EPA toxicology tests were even in existence. DuPont had a massive laboratory in Delaware called Haskell Labs, where its scientists helped develop the field of toxicology.

These scientists, recognizing the unique chemical structure of PFOA, recommended doing toxicity testing in the early 1960s. They found multiple adverse effects on different organ systems in various animal species: rats, rabbits, guinea pigs, beagles, and later monkeys. Eventually, in the 1980s, they found that the chemical could cause cancer in rats. A second study confirmed this in the early 1990s.

So DuPont's top scientists had produced a wealth of internal toxicology data, but the company didn't give that information to the EPA. Instead DuPont continued releasing PFOA into the air, into the water, and into the soil outside its manufacturing plants, exposing workers and people in the community.

Frisch: Had PFOA been studied by the government or any independent scientist at the time that you began

representing Earl Tennant?

Bilott: The only data I was seeing had been generated by either 3M or DuPont. To my knowledge there wasn't anyone outside those corporate circles who was even aware the chemical existed.

Frisch: Are companies legally required to share this information with consumers and the government?

Bilott: When the Toxic Substances Control Act was passed in 1976, the EPA basically left it up to companies to reveal if any of the tens of thousands of chemicals already in use posed a substantial risk to human health or the environment. If a company like DuPont had such information due to its own research, it had an obligation to tell the agency.

Frisch: Were there any penalties for failure to do so? Because it appears that DuPont simply flouted the law.

Bilott: In 2001 I began sending documents to the EPA to show what DuPont knew about the potentially toxic effects of PFOA and the fact that it was in the drinking water of thousands of people. The EPA began a priority review of the chemical, and in 2004 it actually sued DuPont, claiming that the company had withheld information from the agency about the risks.

DuPont ended up settling and paying what at the time was supposedly the largest civil administrative penalty in the history of the EPA: about $16.5 million. A couple of years later 3M also paid a civil-penalty settlement for claims that it had withheld information about certain PFAS compounds from the EPA.

Frisch: Was DuPont's penalty sufficient to deter that kind of wrongdoing in the future?

Bilott: A lot of folks feel the size of the penalties that are assessed actually encourages companies *not* to disclose toxicity data to the EPA. Even if the companies end up getting caught and having to pay a penalty, it is minuscule in comparison to the amount of profit that can be made by not disclosing the information.

Frisch: Through the discovery process and the depositions your team did as part of your lawsuits against DuPont, did you find out about any other unethical practices?

Bilott: There was a pattern of similar instances: DuPont's scientists would find additional evidence of the chemical's toxicity, and they would recommend switching to a different chemical or warning the community. Over and over the business executives would decide not only to continue using the material but to *increase* emissions into the environment.

For example, I found a memo about a 1984 meeting in Wilmington, Delaware, where DuPont executives reviewed information about the toxicity of PFOA. Sales of Teflon were increasing, and with that came the prospect that emissions might increase. They discussed whether to switch to an alternative chemical and ultimately decided not to. And emissions did, in fact, increase as expected.

We laid out that information to juries in multiple trials, and two came back with punitive-damage verdicts. They believed the company had acted with conscious disregard of the risk, and had continued to do so for years, until litigation forced it to finally stop.

Frisch: Wasn't DuPont a leader in a "sustainable-business" organization?

Bilott: Right. In the 1980s the chemical industry developed a program called Responsible Care. DuPont helped set up the program in order to counter the negative publicity generated by the disaster in Bhopal, India. [*A Union Carbide factory accidentally released forty-five tons of methyl isocyanate gas into the air, killing between fifteen and twenty thousand people and injuring more than a half million. —Ed.*] It just so happened that information about PFOA having potentially carcinogenic effects was coming to DuPont's attention around the same time.

Frisch: You've demonstrated how the legal system can be used to hold a corporation accountable for environmental crimes. Is this approach within the reach of most communities?

Bilott: I'll be the first to tell you, even as a lawyer, that no community should have to go through what we did: spending all of these years, having to bring tens of thousands of people together to give blood and participate in massive health studies, just to be able to counter companies' claims that there was insufficient evidence the chemicals posed a risk.

Look at what it took to actually meet the burden of proof in this case in West Virginia. And PFOA is just one of hundreds — if not thousands — of man-made PFAS compounds that have gotten into our environment, our drinking water, our soil, and our blood. Yet we are still hearing the same argument from these companies: that the exposed people can't prove these chemicals are so toxic, because they don't have enough evidence.

I sent my letter to the EPA back in 2001, and to this day we still lack enforceable federal drinking-water limits for PFOA or PFOS. States are moving forward on their own. And people are still having to resort to lawsuits to try to force these companies to take responsibility for the contamination they've caused. We're fortunate that we at least have legal recourse in the United States, but we shouldn't have to resort to it. Right now the only way folks have gotten clean water and compensation for their cancers has been by going to court.

Frisch: It sounds like corporations use the legal system to their advantage to avoid responsibility.

Bilott: A lot of folks don't realize who has the burden of proof in a case like this. If you're exposed to a chemical in your drinking water that may cause cancer or other problems, *you're* the one who has to prove in court that the chemical is harmful. The company can sit back and say, "Your evidence isn't good enough. Your study isn't big enough. Your expert isn't credible," or whatever other argument it wants to make. And it's very difficult to bring these

claims to court in the first place.

That's why, through our class-action settlement for the affected communities in West Virginia and Ohio, we asked to have an independent science panel resolve the basic legal question of whether PFOA can cause disease in humans and at what levels. And scientists have thoroughly answered this question, such that the company can no longer dispute it as to these people and litigate it forever. It was one of the few times that has ever happened in a court settlement.

Frisch: Could DuPont still argue that, because people have been exposed to so many other toxic substances, the health damage can't be pinned on PFOA?

Bilott: The scientists charged with addressing the PFOA issue also addressed whether other factors could be contributing. They were able to set up some of the most comprehensive human-health studies ever done to address those exact questions.

But we've got a rather unique problem with these PFAS chemicals: It's very difficult to find a clean control group — a human population with no prior exposure — because PFAS chemicals are in all of our bodies. Having such massive, widespread exposure really complicates the issue.

Frisch: Let's talk about attempts to limit class-action lawsuits and thus make it harder for people to sue corporations for damages.

Bilott: A number of groups have tried to place additional legal hurdles to prevent cases from proceeding as class actions. The Class Action Fairness Act has made it more difficult to bring such cases in state courts. Many of them are now required to be brought in federal courts, where some say there are more hurdles in place for those trying to bring these types of claims. If anything, our West Virginia case highlights the importance of class actions. The individual value of a claim may not be very high, so if a person had to pursue the claim alone, the cost of the litigation would be more than they would ever recover, and they wouldn't pursue it. Allowing people to group claims together makes it economically viable.

Frisch: Did you ever worry that it would be risky to push for an epidemiological study of PFOA? Or was there such a preponderance of evidence this chemical was harmful that you didn't see a downside?

Bilott: Frankly we weren't sure how it would play out. We couldn't find any precedent where something like this had been done. But, looking at the documents and the data that we already had from the company itself, the science seemed pretty clear. We expected the study to confirm what we had already seen in the company's files. It was not a given, however.

We had to make sure we were selecting completely independent scientists to do this work, scientists who would not somehow be influenced by one side or the other and whose work would withstand the type of scrutiny it would likely be subjected to. It was stressful for everyone involved.

The science panel ended up confirming probable links between exposure to PFOA in drinking water and six diseases: testicular cancer, kidney cancer, ulcerative colitis, thyroid disease, preeclampsia, and high cholesterol.

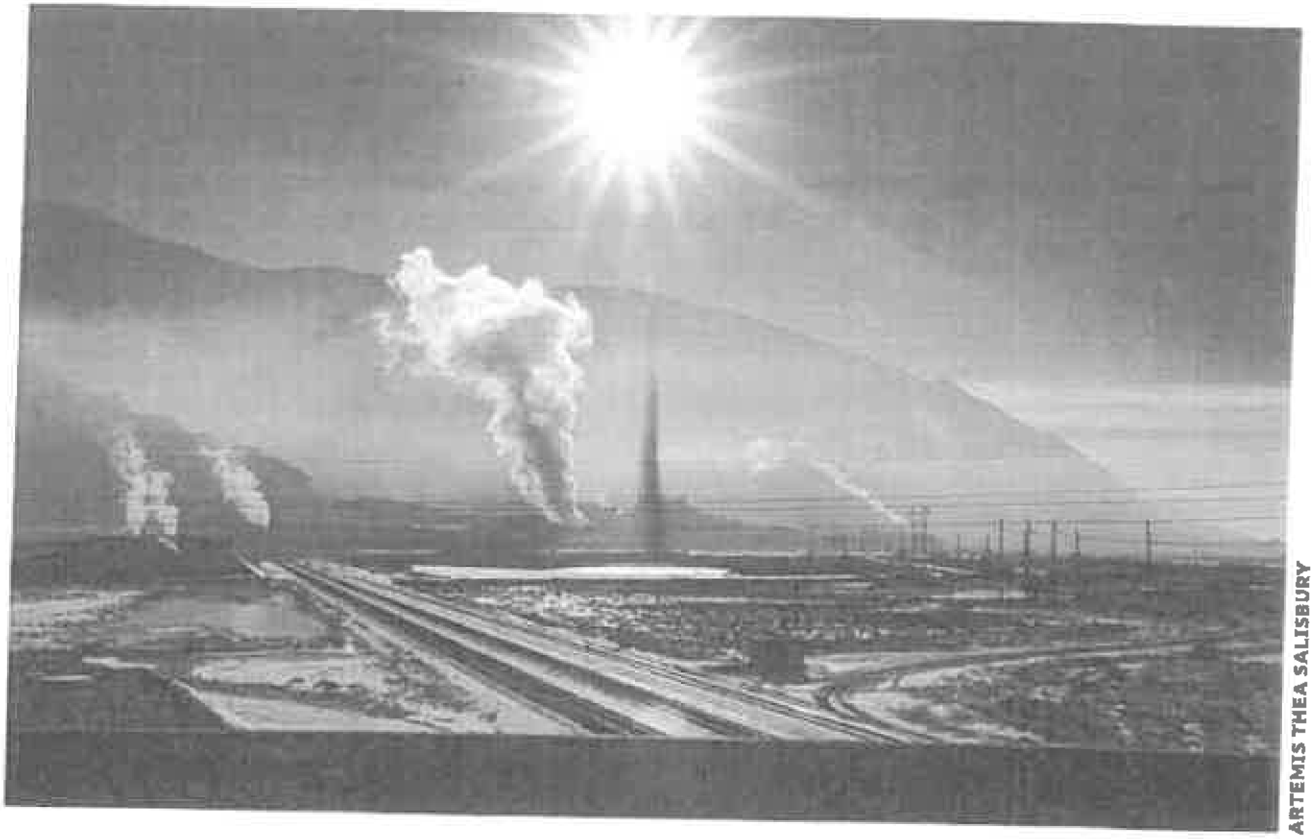
It took a lot longer than anybody expected — years — but the result was incredible. The science panel ended up confirming probable links between exposure to PFOA in drinking water and six diseases: testicular cancer, kidney cancer, ulcerative colitis, thyroid disease, preeclampsia, and high cholesterol. The science was done in such an outstanding way that scientific organizations all over the world, including the EPA, have been relying on it. I think everyone involved would probably say it was worth the risk.

DuPont wasn't using PFOA just to make Teflon in West Virginia. The chemical was used at other manufacturing sites as well. And 3M had made it in Minnesota. Some of the waste from West Virginia was being sent to landfills in New Jersey and to other locations across the country. So after people started reading about the settlement in West Virginia, sure enough, sampling started at some of those other places.

The State of Minnesota found PFOA around the plant that made it there. The State of New Jersey started testing for PFOA in the water outside of the DuPont Chambers Works plant there. The same happened in Alabama. And so on.

Frisch: What actions has the EPA taken to date to control PFAS chemicals?

Bilott: After the study first came out, the EPA finally put PFOA and PFOS on the list of unregulated contaminants



ARTEMIS THEA SALISBURY

that must be sampled for in larger public drinking-water supplies — typically those that serve more than ten thousand people. That was in 2013.

In January 2016 *The New York Times Magazine* published our story and mentioned that these chemicals were being found in public water supplies across the country. People began demanding that the EPA determine a safe level. A few months later the EPA came out with its first long-term drinking-water guideline for PFOA and PFOS.

But before the EPA could start the process of actually regulating these chemicals, it first needed to determine whether this was a national problem, or one that should be left to the states. That process was slowly grinding away until 2020, when the EPA finally announced that the contamination was widespread enough for the federal agency to act. It's going to move forward with setting a national drinking-water standard, which may take several more years.

I don't know if we've even had a single new drinking-water standard set in the last twenty years, because of how difficult the process has become. That's why federal legislation is being proposed that would just designate these chemicals as regulated and hazardous under the law, rather than waiting for the regulatory process to play out. And that's why states are setting standards themselves, as opposed to waiting for the federal EPA.

Frisch: What makes federal and state environmental-protection agencies so incapable of protecting the environment and human health?

Bilott: I think it's incredibly complicated. The EPA has thousands of employees. There are long-term career people there trying their best to do what needs to be done. And then you've got political appointees with decision-making power who come and go with each change of administration. It's also seriously underfunded, with insufficient staff to process all the information coming in about different chemicals.

Frisch: There is a growing global movement to recognize the rights of nature, with citizens bringing lawsuits on behalf of bodies of water. What implications might this have for toxic-chemical threats?

Bilott: I'm aware of those concepts being discussed, but I'm not intimately familiar with the laws or litigation about them. I think the basic idea is that there should be a human right to clean water, or that we should have a right to keep our blood free of man-made pollutants. If those rights were recognized, it could provide an additional basis for people to seek relief in court. Currently there are those in the U.S. who say you don't have a right to completely clean water, because the government can give people and companies

the right, through permits, to pollute it.

Frisch: Another approach is the precautionary principle, which puts the burden of proof on the chemical manufacturer, rather than on the injured party. The chemical is considered potentially harmful until it's proven safe, rather than the other way around.

Bilott: The precautionary principle has been more widely embraced in Europe. It suggests that you don't have to wait until the hazards are absolutely proven before you do something. An issue came up in our litigation where the other side argued that we shouldn't be allowed even to use the words *precautionary principle* in front of a jury, because it suggests a different legal burden than is required in the U.S., where, they argued, the injured person must prove harm.

Frisch: All PFAS chemicals contain the element fluorine. Is the mere presence of fluorine in a product or manufacturing process something that should make us concerned?

Bilott: I have heard a number of scientists say that the presence of that element is a bit of a red flag. These particular chemicals, with their combination of carbon and fluorine, are basically organic fluorine compounds, which almost never occur in nature, so our bodies don't know how to deal with them. We don't eliminate them from our system very well, and they end up in the blood. It is a very troubling situation. PFAS compounds may have some great uses in the manufacturing world, but living beings have a real problem dealing with them.

Frisch: Seventy years after they were introduced, PFAS chemicals are now in the blood of virtually every American — indeed, most of the human population worldwide. How have these chemicals gotten dispersed so widely?

Bilott: Unfortunately they tend to move pretty efficiently through the environment. If they emerge from a smokestack, for example, they can travel through the air. I've heard about them being found in polar-bear blood and in arctic ice. They can get into clouds and move around globally. Although PFOA, for example, has been phased out in the U.S., some of these chemicals continue to be made in other countries, like China. And since the pollution can move with clouds and come down in the rain, it can move into the groundwater table. Vegetation can take it up, pulling it out of the soil and the water. So it gets into plants, and from there into other living things. It doesn't go away. It just continues to be cycled through, and humans end up being a sort of repository for a lot of it.

Frisch: Once these chemicals get into our drinking water, is there any way to remove them?

Bilott: Some filtration systems are very effective at removing certain types of PFAS chemicals from water supplies. In particular, granular, activated-carbon systems can filter out what we call the "long-chain" PFAS chemicals — those that have eight or more carbons, like PFOA or PFOS. But some of the newer replacement PFAS chemicals — short-chain PFAS with six carbons or fewer — aren't captured as well. For these a different type of water-filtration system, like reverse osmosis, may be required, which is a lot more expensive.

Frisch: I understand that tap water can be filtered, but doesn't the water in wells or in a reservoir stay contaminated?

Bilott: Yes, typically the filtration system cleans the water before it goes out to municipal customers, or before it comes into the house. It's not actually cleaning up the groundwater. And even if we were able to clean up the groundwater, it would likely continue to become contaminated. In Little Hocking, Ohio, for example, a massive amount of PFOA was emitted into the air over the years. It fell on the ground and seeped into the soil. So even if you could clean up the groundwater, the soil is still a continuing source of contamination.

Frisch: It seems that once these "forever" PFAS chemicals enter the environment, we're screwed.

Bilott: Right. And that's why a lot of folks are trying to make sure that, at a minimum, we stop any further releases of these materials.

Frisch: Under immense pressure — a lot of it stemming from the publicity your work has generated — DuPont stopped producing and using PFOA in 2013. That sounds like a significant advance, but you're suggesting that it won't solve the problem.

Bilott: In 2006, through an EPA program, DuPont committed to stop manufacturing PFOA in the U.S. by 2015, but a DuPont spin-off called Chemours continues to produce those short-chain PFAS chemicals I just mentioned, which can generate PFOA in the environment. This is the subject of a lot of current investigation and litigation.

Beginning in 2009 DuPont started shifting from PFOA to a new chemical manufactured in Fayetteville, North Carolina. They refer to this replacement chemical as "GenX." It's used just as PFOA was. GenX goes up the smokestacks and gets discharged into the river. So basically the cycle continues with a slightly different chemical.

In 2015 DuPont spun off its entire chemical division — the one that makes GenX — into this new company called Chemours. Then DuPont claimed it was Chemours that had all liabilities associated with PFAS. But analysts and commentators said Chemours had been created with insufficient assets to handle all of those liabilities. Chemours ended up suing DuPont, arguing that it had been set up to take the fall. The dispute was eventually settled, with the two companies sitting down and figuring out which would pay what part of the first $4 billion in PFAS liabilities going forward.

Frisch: There's a Maine dairy farm that can no longer sell its cows' milk or crops due to high levels of PFAS chemicals. The source of the contamination was a 1980s state program that promoted the use of sewage sludge as agricultural fertilizer. What should be done about this?

Bilott: This is another issue the general public believes has just been discovered, but the concern about PFAS

There are those in the U.S. who say you don't have a right to completely clean water, because the government can give people and companies the right, through permits, to pollute it.

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chemicals in biosludge or biosolids [sewage sludge] dates back well over a decade. The federal EPA looked into this issue down in Alabama as early as 2008, where wastewater biosludge had been given to farmers and spread on fields. There was great concern that it would not only potentially contaminate drinking water but also get into the soil that the farmers were using to grow feed for beef cattle. Yet not much was done to educate and alert people about the issue.

Frisch: In 2020 I talked to the environmental scientist in charge of my state's sewage-sludge program. She was looking forward to being able to test for PFAS chemicals in sewage sludge *starting* in 2021. Later she said there wasn't funding to do the testing last year.

Bilott: I suspect you would find the same situation all over the country. A lot of water supplies are not yet tested for PFAS chemicals. It's expensive, and, the municipalities will argue, "There's no regulatory standard, so what would we do with that data?"

Frisch: In Maine, which now regulates PFAS chemicals in sewage sludge, forty-four samples of sludge that was to be spread on farmland were recently tested. Almost all had PFAS chemicals at levels above the state safety threshold, which some environmental groups say is ten times higher than it should be. So most people's exposure to PFAS chemicals doesn't come from direct industrial releases. It comes from ingesting food.

Bilott: It comes from a wide variety of sources. There could be downstream users of this material who dispose of it in landfills or send it to wastewater-treatment systems without even knowing they've been using the chemicals. Since they are unregulated, they may not even be listed on Material Safety Data Sheets or in product information. Also the materials have been used in many different consumer products, like fast-food wrappers and packaging and stain-resistant carpeting. But if you're in a community with contaminated drinking water, that is likely to be your primary source of exposure.

Frisch: I was alarmed to find that even hand sanitizers may contain PFAS chemicals.

Bilott: People are only now starting to understand the full scope of the product range. It's not easy to find out where these chemicals were used because, again, they often weren't listed on labels. There are groups out there trying to make that information available to the public. The manufacturers of the chemicals have withheld pertinent information as "confidential." So it's difficult to know whether or not you're exposing yourself to PFAS chemicals through a certain product.

Some companies are making it known that they are switching away from all PFAS chemicals, so people do have some choice.

Frisch: What should justice for people harmed by these types of environmental crimes look like?

Bilott: I hope it looks like what you saw at the end of *Dark Waters*, where people obtain access to clean water and get compensated for their injuries, and states and municipalities are able to get reimbursed for the multimillion-dollar costs of water treatment and sampling and monitoring equipment. Those costs should be paid for by the companies that actually caused the problem, that knew this would happen, and that treated people like guinea pigs.

Frisch: We also need to rebalance the warped set of incentives and penalties that exist, so that this doesn't happen again and again.

Bilott: Right. There's got to be a sufficient deterrent, so that it doesn't make good business sense to do what DuPont did.

We have more than enough information to take action on all PFAS compounds based on what we know about PFOA. That information should be used in a precautionary way to evaluate chemicals that are similar in structure and toxicity. We shouldn't be waiting for more people to get cancer and die before we take appropriate action to address the problem.

Frisch: What do you say to people who find this information too overwhelming?

Bilott: It can be overwhelming, but if you step back and look at this particular story of Earl Tennant, it can be inspiring. A farmer in a small community in West Virginia was able to take on DuPont, and we got the information out, and laws are being changed. Rules are being changed. Products are being changed. The public is becoming aware of something we weren't aware of before. So we can make a difference. ▪

PFAS and SEWAGE SLUDGE BIOCHAR

By Dave Walker, Geology Professor Emeritus, Columbia University

Biochar (pyrolyzed organic matter, such as agricultural wastes) is well established as a soil enhancer and/or a source of biogas. Pyrolysis is also an agri-waste disposal mechanism. The process involves heating biomass in the absence of air so that it does not burn. Instead as temperature rises, a progressively more carbon-rich solid develops by loss of moisture and calorific flammable gases like methane and carbon monoxide. The residual carbon-rich char serves as a fertilizer, sorbent, and moisture stabilizer when added to soils, and the gaseous byproducts can be partitioned between fueling the pyrolysis and other fuel uses. The pyrolysis itself is anaerobic whereas the use of biogas as a fuel involves combustion and its products. A variety of products may be produced from various feedstocks, heating rates, and temperatures achieved. The process is uncontroversially green for agricultural wastes like cornstalks or grass clippings or manure, unless there are residual pesticides or hormones incorporated within the particular waste stream. CO_2 produced by biogas fuel-use is not fossil and does not contribute to climate change.

Things are a bit more complicated when sewage sludge is the waste stream [feedstock] for pyrolysis, because of its potential content of toxic substances. Microbes and related biotoxins are of course sterilized during the pyrolysis; metals are not. They may join the char or be expelled with the gases. In assessing the potential impacts of a biochar production project, it is important to know what toxins may be present, and what their likely disposition during the processing may be. PFAS chemicals are of some interest because they are found widely distributed in sewage, usually, but not always, at low levels. They are highly toxic and difficult to destroy. Thus when municipal sewage sludge is spread on agricultural land for its nutrient content, serious degradation of crops may result from plants absorbing any toxins like PFAS from the sewage-treated soil. In this context, it is important to ask what happens to PFAS during pyrolysis of municipal sewage. Unfortunately, our present state of knowledge does not allow a clear answer which could inform any decisions about the worth of such projects.

Current literature on the subject is sparse and contradictory. For instance Thoma et al (2022) reported that pyrolysis temperatures of 600 C left no detectable PFAS residue in sludge-derived biochars. 400 C was not sufficiently high in temperature to achieve this result. At face value this would imply that biochar produced by their 600 C process would be safe to spread on fields as far as PFAS contamination is concerned. However an important question (What happened to the PFAS?) was not satisfactorily answered. It was not found in the scrubber effluent nor the gaseous emissions. So it is not know whether it was fully degraded, or partially degraded into substances not analysed and emitted with the vapors. Thus the full impact of the process for determining the full environmental PFAS toxicity disposition is unknown. It is possible that one simply trades contaminating your crops with PFAS for contaminating your air by direct PFAS emissions or degraded but still toxic PFAS emissions.

Thoma et al (2022) contradicted the earlier study of Kundu et al (2020), which also studied sludge pyrolysis at 600 C. Their finding was that the removal of PFAS was very spotty and inconsistent. Some common PFAS were removed at 98% efficiency from the biochar, whereas other closely related PFAS were only removed at 1%. Kundu et al. also had difficulty in determining what happened to the PFAS they did lose. But they got a little farther than Thoma et al. in that they determined that the scrubber waters had substantially increased their content of fluorotelomers, partial degradation products of PFAS which themselves are suspected of being powerful toxins. So the Kundu version of the

process is a definite NO for PFAS emission in the production process and for the biochar product toxicity. The Thoma variant is an unproven MAYBE. These studies indicate that the present state of knowledge is not sufficient to make an informed determination of the full implications of PFAS treatment in the biochar-from-sludge production process. The precautionary principle says NO for now.

Thoma ED, Wright RS and 7 others (2022). Pyrolysis processing of PFAS-impacted biosolids, a pilot study. JOURNAL OF THE AIR & WASTE MANAGEMENT ASSOCIATION, VOL. 72, NO. 4, 309–318 https://doi.org/10.1080/10962247.2021.2009935

Kundu S, Patel S, and 10 others (2020). Removal of PFASs from biosolids using a semipilot scale pyrolysis reactor and the application of biosolids derived biochar for the removal of PFASs from contaminated water. ENVIRON. SCI.: WATER RES. TECHNOL., 7, 638–649 DOI: 10.1039/d0ew00763c

PS From Dave,

The kundu paper was not so much that PFAS was destroyed, but that their biochar product was a good sorbent for removing pfas from water by absorbing it like an activated charcoal filter would, so definitely NO for putting it on crop lands but use it instead as a PFAS filtrant because it will absorb more PFAS above what it still has.

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Removal of PFASs from biosolids using a semi-pilot scale pyrolysis reactor and the application of biosolids derived biochar for the removal of PFASs from contaminated water†

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This study focuses on the conversion of biosolids to biochar and its further use in adsorbing per- and polyfluoroalkyl substances (PFASs) from contaminated water. In particular, this study aims to (a) investigate the performance of a semi-pilot fluidised bed pyrolysis unit in converting biosolids into biochar, (b) examine the ability of the pyrolysis-combustion integrated process to destruct PFASs present in biosolids and (c) study the application of biosolids derived biochar for removing PFASs from contaminated water. The semi-pilot fluidised bed pyrolysis unit demonstrated stable temperature and oxygen profiles in the reactor. The yield of biochar was found to be 36–45% at studied temperatures (500–600 °C). The produced biosolids derived biochar samples, due to their lower H/C and O/C ratio, were found to be extremely stable with an expected long (millennia) residence time in soil. It was concluded that >90% removal of perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA) from biosolids derived biochar could be achieved in the pyrolysis-combustion integrated process. The biosolids derived biochar demonstrated >80% adsorption of long-chain PFASs and 19–27% adsorption of short-chain PFASs from PFAS contaminated water.

Water impact

The effectiveness of a fluidised bed pyrolysis for reducing biosolids volume and producing biochar material was demonstrated. Over 90% of PFOS and PFOA was safely removed from the resultant biochar during pyrolysis. The produced biochar was able to adsorb PFASs from contaminated water in the range of 20 to over 95%, depending on the individual PFAS considered.

1. Introduction

Stabilised sewage sludge, produced by wastewater treatment plants (WWTPs), is known as biosolids. This material is an unavoidable by-product that originates from households and many industries.[1] The rapid increase in population as well as urbanisation contributes to a continued increase in the production of biosolids.[2,3] Biosolids contain many macronutrients such as nitrogen, phosphorus, sulphur, potassium, calcium and magnesium as well as micronutrients such as zinc, copper, boron, molybdenum, manganese and iron.[4] Therefore, biosolids are attractive for agricultural applications, and the majority of this material is currently utilised for this purpose in many countries including Australia.[5,6] However, biosolids may contain harmful pathogens and current regulations (particularly in

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Victoria, Australia) require biosolids to be stockpiled onsite for 1–3 years to reduce pathogen levels to the highest possible treatment grade for soil amendment. Also, heavy metals, micro-plastics, pesticides, chemicals, herbicides and pharmaceutical ingredients are present in biosolids.[2,3,7] Recently, biosolids have been recognised as a potential source of PFAS contamination in soil and groundwater which may restrict their land application in the near future.[8,9]

PFASs are anthropogenic compounds and, historically, have been used in a wide range of applications including fire-fighting foams, non-stick cookware, stain- and water-repellent fabrics, polishes, waxes, paints and cleaning products.[10,11] To date, more than 3000 PFASs and their potential precursors have been identified[12] and their numbers increase with time as research progresses. Consequently, PFASs have become ubiquitous in terrestrial and aquatic environments. These chemicals are persistent, accumulative and leachable. PFOA and PFOS are the most-studied PFASs. 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 human bodies may include, but are not limited to, increased cholesterol,[13] hepatotoxicity and alterations in the immune system[14] as well as thyroid hormone disruption.[15] Besides, these chemicals may cause low infant birth weights,[16] and they are also suspected of causing cancer.[17]

PFASs have been detected in WWTP influent, effluent and biosolids globally.[18] Hydrophobic partitioning in WWTPs is expected to result in the retention of long-chain PFASs in the sludge/biosolids.[19] The major PFASs in biosolids, reported in a study on US biosolids, were PFOS (403 ± 127 ng g^{-1} dry weight) and PFOA (34 ± 22 ng g^{-1} dry weight).[19] The other PFAS values were lower and in the range of 2 and 26 ng g^{-1} dry weight. Similar results were obtained in Australian studies.[9,20] PFAS management guidelines have become available in several Australian states, for example, in Victoria (regulated by EPA Victoria).[8] These may potentially impact the wider land application of biosolids in the near future. Therefore, a reliable and cost-effective technological platform is warranted that minimises/eliminates the PFAS risks of biosolids for land application.

PFASs have strong chemical structures, are thermally very stable and require high reaction energy/high temperatures to break down their chemical bonds. The available literature suggests that immobilisation could be the most cost-effective method for remediation of PFASs in biosolids and biosolids amended soils.[21] However, keeping PFASs immobilised in a solid matrix for a long time still needs to be verified by further investigation. 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. Most of the studies in the literature have focused on investigating PFAS destruction through incineration.[22–26] Studies on the potential of pyrolysis and gasification technologies to destruct PFASs are very limited.

The pyrolysis process decomposes carbonaceous materials, such as biosolids, in the absence of oxygen.[2] Usually, a sweeping gas flow is provided in the pyrolysis process (except vacuum pyrolysis). In the case of fluidised bed pyrolysis, the flow-rate of the sweeping gas is high and it may be economically feasible to recycle the CO_2 containing hot pyrolysis/flue gas as the sweeping gas rather than using a high purity and expensive inert sweeping gas such as N_2. Biochar (solid), bio-oil (liquid) and bio-gas are the three products that are generated from the pyrolysis of biosolids. The yield distribution of these products depends on a number of parameters including the composition of biosolids, pyrolysis temperature, heating/energy transfer rate, and flow rate of the sweeping gas as well as the catalyst/additive if used. Bio-oil and bio-gas could be used as fuel[24,27] while biochar could be used as a soil amendment material,[24,27] as a catalyst in the production of carbon nanomaterials[28] or as an adsorbent for removing micropollutants.[29,30] If there is a priority between biochar and bio-oil, the heating/energy transfer rate is usually considered to be tweaked. When bio-oil is considered to be the primary product, a high heating rate is applied while a slow heating rate is applied when biochar is considered to be the primary product. Previous studies suggested that pyrolysis can successfully destroy impurities such as pathogens, micro-plastics, pesticides and pharmaceutical ingredients and the products from this process can be free from these nuisances.[31–34] If the destruction of PFASs from biosolids can be safely performed by a pyrolysis process, it can assist water industries in reducing biosolids volume and creating an indisputable application of biosolids derived biochar as a soil amendment material as well as its other applications in chemical processing.

Pyrolysis can be carried out in both fixed bed and fluidised bed reactors. The poor gas–solid contact in fixed bed reactors may compromise the quality of biochar. Biochar with uniform characteristics is beneficial and desired, particularly if the considered end use is being a catalyst or an adsorbent. Fluidised bed reactors ensure uniform heating even at high heating rates leading to the production of high quality biochar with uniform characteristics. This opens up the possibility of extending the application of biosolids derived biochar, produced from fluidised bed reactors, in the adsorption of PFASs from contaminated water.

Several reactor designs have been evaluated in a large scale for the pyrolysis of biosolids. For instance, a microwave heating system was applied aiming to produce bio-oil as a primary product from the transformation of sewage sludge using several additives such as KOH, H_2SO_4, H_3BO_3, $ZnCl_2$ and $FeSO_4$.[35] The technological feasibility was found to be dependent on the optimisation of process parameters and selection of appropriate additives. In a different study, sewage sludge was blended with other feedstock such as manure and studied in a fixed bed pilot-scale reactor with positive findings.[36] A few other pilot-scale studies were carried out using a fixed bed reactor in non-catalytic, autocatalytic or catalytic mode. However, the application of

fluidised bed pyrolysis reactors is found to be rare for pyrolysis of biosolids. In addition, pyrolysis is an endothermic process and the optimisation of energy is vital for the commercial viability of any technology. Therefore, a fluidised bed pilot scale reactor integrated with a combustion chamber, which aims to run pyrolysis in autothermal mode (*i.e.* no need for external energy), is in demand in the search for sustainable uses of biosolids.

Typically, pyrolysis of carbonaceous materials is carried out between 300 to 1000 °C.[37] Lower pyrolysis temperature generates biochar with a lower surface area and high oxygen containing functional groups. As the pyrolysis temperature increases, the surface area of biochar increases at the expense of functional groups. Therefore, low temperature pyrolysis is generally preferred for producing biochar for soil application while high temperature is desired when biochar with a high surface area needs to be produced. Choosing a pyrolysis temperature is challenging and a few aspects could be taken into consideration. (a) This work aims to produce biochar to be used as an adsorbent; therefore, a high surface area and an improved morphology is critical. Our previous work suggests that the pyrolysis temperature has a tremendous impact on the morphology of biochar and a pyrolysis temperature between 500 and 700 °C can generate biochar with a high porosity and surface area from biosolids.[28] (b) The second aspect may be the destruction of pollutants, particularly PFASs which are inherently present in biosolids. The devolatilisation and destruction of PFASs at high temperature during combustion have been established.[38,39] However, biosolids contain a reasonable concentration of metals and minerals that are expected to function as catalysts for the destruction of PFASs at relatively low temperature in an integrated pyrolysis–combustion process which has not been studied in the literature. (c) The third aspect may be the formation of polycyclic hydrocarbons (PAHs). Below 500 °C pyrolysis temperature, PAHs are formed *via* carbonisation and aromatisation.[40,41] Above 500 °C, a free radical pathway, followed by pyrosynthesis, dominates the formation of PAHs.[40–42] When investigating PAH formation in the pyrolysis temperature range of 100–700 °C, researchers found that the formation of PAHs is the highest in the temperature range of 400–500 °C.[43,44] Applying a pyrolysis temperature ≥500 °C is often suggested to minimise extractable PAHs in biochar.[43,45] Accounting for all these aspects, a moderate temperature range of 500–600 °C could be considered which is a trade-off between minimising PAHs and obtaining high quality biochar while assisting in the investigation of destruction of PFASs in biosolids at relatively low temperature.

PFAS contamination in ground water and industrial wastewater is a serious problem and their concentrations often reach above those set by the regulatory guidelines.[46] So far, granular activated carbon (GAC) from various sources (*e.g.*, coconut shell and coal) has been extensively studied for the adsorption of PFASs.[46–50] Biomass derived biochar has also been used in PFAS adsorption studies.[51,52] However, biosolids derived biochar has been rarely used in adsorption studies of PFASs.

The aim of the current study is to (a) investigate the performance of a semi-pilot fluidised bed pyrolysis unit in converting biosolids into biochar, (b) examine the ability of the pyrolysis–combustion integrated process to destruct PFASs present in biosolids and (c) study the application of biosolids derived biochar for removing PFASs from contaminated water.

2. Methodology

2.1. Pyrolysis of biosolids

2.1.1. Biosolids sample. The biosolids sample employed in this study was sourced from the Mount Martha Water Recycling Plant (38°16′06″S and 145°03′31″E) of South East Water Corporation, Victoria, Australia. This plant predominantly receives domestic and trade sewage, and treats sewage sludge through an activated sludge process followed by anaerobic digestion. After digestion, the solids are processed through a dewatering plant (*i.e.*, centrifuge) and solar drying facility before they are sent to stockpiling. Thus, the samples used in this study were processed through a solar dryer shed.

The biosolids sample was initially ground using a pin mill (Chenwei Machinery CW-20B) and then segregated using a vibrating screen (Sanfeng Machinery, SF-600) at FA Maker Pty. Ltd., Victoria, Australia. The pin mill and vibrating screen employed in this study are shown in Fig. S1.† The biosolids, used in the trials, were 0.5–2 mm in particle size. The detailed proximate and ultimate analyses of biosolids are presented in Table 1.

2.1.2. Description of the semi-pilot unit employed for the pyrolysis of biosolids. The process block diagram is shown in Fig. 1 (actual image of the semi-pilot pyrolysis plant can be found in ESI† Fig. S2). Each pyrolysis trial was conducted for 5 hours. Trials were performed in triplicate (n = 3 for each trial) to ensure consistency of the data and the average values are presented in this manuscript. The run mode of this system is considered as semi-continuous since the biosolids

Table 1 Proximate and ultimate analyses of biosolids

Proximate and ultimate analyses of biosolids								
Proximate analysis[a] (%)				Ultimate analysis[a] (%)				
Moisture	Volatiles	Ash	Fixed carbon	C	H	N	S	O[b]
11.0	60.6	29.0	10.4	38.3	4.7	6.02	0.96	21.02

[a] Values on a dry weight basis. [b] Value determined by difference.

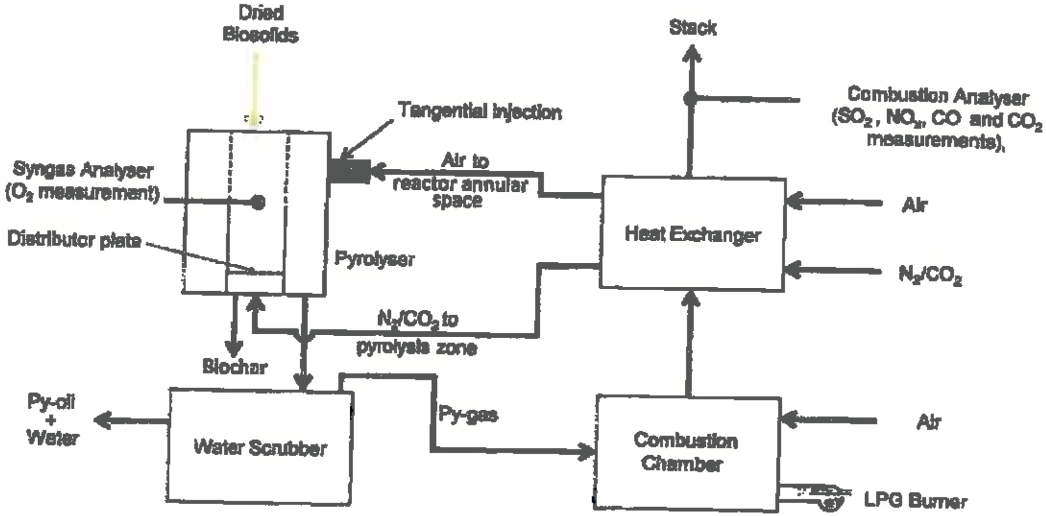

Fig. 1 Process block diagram for the semi-pilot plant setup.

were fed continuously throughout the trial period while char was collected only after the 5-hour period at the end of each trial.

During start-up, the semi-pilot plant was heated *via* a liquefied petroleum gas (LPG) burner. The hot flue gas leaving the LPG burner was used to pre-heat the gases (*i.e.* air and N_2/CO_2) entering the semi-pilot plant *via* a heat exchanger. The pre-heated air and N_2/CO_2 gases were then circulated in the reactor to heat the reactor to a desired temperature. The hopper was filled with the biosolids sample at the beginning of each trial (Fig. S2†). The hopper was charged with N_2 *via* a N_2 purging line. Once the desired temperature of the reactor was attained, biosolids were continuously charged at 0.25 kg h^{-1} from the hopper to the reactor *via* a pre-calibrated screw-feeder with continuous N_2 purging. The screw-feeder was calibrated for each trial.

The reactor, employed in this study, was constructed from stainless steel 253MA and insulated with ceramic fibre insulation to minimise heat losses. It was of concentric geometry, where the inner tube functioned as the pyrolyser. The bottom half of the inner tube was made of pipe, while the top half of the inner tube consisted of a wedge-wire screen. Biosolids were pyrolysed under bubbling fluidised conditions using a pre-heated N_2/CO_2 mixed stream containing 85% N_2 and 15% CO_2, v/v. The reason for using a N_2/CO_2 mixed stream (85% N_2, 15% CO_2, v/v) in the pyrolyser was to mimic the scenario of pyrolysis in the presence of recycled flue gas. The produced gas and oil vapours from the inner pyrolyser tube were then transferred to the annular space *via* the wedge-wire screen from the top half of the reactor while the biochar produced remained at the bottom of the inner pyrolyser tube. At the end of each trial, biochar was kept further in that inner tube with an inert environment for cooling and then collected further for analysis. The annular space acted as a partial combustor for py-gas and py-oil vapours. The temperature in the annular space was controlled by adjusting the air inlet rate. The temperature at the annular space was purposefully kept lower or equal to the pyrolysis temperature to find out whether or not PFASs are destroyed at lower temperatures in thermal systems.

By employing pre-heated air tangentially at a >10 m s^{-1} velocity in the annular space, the py-gas and py-oil vapours were partially combusted and PFASs, if they survived in the pyrolyser, were destructed in this annular space. The remaining py-gas and py-oil vapours were rapidly transported from the annular space to a water scrubber, where they were immediately quenched. The reason for using tangential entry and high-velocity air was to ensure that the pyrolysis reaction environment is not affected and the py-gas and py-oil vapours are immediately quenched without any secondary reactions. The py-oil was condensed in the scrubber water, while non-condensable py-gas was sent to the combustion chamber of the LPG burner to ensure that it was combusted before releasing to the environment. The energy required for pyrolysis was provided by the hot air and N_2/CO_2 gases, which were pre-heated using the combustion of LPG and py-gas (once produced). At the end of each trial, the sample from the water scrubber was collected for oil and PFAS analysis. Any PFAS species carried by the gas stream, if they survive in the pyrolysis–combustion system, should be trapped in the water scrubber. The reason is that the boiling points of PFASs, even for short chain PFASs (*e.g.*, the boiling point of pentafluorobenzoic acid (PFBA) is 220 °C), are higher than the water boiling point.

An online gas monitor (combustion analyser, MRU Optima 7) was employed to measure the concentrations of various gaseous species (CO, CO_2, NO_x and SO_2) in the stack. The reactor was equipped with four thermocouples and they measured the following temperatures: 1) pyrolyser temperature, 2) annular space temperature, 3) reactor inlet N_2/CO_2 stream temperature and 4) reactor inlet N_2 temperature. The pyrolysis trials were carried out at three different temperatures: 500, 550

and 600 °C. The average temperature at the pyrolyser thermocouple was considered as the pyrolysis temperature. The concentration of O_2 in the pyrolyser was continuously monitored by an online gas monitor (syngas analyser, Madur Aqua GA40T Plus). Biochar produced from biosolids in the semi-pilot trials at 500, 550 and 600 °C are labelled as BSBC-500, BSBC-550 and BSBC-600, respectively.

Biochar produced during the trial was characterised by surface imaging using a scanning electron microscope (SEM) of the Philips XL30 model and a Brunauer–Emmett–Teller (BET) analyser (Micromeritics 2000/2400). The particle size distributions of both biosolids and biochar were determined using a Malvern particle size analyser (Mastersizer 3000). Analyses related to PFAS, py-oil and heavy metals were performed externally (by ALS Limited, Australia). ALS laboratories are NATA (National Association of Testing Authorities, Australia) accredited laboratories. They have applied their WP045B, WP075A and WP0125A methods for py-oil analysis, EP231 method for PFAS analysis and WG020B for heavy metal analysis.

2.2. PFAS adsorption

2.2.1. Biochar preparation for PFAS adsorption. Biomass biochar was produced at 600 °C pyrolysis temperature to make a comparison with biosolids biochar produced at the same temperature (BSBC-600) mainly for exploring its potential to adsorb PFASs from PFAS contaminated water. The biomass biochar produced at 600 °C in this study is referred to as BMBC-600. Sawdust (predominantly Australian pine wood, sourced from a mechanical workshop at RMIT University) of the same initial particle size as the biosolids (*i.e.*, 0.5–2 mm) was used in the production of biomass biochar. Instead of a semi-pilot plant, a muffle furnace (Barnstead Thermolyne 30400) was employed for the production of biomass biochar, where the furnace was operated at 600 °C for 1 hour. The furnace was then kept closed until it was cooled down naturally to room temperature. Afterwards, the biochar sample was taken out and stored in a desiccator. Both BMBC-600 and BSBC-600 were sieved to obtain a particle size of 0.3–0.5 mm and further employed in the PFAS adsorption study. The BET surface areas of these samples were measured and found to be 79.87 $m^2\ g^{-1}$ and 55.29 $m^2\ g^{-1}$ for BMBC-600 and BSBC-600, respectively.

2.2.2. Procedure for PFAS adsorption. Two PFAS contaminated water samples (sources can't be revealed) were used in this study. The PFAS content in sample 1 was significantly higher than that in sample 2 (Table 2). In addition, several PFAS species in sample 2 were below the detection limit of the analytical instrument, and therefore, they were excluded from the adsorption study. The pH values of sample 1 and sample 2 were 4.3 and 7.85, respectively. In this study, we have not adjusted the pH level for the adsorption tests.

Initially, PFAS contaminated water samples were filtered through 6-micron polyethersulfone (PES) membrane filter paper to remove any suspended solids. Two adsorbents were employed to remove PFASs from these samples as detailed earlier: 1) biosolids biochar (BSBC-600) and 2) biomass biochar (BMBC-600). For each study, one gram of adsorbent was taken in a conical flask, and 50 mL of PFAS contaminated water was introduced into the conical flask. For each set of adsorption study, there was a repeat test. The tops of the conical flasks were wrapped with aluminium foil, and they were placed in an orbital shaker (Thermoline TS-400) set at 180 rpm. The samples were shaken for 48 hours. After the completion of trials, solid adsorbents were separated using 0.45-micron polyethersulfone (PES) membrane filter paper. The filtrates as well as raw samples were then sent to ALS Limited, Australia for analysis. The adsorption of PFASs by various adsorbent materials was determined using the ALS generated data.

3. Results and discussion

3.1. Process stability

Process stability with respect to important process parameters such as temperature and O_2 concentration is vital in obtaining products of desired quality as well as maintaining the energy balance of the semi-pilot pyrolysis unit. The integration and operation of pyrolysis–combustion has been demonstrated in fixed bed and Auger type reactor designs in the literature.[53] However, an integrated fluidised bed pyrolysis–combustion process has not been demonstrated yet in the literature. The present work demonstrated a stable

Table 2 Concentrations of various PFASs in contaminated water

Species	Chemical formula	Concentration ($\mu g\ L^{-1}$)	
		Sample 1	Sample 2
Perfluorooctanesulfonic acid (PPOS)	$F(CF_2)_8SO_3H$	480	0.08
Perfluorooctanoic acid (PFOA)	$F(CF_2)_7COOH$	24	0.36
Perfluorohexanesulfonic acid (PFHxS)	$F(CF_2)_6SO_3H$	210	0.61
Perfluorobutanesulfonic acid (PFBS)	$F(CF_2)_4SO_3H$	80	0.05
Perfluoropentanesulfonic acid (PFPeS)	$F(CF_2)_5SO_3H$	56	—
Perfluoroheptanesulfonic acid (PFHpS)	$F(CF_2)_7SO_3H$	20	—
Perfluorododecanoic acid (PFDoA)	$F(CF_2)_{11}COOH$	0.22	—
Perfluorotridecanoic acid (PFTrDA)	$F(CF_2)_{12}COOH$	0.07	—
Perfluorotetradecanoic acid (PFTeDA)	$F(CF_2)_{13}COOH$	0.07	—

integrated fluidised bed pyrolysis–combustion system that can achieve highly stable temperature and oxygen concentration profiles. The advantage of such an integrated process is the compact design which can help reduce the capital and operating costs as well as improve the product quality.

Fig. 2 shows an illustrative presentation of the temperature profiles of various thermocouples as well as the O_2 concentration profile during a trial performed at 600 °C. Temperature fluctuation was found to be minimal. In addition, the O_2 concentration was far below 1% during the entire trial and, consequently, the process atmosphere was nearly inert. This demonstrates that this technology offers a stable process for biochar production.

The monitoring of major components of flue gas during the trial is shown in Fig. 3. The concentration of CO_2 ranged between 13 and 15%. This range of CO_2 values provides a justification for choosing a mixture of 85% N_2 and 15% CO_2 as the fluidising gas. The concept applied here is that the flue gas may be recycled and utilised as the fluidising gas.

The gas analysis was performed at the stack. The level of SO_2 was observed to be very low (4–10 ppm) in all of our trials. NO_x was also low and in the range of 120 to 125 ppm while CO was between 40 and 50 ppm (Fig. 3). The concentrations of hydrocarbons were also measured; however, the values were not detectable and therefore, not reported here. These values were found to be well below the emission limits recommended by the Industrial Emissions Directive (IED) 2010/75/EU.

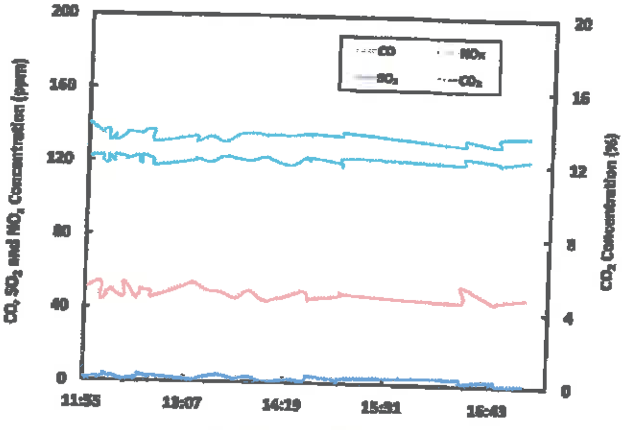

Fig. 3 Analysis of flue gas using an online IR analyser for the 600 °C trial.

3.2. Product distribution of py-oil

The analysis of the scrubber water sample (*i.e.*, product distribution of py-oil) is shown in Fig. 4. The Py-oil components were divided into six major groups, which include polyaromatic hydrocarbons (PAHs), monoaromatic hydrocarbons (MAHs), alcohols, phenols, and C10–C14 and C15–C28 liquid hydrocarbons. This grouping was done following previous studies.[54,55] It was found that the production of PAHs and MAHs were minimal in the py-oil sample. The major components of py-oil were hydrocarbons followed by alcohols and phenols. This product distribution is favourable if py-oil is considered for combustion to provide energy to the pyrolysis system.

While the py-oil product distribution is favourable in the context of combustibility, it will still require pre-treatment before it can be used as a fuel in traditional power generators.[24] A better approach could be combusting py-oil to provide energy to the pyrolysis process. In the current semi-pilot plant, a lower combustion temperature was applied with the intention to investigate PFAS destruction. In the real world, a higher combustion temperature could be applied which would combust py-oil and py-gas and provide the required energy to the system.

3.3. Yield and stability of biochar

The biochar yield against pyrolysis temperature is shown in Fig. 5. In this study, py-gas and py-oil were partially

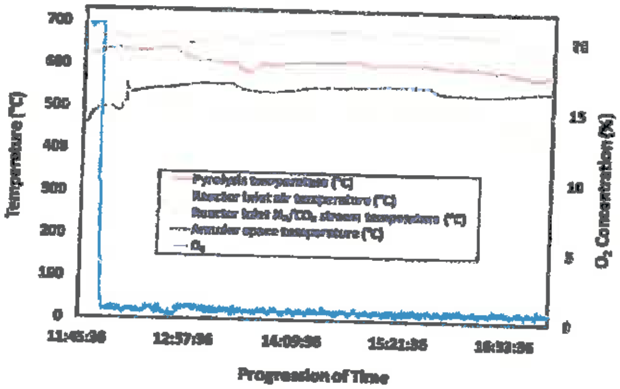

Fig. 2 Temperature profiles and oxygen concentration (in the pyrolysis zone) for the 600 °C trial.

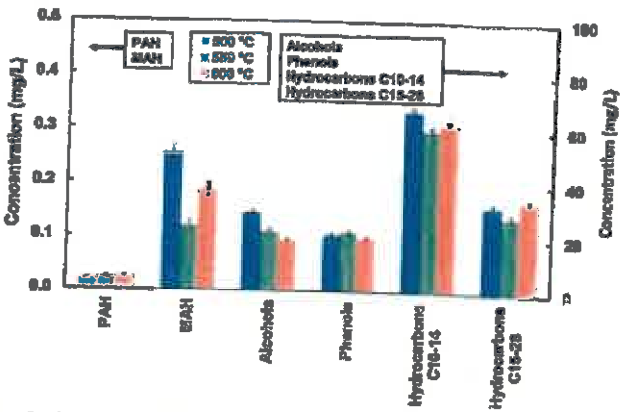

Fig. 4 Analysis of the scrubber water sample (product distribution of py-oil).

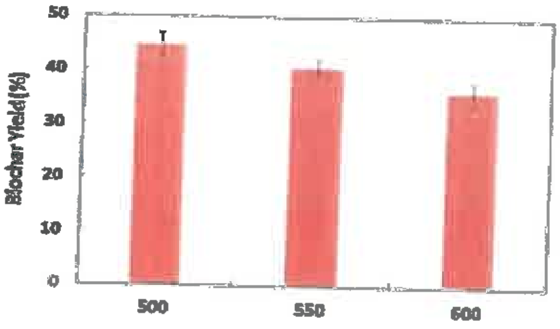

Fig. 5 Biochar yield against pyrolysis temperature.

combusted. The uncombusted py-oil was captured in the water scrubber while uncombusted py-gas was detected in the flue gas. As the combusted portion was not measured, the determination of yields of py-gas and py-oil was not possible. Therefore, biochar yield data are only obtained and presented. Pyrolysis of biosolids results in the decomposition of carbohydrates, proteins, lipids, polyphenols and other macromolecular humic substances as well as microorganisms.[56,57] The level of decomposition of these species increases with pyrolysis temperature, leading to lower biochar yield.

The effects of pyrolysis temperature on biochar formation is further reflected by the proximate and ultimate analyses of the biochar samples (Table 3). As expected, with the increase of temperature, the volatile matter and fixed carbon decreased while the ash content increased. According to the ultimate analysis, C, H and N decreased with the increase of temperature. However, the variation of S was found to be minimal in the investigated temperature regime. This suggests that the sulphur containing species do not degrade significantly within the temperature regime investigated. The proximate and ultimate analyses of biosolids and biochar were also used to construct a Van Krevelen diagram (Fig. S3†). This diagram is an illustration of the maturity/stability of biochar materials.[58] Both H/C and O/C ratios decreased significantly from biosolids to biochar as confirmed in Fig. S3.†

The detailed transition of H/C and O/C values from biosolids to biochar is shown in Table 4. It was found that both ratios decreased with the increase of pyrolysis temperature. A similar result was reported by Fryda and Visser.[58] This was possible because demethylation (loss of CH_3) and decarboxylation (loss of CO_2) reactions are enhanced with the increase of pyrolysis temperature. The increase of demethylation reactions decreases the H/C ratio while the increase in decarboxylation reactions reduces the O/C ratio.[59]

Table 4 H/C and O/C mole ratios of biosolids and biochar

	Biosolids	BSBC-500	BSBC-550	BSBC-600
H/C mole ratio	1.4726	0.6800	0.6761	0.6087
O/C mole ratio	0.4116	0.0125	0.0111	0.0095

BSBC-500: biochar produced at 500 °C, BSBC-550: biochar produced at 550 °C, BSBC-600: biochar produced at 600 °C.

The highest H/C mole ratio was found to be 0.68 for the biochar produced at 500 °C and this value was lower than that from the International Biochar Initiative guidelines (the suggested maximum H/C mole ratio by the guidelines is 0.7).[60] The highest O/C mole ratio was 0.0125 for the biochar produced at 500 °C. This O/C ratio value is in the lower range when compared to that of other biochar samples, and this seems indicative of a very long half-life (more than 1000 years) when added to soil.[61] Therefore, it is worth noting that the produced biochar samples are very stable carbon materials and suitable for soil carbon sequestration.

3.4. Biochar morphology and surface area

The morphological analyses of biochar produced at 500, 550 and 600 °C were performed using a scanning electron microscope (SEM) (Fig. 5). It can be seen that a porous structure was evident at all temperatures and the porosity was found to increase slightly with the increase in temperature from 500 to 600 °C. The BET surface area of the biochar samples was measured and the values obtained are in the range of 26 to 55 $m^2\ g^{-1}$ (mean values were 26.45, 44.06 and 55.29 $m^2\ g^{-1}$ for the 500, 550 and 600 °C trials, respectively). These values are well aligned with the SEM findings.

The particle size distributions of biosolids and biochar particles are shown in Fig. 7. It was found that the particle size decreases from biosolids to biochar. The median value (for a volume distribution value), D_v (50), decreased from 829 to 587 μm. D_v (50) represents the median value for a volume distribution. As shown in Fig. 6, the biochar yield was in the range of 36–45%, depending on temperature. This huge

Table 3 Proximate and ultimate analyses of biochar

Sample	Proximate analysis[a] (%)				Ultimate analysis[a] (%)				
	Moisture	Volatiles	Ash	Fixed carbon	C	H	N	S	O[b]
BSBC-500	1.7	13.2	64.88	19.1	29.27	1.66	3.25	0.46	0.49
BSBC-550	1.3	12.1	66.77	21.4	28.01	1.58	2.78	0.44	0.41
BSBC-600	2.0	10.9	68.03	10.9	27.21	1.38	2.60	0.43	0.35

[a] Values on a dry weight basis. [b] Value determined by difference; BC-500 represents biochar produced at the pyrolysis temperature of 500 °C and similar definitions apply for BC-550 and BC-600.

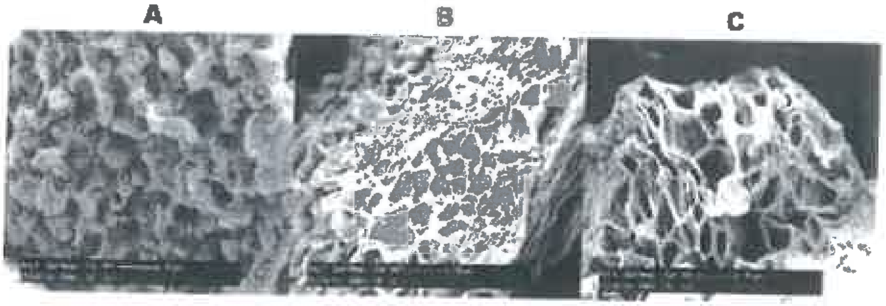

Fig. 6 SEM images of the biochar samples: (A) BSBC-500, (B) BSBC-550 and (C) BSBC-600.

percentage reduction of mass leads to a decrease in solid particle size as confirmed by the particle size distribution results. The bulk densities of solid particles were also reduced. The bulk density of 0.5–2 mm biosolids was found to be 660 kg m^{-3}, while the biochar obtained from the pyrolysis of these biosolids at 500 °C exhibited a bulk density of 620 kg m^{-3}.

3.5. Heavy metal composition

The concentrations of various heavy metals in the biosolids employed and biochar samples produced from the trials are presented in Table 5. Also, the allowable concentrations of heavy metals for land application suggested by EPA Victoria (for biosolids)[62] and the International Biochar Initiative[60] are also provided for comparison. Contamination grade 1 (C1) biosolids, as per the EPA Victoria guidelines, correspond to the highest quality biosolids consisting of the lowest level of heavy metal contamination, and therefore, they are allowed to be used in land application without any specific control measures. In contrast, contamination grade 2 (C2) biosolids are allowed with controlled application.

The mass and volume reduction from biosolids to biochar during the pyrolysis process increased the concentrations of heavy metals. The only exception observed was Hg. This is because of the lower boiling point of Hg, leading to vapourisation of this element at the studied pyrolysis temperatures. While the heavy metal concentrations increased in biosolids biochar, the values were still below the threshold values of the C2 grade suggested by the EPA Victoria and International Biochar Initiative guidelines.

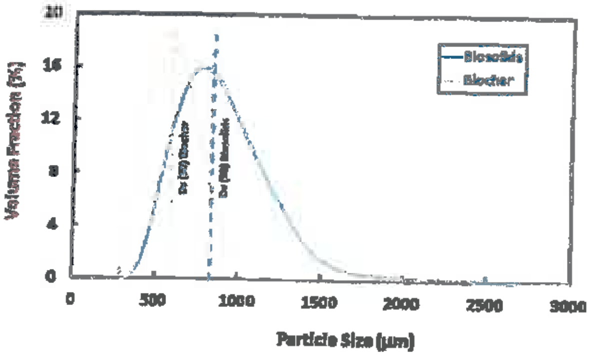

Fig. 7 Particle size distributions of biosolids and biochar.

3.6. Destruction of biosolids PFASs

Fig. 8 highlights the PFAS analysis data for biosolids, biochar and scrubber water. While the concentrations of a majority of PFAS species in the biosolids were found to have definite values, all PFAS species were extremely low (less than detectable values) in both biochar and scrubber water. This confirmed that PFASs were vapourised from biosolids at pyrolysis temperature leading to the production of nearly PFAS free biochar. Similar findings were published by Bioforcetech.[63,64] The extremely low concentrations of PFAS species in both biochar and scrubber water suggest that several PFAS species might have been partially or completely destroyed in the integrated pyrolysis–combustion environment maintained in the pyrolysis reactor and its adjacent annular space. Temperature, gas residence time, oxygen, water vapour and the gas phase chemistry of alkali and alkaline earth minerals (*i.e.* K, Na, Ca, and Mg) might have played critical roles in PFAS destruction followed by mineralisation. The roles of temperature and residence time are well-known as higher temperature and residence times can improve the destruction kinetics.[65] The literature has demonstrated that oxygen and water vapour can play critical roles in the destruction of fluorinated hydrocarbons.[66,67] In a similar way, oxygen and water vapour (generated from combustion of pyrolysis gas vapours) can play important roles in PFAS destruction. The release of alkali and alkaline earth minerals into the vapour phase and their gas phase chemistry with PFASs and destructed fluorine can also enhance PFAS destruction and mineralisation efficiency.[66,68] There is also a possibility that PFASs might have converted into some unknown organofluorine compounds which might not be in the analytical range.[26,69] Such compounds could be gaseous organofluorocarbons such as CF_4 and C_2F_6. Unfortunately, the nature of the semi-pilot scale trials presented in this work did not allow the authors to investigate the role of each of these parameters in detail.

Mass balance for PFASs could not be developed for the semi-pilot trials as several PFAS concentration values in the

Table 5 Total metal concentrations (mg kg^{-1}) of the biosolids and corresponding biochar samples

Metals	BS	BSBC-500	BSBC-550	BSBC-600	C1 grade[a]	C2 grade[a]	Biochar guidelines[b]
As	<5	5	5	<5	20	60	13–100
Cd	1.4	1.9	1.6	1.6	1	10	1.4–39
Cr	24	44	50	78	400	3000	93–1200
Cu	660	1100	1200	1100	100	2000	143–6000
Pb	19	40	42	39	300	500	121–300
Hg	0.79	<0.05	<0.05	<0.05	1	5	1–17
Ni	18	37	68	180	60	270	47–420
Se	6	6	6	5	3	50	2–200
Zn	870	1600	1700	1700	200	2500	416–7400

BS: biosolids. [a] EPA Victoria Biosolids guidelines.[62] [b] International Biochar Initiative guidelines.[60]

liquid and biochar samples were not specific. However, attempts were made to gain some understanding on PFAS removal efficiency (Table S2†). In this estimation, the concentration values, shown with the '<' sign in Table S1† (also presented in Fig. 8 with a marker), were considered as the final concentration values for PFASs. For instance, the concentration of PFOS in biochar was <0.0002 mg kg^{-1} (Table S1†). In the estimation, the concentration of PFOS was considered as 0.0002 mg kg^{-1}. This estimation provides the removal values of PFBS, PFOS, PFPeA, PFHxA, PFHpA and PFOA as follows: 74, 98, 75, 84, 54 and 96%, respectively. While this is a very rough estimation, this still tells that several PFASs were removed in the pyrolysis process. The removal of other PFAS compounds was either low or they were forming during the process.

To confirm this as well as to explore the mechanism of PFAS destruction, more scientific experiments would be required in the future. As described previously, closing the mass balance for all PFASs was extremely difficult due to the low values of PFASs in the initial biosolids samples. A practical method for the way forward could be performing systematic spiking experiments (*i.e.* spike different PFASs into biosolids) in a lab-environment in a more controlled manner as spiking at a semi-pilot or pilot scale can be very challenging. Lab-scale spiking experiments in a controlled environment may help not only in closing the mass balance but also in exploring the reaction mechanism of PFAS destruction in biosolids pyrolysis, where the feed material is highly heterogeneous, including organic and inorganic materials.

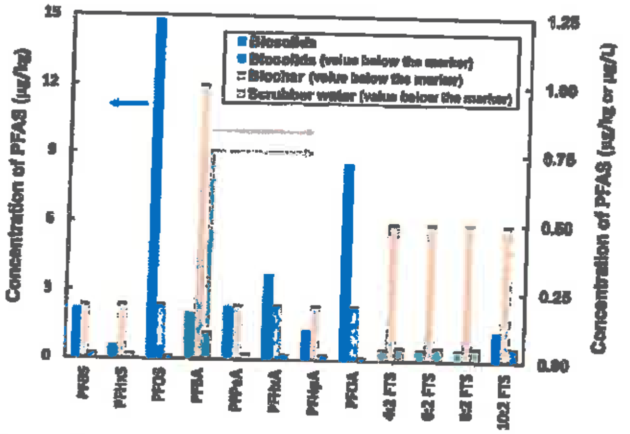

Fig. 8 PFAS concentration data for biosolids (µg kg^{-1}), biochar (µg kg^{-1}) and scrubber water (µg L^{-1}). Columns with markers represent values less than the marker values (see detailed data in Table S1†).

From this study, the authors would like to highlight that PFASs in biosolids, when compared with pure PFASs, might not require higher temperatures (*i.e.* ~1000 °C for pure PFASs[70]) for their destruction due to the different gas-phase chemistry and potential catalytic effects of minerals/heavy metals present in the biosolids. More scientific work will be required to investigate this fundamentally. Specifically, spiking experiments with particular PFAS compounds at the lab scale in a controlled environment are desirable to evaluate the destruction and mineralisation efficiency and mechanism.

3.7. PFAS adsorption

The adsorption efficiency (% adsorption) of char materials for PFASs of contaminated water samples (*i.e.*, sample 1 and sample 2) is shown in Fig. 9. For this study, BSBC-600 and BMBC-600 were used. It is well known that pH has a great impact on the adsorption of PFASs.[22,71] This has also been reflected in the present study. For example, there was a higher PFOS adsorption efficiency for sample 1 compared to that for sample 2. This was due to the lower pH of sample 1 than that of sample 2 (4.3 *vs.* 7.85), and this is consistent with the literature.[71] At low pH of the contaminated water sample, electrostatic attraction between the positively charged adsorbent surface and the negatively charged PFOS molecules is strong,[72] and this assists in enhanced adsorption of PFOS molecules.

The length of PFAS chains has significant impacts on PFAS adsorption. Short-chain PFASs are difficult to adsorb by many adsorbents, including commercially available granular activated carbon (GAC). For example, perfluorobutanesulfonic acid (PFBS) is a C4 PFAS. The adsorption efficiency of these species by both BSBC and BMBC is low with a range of 19–27% (Fig. 9a). However, the adsorption efficiency of PFBS was

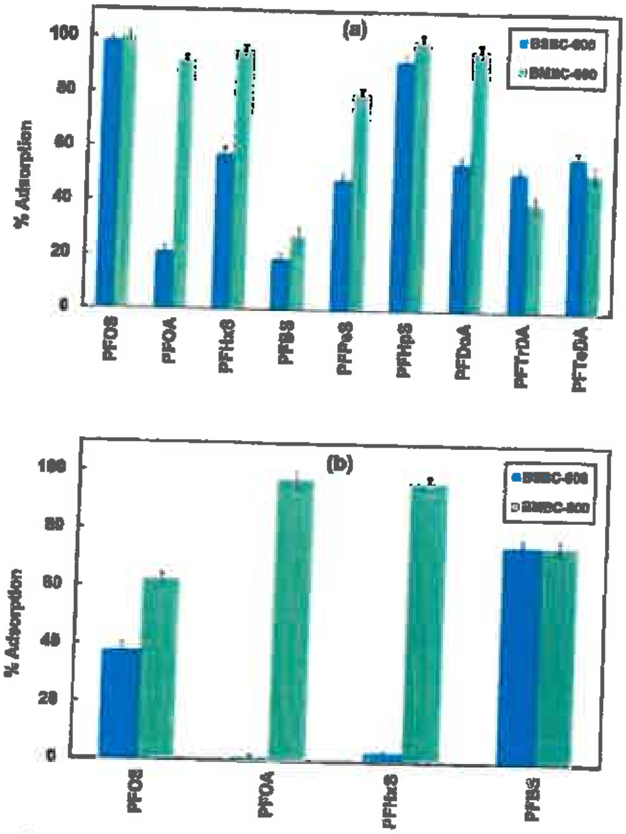

Fig. 9 PFAS adsorption efficiency by various char samples: (a) contaminated water sample with high concentration (*i.e.*, sample 1) and (b) contaminated water sample with low concentration (*i.e.*, sample 2). Note that BSBC represents biosolids biochar, and BMBC represents biomass biochar.

found to increase for the low concentration sample with both adsorbents (Fig. 9b). Using the BSBC adsorbent, the effect of concentration on the adsorptions of PFOS, PFOA and PFHxS was found to be the opposite of that for PFBS. With the decrease of concentration, the adsorption of the three PFASs decreased when BSBC was applied. The impact of concentration on PFAS adsorption with BMBC was found to be relatively low. This is most likely due to the higher surface area of BMBC (BET surface area, BMBC-600: 79.87 $m^2\ g^{-1}$; BSBC-600: 55.29 $m^2\ g^{-1}$). This finding is aligned with a previous study conducted by Bentley *et al.* who investigated micropollutant adsorption using biosolids biochar and pine biochar.[73]

The terminal functional groups may have an impact on PFAS adsorption. Regardless of concentration, BSBC underperformed in PFOA adsorption when compared to BMBC. It appears that PFASs with carboxylic acids as functional groups have lower adsorption affinity to BSBC. However, the difference of adsorption affinity between BSBC and BMBC becomes very low for PFASs with sulphonic acids as a terminal functional group.

The hydrophobic interactions between PFASs and the adsorbent can assist in PFAS removal from contaminated water as a hydrophilic functional group with a hydrophobic tail is present in PFASs.[74,75] Briefly, the hydrophobic surface of adsorbents enhances PFAS adsorption.[76,77] The metal content was higher in BSBC compared to BMBC. Therefore, it may be possible that the metals in BSBC reduce surface hydrophobicity and decrease the adsorption of PFASs.[78] This may be the reason for the higher PFAS adsorption on BMBC compared to that on BSBC. While BSBC did not perform as effectively as BMBC for adsorption of some PFASs, its production is expected to be comparatively less expensive. Therefore, a higher amount of BSBC can be applied solely or in combination with BMBC and high performing PFAS adsorbents such as GAC and resins. Also, selective application of BSBC for the adsorption of some PFASs such as PFOS and PFBS can also be considered.

4. Conclusions

A semi-pilot pyrolysis unit was employed for the transformation of biosolids into biochar. The semi-pilot unit achieved highly stable thermal and oxygen profiles in the pyrolysis zone. It was observed that with the increase of pyrolysis temperature, the biochar yield and fixed carbon in biochar decreased. It could be noted that the development of pores increased with the pyrolysis temperature. The produced biochar samples were stable and are expected to present a long half-life if used as soil additives. The heavy metal concentration in biochar increased, but it was within the EPA Victoria C2 biosolids grading and the guidelines provided by the International Biochar Initiative. The trials also demonstrated that integrated low-temperature pyrolysis–combustion might be an effective method for removing PFASs from biosolids by converting them into biochar. More scientific experiments in a controlled lab-environment are needed to confirm this.

Biosolids biochar was found to be an excellent adsorbent for removing PFASs from contaminated water. The benchmarking with biomass biochar suggested that the biomass biochar performed better in adsorbing PFASs when compared to the biosolids biochar. Despite this, the lower production cost of biosolids biochar might still make it attractive to be used at a commercial scale.

Conflicts of interest

There are no conflicts of interest to declare.

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each run, paired couples, as well as the settings could be compared (see Fig. 4). Due to the varying sample volumes, the LOQ differed for each ru For S1, paired couple 1 is shown. During the paired run, only minor changes in the concentration of PFOA could be observed compared to tl control run. Additionally, the concentrations of PFDA and PFDoA were slightly above LOQ. No other substance could be found.

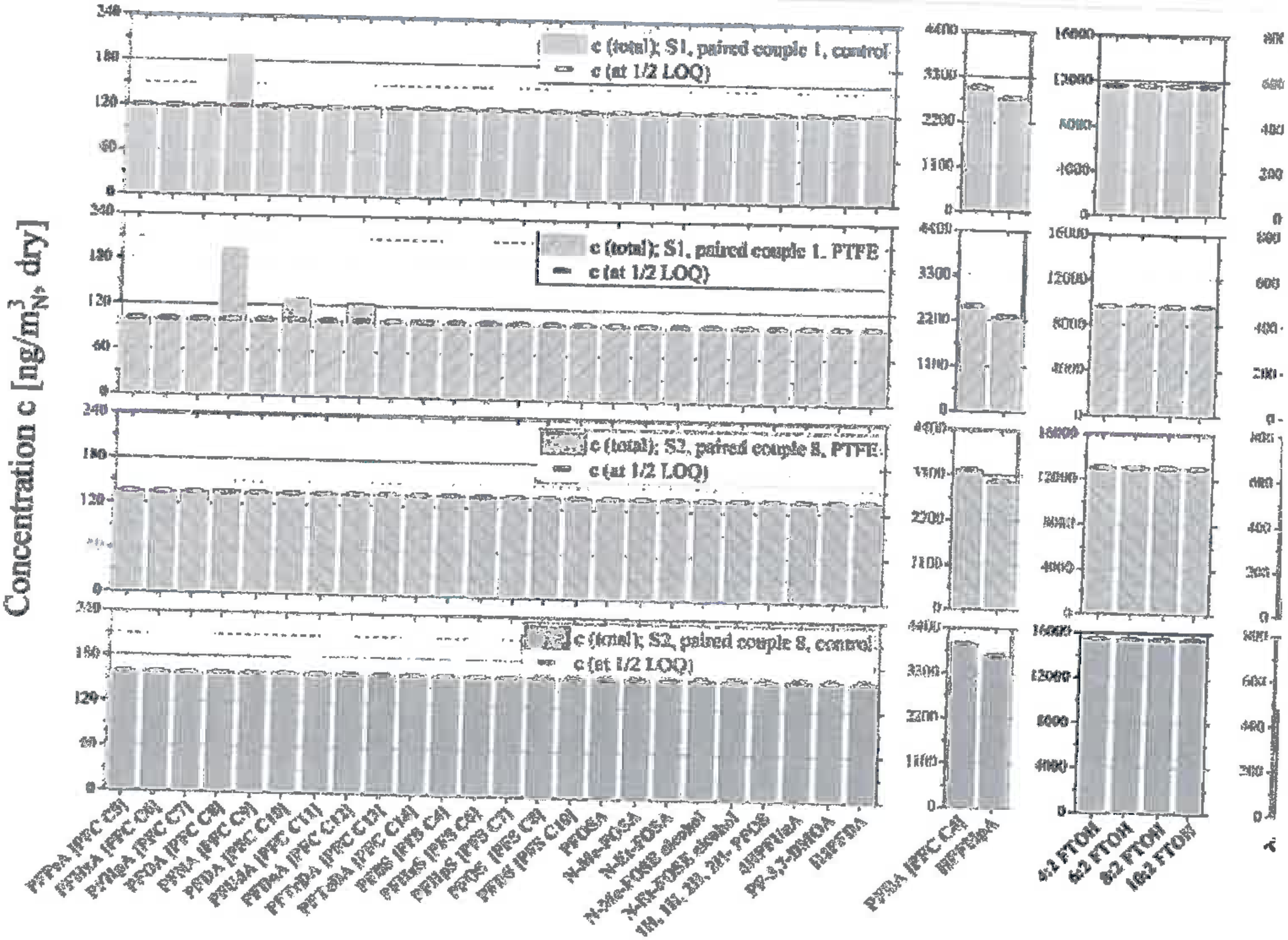

Fig. 4. Pattern of the species for PTFE spiked and control runs for paired couple 1 (S1) and paired couple 8 (S2).

Supplemental Information: Pyrolysis Processing of PFAS-Impacted Biosolids, a Pilot Study

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Solids/Liquids Sampling and Analysis:

Supplemental Information (SI) Table 1 shows the target PFAS compounds analyzed with the abbreviated name used by the Vista Analytical (VA) Lab and Chemical Abstract Services (CAS) registry number, listed in the display order of Figure 2. The mean values of samples with concentrations greater than the lab's minimum detection limit (MDL) and reporting limit (RL) combine values from TA and VA labs in this table. The total number of samples of biosolids and biochar in this analysis was eight (8), with four (4) samples sent to each lab. Cases where N=4 indicate that one of the labs did not provide analysis for that compound. One sample of water influent to the scrubber (tap water) is described in the main text (not shown). Field blanks consisted of sampling spoon rinse before sampling.

SI Table 1: Summary of PFAS Analysis.

Figure 2 Abscissa Order	PFAS Abbreviated Name	CAS Registry Number	Biosolids					Biochar					Scrubber Water					Field Blank				
			Samples (N)	% > MDL	Mean > MDL (µg/kg)	% > RL	Mean > RL (µg/kg)	Samples (N)	% > MDL	Mean > MDL (µg/kg)	% > RL	Mean > RL (µg/kg)	Samples (N)	% > MDL	Mean > MDL (ng/L)	% > RL	Mean > RL (ng/L)	Samples (N)	% > MDL	Mean > MDL (ng/L)	% > RL	Mean > RL (ng/L)
1	PFOA	335-67-1	8	100.0	85.7	100.0	85.7	8	0.0	-	0.0	-	7	42.9	9.1	28.6	13.2	4	0.0	-	0.0	-
2	5:3 FTCA	914637-49-3	4	100.0	47.7	100.0	47.7	4	0.0	-	0.0	-	4	0.0	-	0.0	-	2	0.0	-	0.0	-
3	PFHxA	307-24-4	8	100.0	36.5	100.0	36.3	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
4	MeFOSAA	2355-31-9	8	100.0	28.5	100.0	29.5	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
5	PFOS	1763-23-1	8	100.0	23.7	100.0	23.7	8	37.5	0.5	12.5	0.9	7	0.0	-	0.0	-	4	0.0	-	0.0	-
6	EtFOSAA	2991-50-6	8	100.0	21.7	100.0	21.7	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
7	MeFOSE	24448-09-7	8	100.0	18.1	100.0	18.1	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
8	7:3 FTCA	812-70-4	4	100.0	16.6	100.0	16.6	4	0.0	-	0.0	-	4	0.0	-	0.0	-	2	0.0	-	0.0	-
9	PFDA	335-76-2	8	100.0	12.9	100.0	12.9	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
10	PFHpA	375-85-9	8	100.0	8.9	100.0	8.9	8	0.0	-	0.0	-	7	42.9	0.2	0.0	-	4	25.0	0.5	0.0	-
11	PFPeA	2706-90-3	8	100.0	7.1	100.0	7.1	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
12	PFDoA	307-55-1	8	100.0	6.9	100.0	5.9	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
13	PFBA	375-22-4	8	100.0	8.7	100.0	8.7	8	50.0	0.2	12.5	0.2	7	42.9	0.6	0.0	-	4	25.0	0.4	0.0	-
14	EtFOSE	1691-99-2	8	50.0	6.5	50.0	6.3	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
15	PFNA	375-95-1	8	100.0	5.4	100.0	5.4	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
16	PFUnA	2058-94-8	8	100.0	4.2	100.0	4.2	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
17	PFBS	375-73-5	8	50.0	4.1	50.0	4.1	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
18	8:2 FTS	39108-34-4	8	100.0	4.9	50.0	3.8	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
19	10:2 FTS	120226-60-0	8	100.0	2.6	50.0	3.8	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
20	PFTeA	376-06-7	8	62.5	2.2	62.5	2.2	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
21	6:2 FTS	27619-97-2	8	75.0	1.8	25.0	1.5	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
22	PFOSA	754-91-6	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	100	27.9	100	27.9	4	0.0	-	0.0	-
-	PFPrS	423-41-6	4	0.0	-	0.0	-	4	0.0	-	0.0	-	4	0.0	-	0.0	-	2	0.0	-	0.0	-
-	3:3 FTCA	356-02-5	4	0.0		0.0	-	4	0.0	-	0.0	-	4	0.0	-	0.0	-	2	0.0	-	0.0	-
-	4:2 FTS	757124-72-4	8	0.0		0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFPeS	2706-91-4	8	0.0		0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	HFPO-DA	13252-13-6	8	0.0		0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	ADONA	919005-14-4	8	0.0		0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFHxS	355-46-4	8	0.0		0.0	-	8	0.0	-	0.0	-	7	42.9	0.1	0.0	-	4	50.0	0.2	0.0	-
-	PFecHS	646-83-3	4	0.0		0.0	-	4	0.0	-	0.0	-	4	0.0	-	0.0	-	2	0.0	-	0.0	-
-	PFHpS	375-92-8	8	0.0		0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	9Cl-PF3ONS	756426-58-1	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFNS	68259-12-1	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFDS	335-77-3	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	11Cl-PF3OUdS	763051-92-9	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	MeFOSA	31506-32-8	8	25.0	0.8	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFTrDA	72629-94-8	8	25.0	1.0	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFDoS	79780-39-5	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	EtFOSA	4151-50-2	8	12.5	0.3	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFHxDA	67905-19-5	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-
-	PFODA	16517-11-6	8	0.0	-	0.0	-	8	0.0	-	0.0	-	7	0.0	-	0.0	-	4	0.0	-	0.0	-

SI Table 2 summarizes the compound-specific MDLs, mean biosolid PFAS concentrations and removal efficiency (RE) calculations derived from TA and VA results. The RE is expressed as a minimum in terms of detection limits in some cases. The RE does not account for target or non-target PFAS gas-phase or non-target PFAS in solid and liquid media.

SI Table 2: Summary of PFAS Analyses and Calculated REs.

			TA LAB			VA LAB		
Figure 2 Abscissa Order	PFAS Abbreviated Name	CAS Registry Number	Mean Biochar MDL (µg/kg)	Mean Biosolid Conc (µg/kg)	Mean RE > (%)	Mean Biochar MDL (µg/kg)	Mean Biosolid Conc (µg/kg)	Mean RE > (%)
1	PFOA	335-67-1	0.08	86.65	99.96	0.46	84.75	99.75
2	5:3 FTCA	914637-49-3	*	*	*	1.52	47.70	98.58
3	PFHxA	307-24-4	0.04	35.94	99.95	0.21	36.75	99.74
4	MeFOSAA	2355-31-9	0.37	31.25	99.48	0.72	27.79	98.83
5	PFOS	1763-23-1	0.19	25.08	99.66	0.42	22.25	99.08
6	EtFOSAA	2991-50-6	0.35	24.54	99.37	0.68	18.80	98.39
7	MeFOSE	24448-09-7	0.07	19.24	99.85	4.89	17.00	97.21
8	7:3 FTCA	812-70-4	*	*	*	1.29	18.55	96.49
9	PFDA	335-76-2	0.02	19.11	99.93	0.44	12.78	98.45
10	PFHpA	375-85-9	0.03	9.21	99.87	0.47	8.36	97.51
11	PFPeA	2706-90-3	0.07	6.94	99.54	0.39	7.17	97.55
12	PFDoA	307-55-1	0.06	7.37	99.62	0.40	6.47	97.26
13	PFBA	375-22-4	0.09	5.27	99.78	0.34	8.07	98.07
14	EtFOSE	1691-99-2	0.09	6.32	99.76	5.29	**	**
15	PFNA	375-95-1	0.08	5.49	99.73	0.31	5.22	97.34
16	PFUnA	2058-94-8	0.03	5.05	99.70	0.25	3.27	96.49
17	PFBS	375-73-5	0.02	**	**	0.30	4.11	96.55
18	8:2 FTS	39108-34-4	0.23	**	**	0.71	3.80	91.47
19	10:2 FTS	120226-60-0	0.05	**	**	1.00	3.75	88.09
20	PFTeA	376-06-7	0.05	2.29	99.01	0.26	2.16	94.64
21	6:2 FTS	27619-97-2	0.14	**	**	0.64	1.54	81.32
		Mean	0.10	18.92	99.68	1.00	18.92	95.64
					Overall Mean RE >			97.57

Gas Emissions Sampling and Analysis:

SI Table 3 presents the FTIR-measured concentration and emission rate data for the first ten compounds in Figure 3 for each of the 1-hour duration tests (T1-T6) at measurement position LA, located at the exit of the pyrolysis unit emission stack. The statistics of the FTIR-measured concentration data are presented before water correction [8.68% vol (± 0.35 %)]. The dry stack flow rate was 248 scfm (±10 scfm) and emissions were calculated at a reference temperature of 21.1°C. The F10 and F5A FTIR analysis produced one measurement per minute and each data point that was less than the compound's MDC2 value was replaced with MDC2/2 before averaging. Trials with the percentage of data over MDC2 <85% will reflect biased estimates of means.[1] Some test results, indicated by italicized text, produced very low (<30%) or no data over MDC2, with collocated measurements in detection in some cases. Uncertainty exists in the acid gas results due to system start up and line passivation issues as no quality assurance (QA) dynamic spiking trials were performed for these gases. Uncertainty exists regarding MDC2s for QA dynamic spiking gases carbon tetrafluoride (CF_4), hexafluoroethane (C_2F_4), and sulfur hexafluoride (SF_6). These compounds were not detected in canister analysis (SI Table 6) and observance by FTIR may be related to residual gas from dynamic spiking procedures. The derivation of emissions per process mass is described in SI Table 5. The limit of detection (LOD) for the FTIR measurements was the minimum detectable concentration #2 (MDC2) as defined in ASTM Standard Test Method D6348-12.[2] This parameter was determined before the field test by measurement of a simulated flue gas sample without the analytes of interest, but with all interfering species, such as water and carbon dioxide. MDC2 is a precision-based measurement of three times the square root of the standard deviation from seven different concentrations of the interfering species.[3] MDC2 is only a measure of instrument precision and underestimates the true target compound detection limit. Although the precision of the instrument may be exceptional, that does not translate into overall system performance. MDC2 conforms to the International Union of Pure and Applied Chemistry

(IUPAC) recommended approach for determining the LOD.[4] Dynamic spiking line transport and system response QA tests under ASTM D6348-12 utilized 100 ppb to 10 ppm blends of CF_4, C_2F_6, with sulfur hexafluoride at 5 ppm as dilution marker. The results of all QA procedures were within the acceptance criteria of the ASTM method.

SI Table 3: Summary of FTIR concentrations and FTIR-derived emissions results presented Figure 3.

Figure 3 Abscissa Order	Analyte Name	CAS Registry Number	FTIR	Test	Number of One-Minute Analyses (N)	MDC2 (ppm)	Percent of Analyses > MDC2 (%)	Arithmetic Mean Wet Conc. (ppm)	Minimum Wet Conc. (ppm)	First Quartile Wet Conc. (ppm)	Median Wet Conc. (ppm)	Third Quartile Wet Conc. (ppm)	Maximum Wet Conc. (ppm)	Arithmetic Mean Conc. Dry Basis (ppm)	Emission Rate Dry Basis (kg/h)	Emissions Per Unit Dry BS Mass Processed (kg/kg)	Emissions Per Unit Wet BS Mass Processed (kg/t)
1	Nitric Oxide	10102-43-9	FSA	T1	61	4.5E-01	100	2.34E+02	2.08E+02	2.29E+02	2.34E+02	2.45E+02	2.68E+02	2.55E+02	1.30E-01	2.08E-03	5.17E-01
1	Nitric Oxide	10102-43-9	FSA	T2	61	4.5E-01	100	2.52E+02	2.18E+02	2.45E+02	2.51E+02	2.58E+02	2.77E+02	2.74E+02	1.37E-01	2.16E-03	5.40E-01
1	Nitric Oxide	10102-43-9	FSA	T3	61	4.5E-01	100	2.56E+02	2.28E+02	2.51E+02	2.57E+02	2.64E+02	2.72E+02	2.78E+02	1.38E-01	2.17E-03	5.48E-01
1	Nitric Oxide	10102-43-9	F10	T1	61	2.8E-01	100	2.43E+02	2.08E+02	2.34E+02	2.40E+02	2.55E+02	2.83E+02	2.64E+02	1.35E-01	2.12E-03	5.36E-01
1	Nitric Oxide	10102-43-9	F10	T2	61	2.8E-01	100	2.62E+02	2.27E+02	2.55E+02	2.61E+02	2.70E+02	2.69E+02	2.84E+02	8.57E-02	1.36E-03	3.40E-01
1	Nitric Oxide	10102-43-9	F10	T3	61	2.8E-01	100	2.68E+02	2.36E+02	2.59E+02	2.68E+02	2.74E+02	2.84E+02	2.88E+02	1.40E-01	2.25E-03	5.70E-01
1	Nitric Oxide	10102-43-9	F10	T4	61	2.8E-01	100	2.52E+02	2.16E+02	2.47E+02	2.55E+02	2.59E+02	2.70E+02	2.76E+02	1.51E-01	2.39E-03	6.01E-01
1	Nitric Oxide	10102-43-9	F10	T5	61	2.8E-01	100	2.48E+02	2.20E+02	2.44E+02	2.48E+02	2.52E+02	2.69E+02	2.72E+02	1.51E-01	2.38E-03	6.00E-01
1	Nitric Oxide	10102-43-9	F10	T6	61	2.8E-01	100	2.48E+02	2.30E+02	2.48E+02	2.47E+02	2.50E+02	2.59E+02	2.71E+02	1.53E-01	2.46E-03	6.08E-01
2	D3 Siloxane	541-05-9	FSA	T1	61	3.0E-02	100	2.53E+00	1.77E+00	2.37E+00	2.58E+00	2.76E+00	2.98E+00	2.74E+00	1.03E-02	1.58E-04	4.11E-02
2	D3 Siloxane	541-05-9	FSA	T2	61	3.0E-02	100	1.68E+00	1.48E+00	1.48E+00	1.58E+00	1.81E+00	1.82E+00	1.79E+00	6.68E-03	1.05E-04	2.69E-02
2	D3 Siloxane	541-05-9	FSA	T3	61	3.0E-02	100	1.59E+00	1.32E+00	1.54E+00	1.57E+00	1.59E+00	1.63E+00	1.69E+00	6.21E-03	9.76E-05	2.47E-02
2	D3 Siloxane	541-05-9	F10	T1	61	1.0E-02	100	2.84E+00	2.38E+00	2.60E+00	2.78E+00	3.10E+00	3.48E+00	3.06E+00	1.17E-02	1.84E-04	4.64E-02
2	D3 Siloxane	541-05-9	F10	T2	61	1.4E-02	100	3.15E+00	2.98E+00	3.04E+00	3.19E+00	3.24E+00	3.36E+00	3.42E+00	3.78E-03	5.98E-05	1.50E-02
2	D3 Siloxane	541-05-9	F10	T3	61	1.0E-02	100	2.98E+00	1.79E+00	2.87E+00	2.88E+00	3.03E+00	3.88E+00	3.29E+00	1.18E-02	1.89E-04	4.74E-02
2	D3 Siloxane	541-05-9	F10	T4	61	1.0E-02	100	1.81E+00	1.73E+00	1.80E+00	1.82E+00	1.88E+00	1.84E+00	1.98E+00	8.08E-03	1.27E-04	3.21E-02
2	D3 Siloxane	541-05-9	F10	T5	61	1.0E-02	100	1.74E+00	1.94E+00	1.74E+00	1.75E+00	1.76E+00	1.78E+00	1.94E+00	7.28E-03	1.24E-04	3.12E-02
2	D3 Siloxane	541-05-9	F10	T6	61	1.0E-02	100	1.73E+00	1.64E+00	1.71E+00	1.82E+00	1.85E+00	1.88E+00	1.98E+00	8.17E-03	1.28E-04	3.25E-02
3	D4 Siloxane	556-67-2	FSA	T1	61	2.0E-02	100	2.40E+00	1.59E+00	2.17E+00	2.57E+00	2.82E+00	3.08E+00	2.62E+00	1.82E-02	2.07E-04	5.28E-02
3	D4 Siloxane	556-67-2	FSA	T2	61	2.0E-02	100	9.50E-01	8.12E-01	8.40E-01	9.20E-01	1.03E+00	1.11E+00	1.03E+00	5.12E-03	8.08E-05	2.04E-02
3	D4 Siloxane	556-67-2	FSA	T3	61	2.0E-02	100	8.80E-01	8.27E-01	8.77E-01	8.93E-01	9.00E-01	8.78E-01	9.67E-01	4.74E-03	7.46E-05	1.88E-02
3	D4 Siloxane	556-67-2	F10	T1	61	1.0E-02	100	2.29E+00	1.89E+00	1.88E+00	2.17E+00	2.38E+00	2.84E+00	2.88E+00	1.30E-02	1.89E-04	4.77E-02
3	D4 Siloxane	556-67-2	F10	T2	61	1.0E-02	100	1.93E+00	1.85E+00	1.88E+00	1.80E+00	1.98E+00	2.15E+00	2.07E+00	7.72E-03	1.21E-04	3.07E-02
3	D4 Siloxane	556-67-2	F10	T3	61	1.0E-02	100	1.81E+00	1.68E+00	1.78E+00	1.82E+00	1.84E+00	1.90E+00	1.98E+00	9.64E-03	1.52E-04	3.88E-02
3	D4 Siloxane	556-67-2	F10	T4	61	1.0E-02	100	1.80E+00	1.37E+00	1.46E+00	1.60E+00	1.76E+00	2.02E+00	1.78E+00	9.68E-03	1.52E-04	3.88E-02
3	D4 Siloxane	556-67-2	F10	T5	61	1.0E-02	100	1.70E+00	1.16E+00	1.18E+00	1.20E+00	1.24E+00	1.38E+00	1.88E+00	7.31E-03	1.15E-04	2.90E-02
3	D4 Siloxane	556-67-2	F10	T6	61	1.0E-02	100	1.41E+00	1.22E+00	1.28E+00	1.40E+00	1.52E+00	1.57E+00	1.54E+00	8.60E-03	1.35E-04	3.42E-02
4	Sulfur Dioxide	7446-09-5	FSA	T1	61	5.1E-01	100	7.04E-01	5.70E-01	6.40E-01	6.88E-01	7.48E-01	8.07E-01	7.69E-01	8.35E-04	1.31E-05	3.31E-03
4	Sulfur Dioxide	7446-09-5	FSA	T2	61	5.1E-01	100	7.12E-01	5.87E-01	6.78E-01	7.02E-01	7.64E-01	8.82E-01	7.72E-01	8.28E-04	1.30E-05	3.25E-03
4	Sulfur Dioxide	7446-09-5	FSA	T3	61	5.1E-01	100	7.29E-01	5.87E-01	6.81E-01	7.29E-01	7.75E-01	8.68E-01	7.95E-01	8.40E-04	1.32E-05	3.34E-03
4	Sulfur Dioxide	7446-09-5	F10	T1	61	2.4E-01	100	7.96E-01	6.85E-01	6.31E-01	7.80E-01	8.68E-01	1.04E+00	8.24E-01	9.06E-04	1.41E-05	3.57E-03
4	Sulfur Dioxide	7446-09-5	F10	T2	61	2.4E-01	100	9.67E-01	7.05E-01	7.88E-01	8.48E-01	1.11E+00	1.57E+00	1.04E+00	5.15E-04	8.11E-06	2.05E-03
4	Sulfur Dioxide	7446-09-5	F10	T3	61	2.4E-01	100	9.58E-01	5.28E-01	9.61E-01	1.08E+00	1.18E+00	1.94E+00	1.08E+00	1.15E-03	1.81E-05	4.57E-03
4	Sulfur Dioxide	7446-09-5	F10	T4	61	2.4E-01	100	4.15E-01	2.40E-01	3.88E-01	4.12E-01	4.60E-01	8.12E-01	4.58E-01	3.30E-04	8.38E-06	2.13E-03
4	Sulfur Dioxide	7446-09-5	F10	T5	61	2.4E-01	100	4.78E-01	3.11E-01	3.56E-01	4.60E-01	5.48E-01	6.85E-01	5.28E-01	6.15E-04	9.67E-06	2.44E-03
4	Sulfur Dioxide	7446-09-5	F10	T6	61	2.4E-01	100	5.15E-01	3.08E-01	3.90E-01	5.27E-01	5.87E-01	1.05E+00	5.58E-01	1.20E-03	1.89E-05	4.77E-03
5	Nitrous Oxide	10024-97-2	FSA	T1	61	1.1E-01	100	7.01E-01	2.58E-01	3.38E-01	4.90E-01	8.52E-01	7.17E+00	7.46E-01	3.71E-04	5.86E-06	2.27E-03
5	Nitrous Oxide	10024-97-2	FSA	T2	61	1.1E-01	100	5.22E-01	2.48E-01	3.94E-01	4.98E-01	5.60E-01	8.88E-01	5.67E-01	4.17E-04	6.57E-06	1.66E-03
5	Nitrous Oxide	10024-97-2	FSA	T3	61	1.1E-01	100	6.14E-01	3.85E-01	4.88E-01	6.09E-01	7.61E-01	9.47E-01	6.68E-01	4.88E-04	7.04E-06	1.68E-03
5	Nitrous Oxide	10024-97-2	F10	T1	61	9.0E-02	100	8.74E-01	1.79E-01	5.62E-01	6.22E-01	1.00E+00	6.62E+00	9.38E-01	7.13E-04	1.12E-05	2.88E-03
5	Nitrous Oxide	10024-97-2	F10	T2	61	9.0E-02	100	6.85E-01	4.98E-01	5.85E-01	6.08E-01	7.59E-01	1.08E+00	7.42E-01	5.72E-04	9.03E-06	2.27E-03
5	Nitrous Oxide	10024-97-2	F10	T3	61	9.0E-02	100	7.99E-01	5.04E-01	6.38E-01	7.46E-01	9.21E-01	1.12E+00	8.94E-01	6.09E-04	9.58E-06	2.42E-03
5	Nitrous Oxide	10024-97-2	F10	T4	61	9.0E-02	100	9.50E-01	5.10E-01	6.84E-01	9.20E-01	1.12E+00	1.76E+00	1.04E+00	8.35E-04	1.31E-05	3.12E-03
5	Nitrous Oxide	10024-97-2	F10	T5	61	9.0E-02	100	8.89E-01	6.49E-01	8.40E-01	8.70E-01	9.65E-01	1.30E+00	9.08E-01	7.88E-04	1.24E-05	3.13E-03
5	Nitrous Oxide	10024-97-2	F10	T6	61	9.8E-02	100	8.49E-01	6.78E-01	8.00E-01	8.30E-01	8.72E-01	1.26E+00	9.29E-01	7.68E-04	1.20E-05	3.04E-03
6	Hydrogen Chloride	7647-01-0	FSA	T1	61	2.5E-01	100	1.36E+00	1.11E+00	1.31E+00	1.55E+00	2.53E+00	3.22E+00	2.03E+00	1.25E-03	1.97E-05	4.58E-03
6	Hydrogen Chloride	7647-01-0	FSA	T2	61	2.5E-01	100	2.60E+00	2.30E+00	2.42E+00	2.68E+00	2.76E+00	2.90E+00	2.82E+00	1.72E-03	2.70E-05	6.88E-03
6	Hydrogen Chloride	7647-01-0	FSA	T3	61	2.5E-01	100	1.79E+00	1.48E+00	1.70E+00	1.74E+00	1.78E+00	2.81E+00	1.95E+00	1.17E-03	1.84E-05	4.88E-03
6	Hydrogen Chloride	7647-01-0	F10	T1	61	1.5E-01	100	1.18E+00	8.42E-01	1.01E+00	1.26E+00	1.98E+00	2.57E+00	1.47E+00	9.13E-04	1.44E-05	3.61E-03
6	Hydrogen Chloride	7647-01-0	F10	T2	61	1.5E-01	92	1.65E-01	7.50E-02	1.70E-01	1.94E-01	2.29E-01	2.88E-01	2.11E-01	1.58E-04	2.46E-06	6.18E-04
6	Hydrogen Chloride	7647-01-0	F10	T3	61	1.5E-01	22	4.53E-02	7.50E-02	7.52E-02	2.50E-02	2.80E-02	1.75E-01	4.25E-02	3.08E-05	4.78E-07	1.22E-04
6	Hydrogen Chloride	7647-01-0	F10	T4	61	1.5E-01	100	1.07E+00	6.97E-01	4.17E-01	1.01E+00	1.94E+00	1.71E+00	1.17E+00	7.88E-04	1.23E-05	3.12E-03
6	Hydrogen Chloride	7647-01-0	F10	T5	61	1.5E-01	100	4.20E-01	2.72E-01	3.58E-01	4.02E-01	4.65E-01	7.28E-01	4.61E-01	3.11E-04	4.88E-06	1.24E-03
6	Hydrogen Chloride	7647-01-0	F10	T6	61	1.5E-01	84	1.72E-01	7.90E-02	1.65E-01	1.88E-01	2.02E-01	2.88E-01	1.88E-01	1.29E-04	2.03E-06	5.12E-04
7	Nitrogen Dioxide	10102-44-0	FSA	T1	61	1.2E-01	98	3.48E-01	6.02E-02	2.83E-01	3.94E-01	4.04E-01	8.98E-01	3.80E-01	2.98E-04	4.68E-06	1.18E-03
7	Nitrogen Dioxide	10102-44-0	FSA	T2	61	1.2E-01	100	5.19E-01	3.88E-01	5.01E-01	5.45E-01	5.48E-01	6.71E-01	5.86E-01	4.50E-04	7.09E-06	1.79E-03
7	Nitrogen Dioxide	10102-44-0	FSA	T3	61	1.3E-01	100	3.81E-01	4.50E-01	5.40E-01	3.90E-01	6.25E-01	7.05E-01	4.36E-01	4.81E-04	7.57E-06	1.91E-03
7	Nitrogen Dioxide	10102-44-0	F10	T1	61	1.1E-01	100	3.80E-01	2.00E-01	2.59E-01	3.90E-01	3.39E-01	6.21E-01	3.35E-01	2.62E-04	4.12E-06	1.04E-03
7	Nitrogen Dioxide	10102-44-0	F10	T2	61	1.1E-01	100	3.16E-01	2.30E-01	2.80E-01	3.12E-01	3.40E-01	4.09E-01	3.48E-01	1.72E-04	2.71E-06	6.84E-04
7	Nitrogen Dioxide	10102-44-0	F10	T3	61	1.1E-01	100	4.31E-01	3.44E-01	4.21E-01	4.47E-01	4.82E-01	5.80E-01	4.65E-01	3.72E-04	5.87E-06	1.48E-03
7	Nitrogen Dioxide	10102-44-0	F10	T4	61	1.1E-01	100	5.28E-01	2.78E-01	4.20E-01	5.26E-01	5.80E-01	6.96E-01	5.78E-01	4.38E-04	7.65E-06	1.93E-03
7	Nitrogen Dioxide	10102-44-0	F10	T5	61	1.1E-01	100	5.26E-01	4.38E-01	4.65E-01	5.29E-01	5.86E-01	6.58E-01	5.77E-01	4.32E-04	7.72E-06	1.95E-03
7	Nitrogen Dioxide	10102-44-0	F10	T6	61	1.1E-01	100	6.41E-01	5.37E-01	6.15E-01	6.38E-01	6.73E-01	7.24E-01	7.01E-01	6.05E-04	9.53E-06	2.41E-03
8	Methane	74-82-8	FSA	T1	61	2.0E-01	100	8.84E-01	7.54E-01	8.24E-01	8.63E-01	9.01E-01	1.26E+00	9.78E-01	2.68E-04	4.18E-06	1.05E-03
8	Methane	74-82-8	FSA	T2	61	2.0E-01	100	9.05E-01	8.04E-01	8.44E-01	8.75E-01	9.30E-01	1.21E+00	9.85E-01	2.64E-04	4.13E-06	1.05E-03
8	Methane	74-82-8	FSA	T3	61	2.0E-01	100	8.90E-01	7.58E-01	8.95E-01	8.68E-01	8.36E-01	1.25E+00	9.68E-01	2.57E-04	4.08E-06	1.02E-03
8	Methane	74-82-8	F10	T1	61	2.7E-01	100	8.88E-01	7.18E-01	7.94E-01	8.20E-01	8.01E-01	1.21E+00	9.31E-01	2.54E-04	3.99E-06	1.01E-03
8	Methane	74-82-8	F10	T2	61	2.7E-01	100	8.67E-01	6.56E-01	8.06E-01	8.57E-01	9.38E-01	1.40E+00	9.61E-01	7.08E-04	1.13E-05	1.81E-03
8	Methane	74-82-8	F10	T3	61	2.7E-01	100	8.88E-01	7.13E-01	7.87E-01	4.42E-01	9.15E-01	1.38E+00	8.43E-01	2.50E-04	3.94E-06	9.94E-04
8	Methane	74-82-8	F10	T4	61	2.7E-01	100	1.09E+00	8.64E-01	1.01E+00	1.08E+00	1.14E+00	1.41E+00	1.18E+00	3.47E-04	5.48E-06	1.38E-03
8	Methane	74-82-8	F10	T5	61	2.7E-01	100	9.38E-01	7.71E-01	8.98E-01	8.93E-01	1.00E+00	1.32E+00	1.01E+00	3.04E-04	4.70E-06	1.21E-03
8	Methane	74-82-8	F10	T6	61	2.7E-01	100	8.90E-01	7.81E-01	8.38E-01	8.79E-01	9.22E-01	1.22E+00	9.74E-01	2.98E-04	4.61E-06	1.16E-03
9	Carbon Monoxide	630-08-0	FSA	T1	61	5.0E-01	48	5.14E-01	2.50E-01	2.50E-01	2.50E-01	6.24E-01	2.59E+00	5.63E-01	2.68E-04	4.31E-06	1.05E-03
9	Carbon Monoxide	630-08-0	FSA	T2	61	5.0E-01	25	3.18E-01	2.50E-02	2.80E-01	2.50E-01	2.50E-01	8.48E-01	3.45E-01	1.63E-04	2.54E-06	6.49E-04
9	Carbon Monoxide	630-08-0	FSA	T3	61	5.0E-01	45	4.25E-01	2.50E-01	2.90E-01	2.50E-01	3.98E-01	1.58E+00	4.68E-01	2.14E-04	3.37E-06	8.31E-04
9	Carbon Monoxide	630-08-0	F10	T1	61	3.0E-01	16	2.59E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01	1.42E+00	2.79E-01	1.55E-04	2.09E-06	5.27E-04
9	Carbon Monoxide	630-08-0	F10	T2	61	3.0E-01	5	1.49E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01	5.21E-01	1.76E-01	1.09E-04	2.50E-06	7.92E-04
9	Carbon Monoxide	630-08-0	F10	T3	61	3.0E-01	5	1.72E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01	8.80E-01	1.86E-01	8.82E-05	1.06E-06	3.48E-04
9	Carbon Monoxide	630-08-0	F10	T4	61	3.0E-01	41	4.40E-01	1.50E-01	1.50E-01	1.50E-01	6.40E-01	2.41E+00	4.81E-01	2.49E-04	3.88E-06	8.78E-04
9	Carbon Monoxide	630-08-0	F10	T5	61	3.0E-01	10	1.98E-01	1.50E-01	1.50E-01	1.50E-01	1.50E-01	1.04E+00	2.13E-01	1.22E-04	2.78E-06	4.42E-04
9	Carbon Monoxide	630-08-0	F10	T6	61	3.0E-01	48	3.05E-01	1.50E-01	1.50E-01	1.50E-01	3.90E-01	1.80E+00	3.32E-01	1.76E-04	2.77E-06	6.98E-04
10	Hydrogen Flouride	62778-11-4	FSA	T1	61	1.5E-01	52	2.30E-01	7.50E-02	7.50E-02	1.60E-01	5.52E-01	9.00E-01	2.60E-01	1.26E-04	1.50E-06	4.98E-04
10	Hydrogen Flouride	62778-11-4	FSA	T2	61	1.5E-01	100	2.83E-01	1.77E-01	2.34E-01	2.68E-01	3.06E-01	3.44E-01	2.88E-01	9.62E-05	1.51E-06	3.82E-04
10	Hydrogen Flouride	62778-11-4	FSA	T3	61	1.5E-01	30	1.34E-01	7.50E-02	7.50E-02	7.50E-02	1.50E-01	2.74E-01	1.34E-01	4.12E-05	6.40E-07	1.69E-04
10	Hydrogen Flouride	62778-11-4	F10	T1	61	2.0E-01	100	1.30E+00	8.30E-01	1.23E+00	1.28E+00	1.50E+00	1.81E+00	1.41E+00	4.81E-04	7.35E-06	1.91E-03
10	Hydrogen Flouride	62778-11-4	F10	T2	61	2.0E-01	0	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	2.08E-01	2.65E-04	4.17E-06	1.06E-03
10	Hydrogen Flouride	62778-11-4	F10	T3	61	2.0E-01	0	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	3.02E-05	5.00E-07	1.45E-04
10	Hydrogen Flouride	62778-11-4	F10	T4	61	2.0E-01	100	6.38E-01	4.85E-01	5.80E-01	6.53E-01	7.22E-01	8.40E-01	7.31E-01	2.44E-04	4.15E-06	1.05E-03
10	Hydrogen Flouride	62778-11-4	F10	T5	61	2.0E-01	39	1.78E-01	1.00E-01	1.00E-01	1.00E-01	2.08E-01	4.28E-01	1.94E-01	7.16E-05	1.13E-06	2.84E-04
10	Hydrogen Flouride	62778-11-4	F10	T6	61	2.0E-01	0	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	4.11E-05	6.40E-07	1.60E-04

SI Table 4: Summary of canister-derived emissions results presented Figure 3.

Figure 3 Abscissa Order	Analyte Name	CAS Registry Number	FTIR Outlet Producing Sample	Test	Number of Samples (N)	TO-15 MDL (ppm)	Wet Conc. (ppm)	Conc. Dry Basis (ppm)	Emission Rate Dry Basis (kg/h)	Emissions Per Unit Dry BS Mass Processed (kg/kg)	Emissions Per Unit Wet BS Mass Processed (kg/t)
11	Acetone	67-64-1	F5A	T3	1	2.19E-04	6.16E-02	6.71E-02	6.44E-05	1.01E-06	2.56E-04
11	Acetone	67-64-1	F10	T1	1	2.19E-04	5.60E-02	6.10E-02	6.08E-05	9.48E-07	2.39E-04
11	Acetone	67-64-1	F10	T2	1	2.19E-04	5.29E-02	5.73E-02	5.58E-05	8.77E-07	2.21E-04
11	Acetone	67-64-1	F10	T3	1	2.19E-04	4.14E-02	4.49E-02	4.32E-05	6.80E-07	1.72E-04
11	Acetone	67-64-1	F10	T4	1	2.19E-04	3.29E-02	3.60E-02	3.82E-05	6.01E-07	1.52E-04
11	Acetone	67-64-1	F10	T6	1	2.19E-04	3.59E-02	3.92E-02	4.27E-05	6.72E-07	1.70E-04
12	Benzene	71-43-2	F5A	T3	1	9.55E-06	1.74E-02	1.90E-02	2.45E-05	3.85E-07	9.73E-05
12	Benzene	71-43-2	F10	T1	1	9.55E-06	2.85E-02	3.11E-02	4.12E-05	6.49E-07	1.64E-04
12	Benzene	71-43-2	F10	T2	1	9.55E-06	1.81E-02	1.96E-02	2.56E-05	4.03E-07	1.02E-04
12	Benzene	71-43-2	F10	T3	1	9.55E-06	1.51E-02	1.63E-02	2.12E-05	3.33E-07	8.41E-05
12	Benzene	71-43-2	F10	T4	1	9.55E-06	7.81E-03	8.54E-03	1.22E-05	1.92E-07	4.84E-05
12	Benzene	71-43-2	F10	T6	1	9.55E-06	7.93E-03	8.02E-03	1.18E-05	1.85E-07	4.67E-05
13	1-Butene	106-98-9	F5A	T3	1	1.77E-05	2.19E-03	2.38E-03	2.21E-06	3.48E-08	8.77E-06
13	1-Butene	106-98-9	F10	T1	1	1.77E-05	6.70E-03	7.30E-03	6.96E-06	1.10E-07	2.76E-05
13	1-Butene	106-98-9	F10	T2	1	1.77E-05	7.06E-03	7.65E-03	7.19E-06	1.13E-07	2.85E-05
13	1-Butene	106-98-9	F10	T3	1	1.77E-05	5.70E-03	6.18E-03	5.75E-06	9.05E-08	2.28E-05
13	1-Butene	106-98-9	F10	T4	1	1.77E-05	1.83E-02	2.01E-02	2.06E-05	3.24E-07	8.17E-05
13	1-Butene	106-98-9	F10	T6	1	1.77E-05	1.35E-02	1.48E-02	1.56E-05	2.46E-07	6.18E-05
14	Chloroform	67-66-3	F5A	T3	1	6.14E-06	2.61E-03	2.84E-03	5.60E-06	8.81E-08	2.22E-05
14	Chloroform	67-66-3	F10	T1	1	6.14E-06	4.67E-03	5.09E-03	1.03E-05	1.62E-07	4.10E-05
14	Chloroform	67-66-3	F10	T2	1	6.14E-06	3.05E-03	3.31E-03	6.61E-06	1.04E-07	2.62E-05
14	Chloroform	67-66-3	F10	T3	1	6.14E-06	4.24E-03	4.60E-03	9.10E-06	1.43E-07	3.61E-05
14	Chloroform	67-66-3	F10	T4	1	6.14E-06	1.40E-03	1.53E-03	3.34E-06	5.26E-08	1.33E-05
14	Chloroform	67-66-3	F10	T6	1	6.14E-06	5.34E-03	5.84E-03	1.31E-05	2.06E-07	5.19E-05
15	Acetonitrile	75-05-8	F5A	T3	1	3.00E-05	1.02E-02	1.11E-02	7.54E-06	1.19E-07	2.99E-05
15	Acetonitrile	75-05-8	F10	T1	1	3.00E-05	6.38E-03	6.95E-03	4.85E-06	7.63E-08	1.93E-05
15	Acetonitrile	75-05-8	F10	T2	1	3.00E-05	9.12E-03	9.88E-03	6.80E-06	1.07E-07	2.70E-05
15	Acetonitrile	75-05-8	F10	T3	1	3.00E-05	1.08E-02	1.17E-02	7.95E-06	1.25E-07	3.16E-05
15	Acetonitrile	75-05-8	F10	T4	1	3.00E-05	9.72E-03	1.06E-02	7.98E-06	1.26E-07	3.17E-05
15	Acetonitrile	75-05-8	F10	T6	1	3.00E-05	1.13E-02	1.24E-02	9.52E-06	1.50E-07	3.78E-05
16	Acrolein	107-02-8	F5A	T3	1	3.23E-05	7.60E-03	8.27E-03	7.66E-06	1.21E-07	3.04E-05
16	Acrolein	107-02-8	F10	T1	1	3.23E-05	6.44E-03	7.02E-03	6.69E-06	1.05E-07	2.66E-05
16	Acrolein	107-02-8	F10	T2	1	3.23E-05	6.26E-03	6.78E-03	6.37E-06	1.00E-07	2.53E-05
16	Acrolein	107-02-8	F10	T3	1	3.23E-05	4.82E-03	5.22E-03	4.86E-06	7.64E-08	1.93E-05
16	Acrolein	107-02-8	F10	T4	1	3.23E-05	6.50E-03	7.11E-03	7.29E-06	1.15E-07	2.89E-05
16	Acrolein	107-02-8	F10	T6	1	3.23E-05	6.91E-03	7.56E-03	7.95E-06	1.25E-07	3.16E-05
17	Propylene	115-07-1	F5A	T3	1	2.24E-05	2.31E-03	2.51E-03	1.75E-06	2.75E-08	6.94E-06
17	Propylene	115-07-1	F10	T1	1	2.24E-05	8.08E-03	8.80E-03	6.30E-06	9.91E-08	2.50E-05
17	Propylene	115-07-1	F10	T2	1	2.24E-05	1.18E-02	1.28E-02	9.04E-06	1.42E-07	3.59E-05
17	Propylene	115-07-1	F10	T3	1	2.24E-05	1.04E-02	1.13E-02	7.87E-06	1.24E-07	3.12E-05
17	Propylene	115-07-1	F10	T4	1	2.24E-05	8.17E-03	8.93E-03	6.87E-06	1.08E-07	2.73E-05
17	Propylene	115-07-1	F10	T6	1	2.24E-05	1.03E-02	1.12E-02	8.89E-06	1.40E-07	3.53E-05
18	Acrylonitrile	107-13-1	F5A	T3	1	1.17E-05	7.64E-03	8.31E-03	7.29E-06	1.15E-07	2.89E-05
18	Acrylonitrile	107-13-1	F10	T1	1	1.17E-05	3.26E-03	3.55E-03	3.20E-06	5.04E-08	1.27E-05
18	Acrylonitrile	107-13-1	F10	T2	1	1.17E-05	5.11E-03	5.54E-03	4.92E-06	7.74E-08	1.95E-05
18	Acrylonitrile	107-13-1	F10	T3	1	1.17E-05	4.63E-03	5.02E-03	4.42E-06	6.95E-08	1.75E-05
18	Acrylonitrile	107-13-1	F10	T4	1	1.17E-05	2.69E-03	2.94E-03	2.85E-06	4.49E-08	1.13E-05
18	Acrylonitrile	107-13-1	F10	T6	1	1.17E-05	7.66E-03	8.38E-03	8.34E-06	1.31E-07	3.31E-05
19	o-Ethyltoluene	611-14-3	F5A	T3	1	2.69E-05	2.47E-03	2.69E-03	5.34E-06	8.40E-08	2.12E-05
19	o-Ethyltoluene	611-14-3	F10	T1	1	2.69E-05	2.66E-03	2.90E-03	5.92E-06	9.32E-08	2.35E-05
19	o-Ethyltoluene	611-14-3	F10	T2	1	2.69E-05	1.81E-03	1.96E-03	3.95E-06	6.21E-08	1.57E-05
19	*o-Ethyltoluene*	*611-14-3*	*F10*	*T3*	*1*	*2.69E-05*	*<MDL*	*<MDL*	*<MDL*	*<MDL*	*<MDL*
19	*o-Ethyltoluene*	*611-14-3*	*F10*	*T4*	*1*	*2.69E-05*	*<MDL*	*<MDL*	*<MDL*	*<MDL*	*<MDL*
19	o-Ethyltoluene	611-14-3	F10	T6	1	2.69E-05	2.02E-03	2.21E-03	4.98E-06	7.84E-08	1.98E-05
20	Chloromethane	74-87-3	F5A	T3	1	6.63E-06	1.04E-03	1.13E-03	9.44E-07	1.49E-08	3.75E-06
20	Chloromethane	74-87-3	F10	T1	1	6.63E-06	3.41E-03	3.72E-03	3.19E-06	5.02E-08	1.27E-05
20	Chloromethane	74-87-3	F10	T2	1	6.63E-06	2.90E-03	3.14E-03	2.66E-06	4.18E-08	1.06E-05
20	Chloromethane	74-87-3	F10	T3	1	6.63E-06	4.24E-03	4.60E-03	3.85E-06	6.06E-08	1.53E-05
20	Chloromethane	74-87-3	F10	T4	1	6.63E-06	5.36E-03	5.86E-03	5.41E-06	8.51E-08	2.15E-05
20	Chloromethane	74-87-3	F10	T6	1	6.63E-06	4.04E-03	4.42E-03	4.19E-06	6.59E-08	1.66E-05
21	Carbon Disulfide	75-15-0	F5A	T3	1	1.63E-04	1.86E-03	2.02E-03	2.55E-06	4.01E-08	1.01E-05
21	Carbon Disulfide	75-15-0	F10	T1	1	1.63E-04	1.77E-03	1.93E-03	2.30E-06	3.93E-08	9.91E-06
21	*Carbon Disulfide*	*75-15-0*	*F10*	*T2*	*1*	*1.63E-04*	*<MDL*	*<MDL*	*<MDL*	*<MDL*	*<MDL*
21	*Carbon Disulfide*	*75-15-0*	*F10*	*T3*	*1*	*1.63E-04*	*<MDL*	*<MDL*	*<MDL*	*<MDL*	*<MDL*
21	Carbon Disulfide	75-15-0	F10	T4	1	1.63E-04	1.80E-03	1.97E-03	2.74E-06	4.31E-08	1.09E-05
21	Carbon Disulfide	75-15-0	F10	T6	1	1.63E-04	1.47E-03	1.61E-03	2.30E-06	3.61E-08	9.12E-06
22	2-Butanone	78-93-3	F5A	T3	1	2.64E-05	2.02E-03	2.20E-03	2.62E-06	4.12E-08	1.04E-05
22	2-Butanone	78-93-3	F10	T1	1	2.64E-05	2.05E-03	2.23E-03	2.74E-06	4.31E-08	1.09E-05
22	2-Butanone	78-93-3	F10	T2	1	2.64E-05	1.93E-03	2.09E-03	2.53E-06	3.97E-08	1.00E-05
22	2-Butanone	78-93-3	F10	T3	1	2.64E-05	1.68E-03	1.82E-03	2.18E-06	3.43E-08	8.65E-06
22	2-Butanone	78-93-3	F10	T4	1	2.64E-05	1.81E-03	1.98E-03	2.61E-06	4.11E-08	1.04E-05
22	2-Butanone	78-93-3	F10	T6	1	2.64E-05	1.65E-03	1.81E-03	2.44E-06	3.84E-08	9.70E-06

SI Table 5 summarizes the combined set mean and median values for Test T1-T6 presented in Figure 3. The individual one-minute FTIR data were converted to dry emission rate in kg/h using the stack flow parameters for each test (dry basis). The emissions data derived from the F10 and F5A collocated FTIRs for T1, T2, and T3 were first averaged point by point and then combined with the F10 results from T4-T6 to form 366 one-minute emissions values, with overall mean and median values by compound shown below. The same strategy for replacement of FTIR concentration data <MDC2 described in SI Table 3 was used. Emission data derived from canisters analysis was determined by combining all available emission values for each compound (typically 6) with below <MDL values excluded.

The air emissions per kg of Class A dry BS processed by the pyrolysis system was derived from the kg/h measured emission values by dividing by the mean dried BS input rate to the pyrolysis unit of 63.57 kg/h for the overall tests. This represents a dried BS unit emission factor in kg of emissions per kg BS processed (kg/kg) for the compounds measured and only applies to material after the BioDryer operation. To provide a more direct comparison to SSI, which does not involve a drying step, the air emissions per unit mass of wet BS (dewatered sludge, wet Class B BS in this case) input to the BioDryer/pyrolysis system were estimated and expressed in units of kilograms per metric ton (kg/t). Since air emissions from the BioDrying process were not measured, some compounds, (e.g. ammonia) were not accounted for in the emission estimates.

The emission estimate per wet ton of dewatered sludge was derived by first calculating the input dried BS to produced biochar ratio. In this study, 63.6 kg of dried biosolids where input to the pyrolysis process producing 28.8 kg of biochar indicating a dried biosolids to biochar production ratio of 2.21 [63.6 kg/ 28.8kg = 2.21]. From SVCW site processing data, approximately 3500 t of processed dewatered sludge produces about 400 t of biochar annually, therefore about 884 t of Class A dried biosolids (2.21 * 400 t) are processed by the pyrolysis unit per year. These data indicate an approximate four-fold mass reduction in the BioDryer step (884 t/3500 t = 0.25). The air emissions per metric ton of wet BS mass processed was then estimated by multiplying the Class A dried biosolids unit emission factor in kg/kg by 1000kg/t, then multiplying by the drying mass reduction factor of 0.25. This produces an estimate of kg of emissions per metric ton (kg/t) of Class B dewatered sludge (wet BS mass) entering the BioDryer/pyrolysis process, with the assumption that no emissions occur during water removal in drying.

SI Table 5: Summary of emission results across tests T1-T6 as presented Figure 3.

Figure 3 Abscissa Order	Analyte Name	CAS Registry Number	Number of One-Minute Analyses (N)	Arithmetic Mean Emission Rate Dry Basis (kg/h)	Median Emission Rate Dry Basis (kg/h)	Arithmetic Mean Emissions Per Unit Dry BS Mass Processed (kg/kg)	Median Emissions Per Unit Dry BS Mass Processed (kg/kg)	Arithmetic Mean Emissions Per Unit Wet BS Mass Processed (kg/t)	Median Emissions Per Unit Wet BS Mass Processed (kg/t)
1	Nitric Oxide	10102-43-9	366	1.45E-01	1.47E-01	2.28E-03	2.31E-03	5.75E-01	5.83E-01
2	D3 Siloxane	541-05-9	366	8.96E-03	8.59E-03	1.41E-04	1.35E-04	3.57E-02	3.41E-02
3	D4 Siloxane	556-67-2	366	8.84E-03	7.99E-03	1.39E-04	1.26E-04	3.51E-02	3.18E-02
4	Sulfur Dioxide	7446-09-5	366	8.63E-04	8.88E-04	1.36E-05	1.40E-05	3.43E-03	3.53E-03
5	Nitrous Oxide	10024-97-2	366	6.77E-04	7.11E-04	1.06E-05	1.12E-05	2.69E-03	2.82E-03
6	Hydrogen Chloride	7647-01-0	366	6.41E-04	6.07E-04	1.01E-05	9.55E-06	2.55E-03	2.41E-03
7	Nitrogen Dioxide	10102-44-0	366	4.41E-04	4.40E-04	6.94E-06	6.92E-06	1.75E-03	1.75E-03
8	Methane	74-82-8	366	2.86E-04	2.77E-04	4.50E-06	4.35E-06	1.14E-03	1.10E-03
9	Carbon Monoxide	630-08-0	366	1.68E-04	1.02E-04	2.64E-06	1.60E-06	6.68E-04	4.04E-04
10	Hydrogen Fluoride	62778-11-4	366	1.15E-04	1.31E-04	6.19E-05	2.06E-06	9.74E-07	5.19E-04
11	Acetone	67-64-1	6	5.08E-05	5.08E-05	7.99E-07	7.99E-07	2.02E-04	2.02E-04
12	Benzene	71-43-2	6	2.28E-05	2.28E-05	3.59E-07	3.59E-07	9.06E-05	9.06E-05
13	1-Butene	106-98-9	6	9.71E-06	9.71E-06	1.53E-07	1.53E-07	3.86E-05	3.86E-05
14	Chloroform	67-66-3	6	8.01E-06	8.01E-06	1.26E-07	1.26E-07	3.18E-05	3.18E-05
15	Acetonitrile	75-05-8	6	7.44E-06	7.44E-06	1.17E-07	1.17E-07	2.96E-05	2.96E-05
16	Acrolein	107-02-8	6	6.80E-06	6.80E-06	1.07E-07	1.07E-07	2.68E-05	2.68E-05
17	Propylene	115-07-1	6	6.79E-06	6.79E-06	1.07E-07	1.07E-07	2.69E-05	2.69E-05
18	Acrylonitrile	107-13-1	6	5.17E-06	5.17E-06	8.14E-08	8.14E-08	2.05E-05	2.05E-05
19	o-Ethyltoluene	611-14-3	4	5.05E-06	5.05E-06	7.94E-08	7.94E-08	2.01E-05	2.01E-05
20	Chloromethane	74-87-3	6	3.37E-06	3.37E-06	5.31E-08	5.31E-08	1.34E-05	1.34E-05
21	Carbon Disulfide	75-15-0	4	2.52E-06	2.52E-06	3.96E-08	3.96E-08	1.00E-05	1.00E-05
22	2-Butanone	78-93-3	6	2.52E-06	2.52E-06	3.96E-08	3.96E-08	1.00E-05	1.00E-05

SI Table 6 summarizes other FTIR-measured compounds not presented in Figure 3 in a similar manner as SI Table 3. Experiments with 30% or fewer measurements above MDC2 are highlighted and italicized. Due to the large fraction of values below MDC2, emission estimates are not included for this table.

SI Table 6: Summary of other FTIR measured compounds.

Analyte Name	CAS Registry Number	FTIR	Test	Number of One-Minute Analyses (N)	MDC2 (ppm)	Percent of analyses > MDC (%)	Arithmetic Mean Wet Conc. (ppm)	Minimum Wet Conc (ppm)	First Quartile Wet Conc. (ppm)	Median Wet Conc (ppm)	Third Quartile Wet Conc. (ppm)	Maximum Wet Conc (ppm)	Arithmetic Mean Conc. Dry Basis (ppm)
Carbon Tetrafluoride	75-73-0	FSA	T1	61	5.00E-03	95	7.28E-03	2.50E-03	6.47E-03	7.06E-03	8.60E-03	1.03E-02	7.55E-03
Carbon Tetrafluoride	75-73-0	FSA	T2	61	5.00E-03	100	1.01E-02	8.52E-03	9.57E-03	1.01E-02	1.07E-02	1.22E-02	1.10E-02
Carbon Tetrafluoride	75-73-0	FSA	T3	61	5.00E-03	100	8.61E-03	7.59E-03	8.21E-03	8.59E-03	8.97E-03	9.84E-03	9.38E-03
Carbon Tetrafluoride	75-73-0	F10	T1	61	6.00E-03	30	6.34E-03	3.40E-03	3.00E-03	3.00E-03	1.38E-02	1.55E-02	6.94E-03
Carbon Tetrafluoride	75-73-0	F10	T2	61	6.00E-03	3	3.30E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03	1.25E-02	3.57E-03
Carbon Tetrafluoride	75-73-0	F10	T3	61	6.00E-03	0	3.00E-03	3.00E-03	–	–	–	3.00E-03	3.25E-03
Carbon Tetrafluoride	75-73-0	F10	T4	61	6.00E-03	0	3.00E-03	3.00E-03				3.00E-03	3.28E-03
Carbon Tetrafluoride	75-73-0	F10	T5	61	6.00E-03	0	3.00E-03	3.00E-03				3.00E-03	3.25E-03
Carbon Tetrafluoride	75-73-0	F10	T6	61	6.00E-03	0	3.00E-03	3.00E-03	–	–	–	3.00E-03	3.28E-03
Hexaflouroethane	76-16-4	FSA	T1	61	3.50E-02	3	1.91E-02	1.75E-02	1.75E-02	1.75E-02	1.75E-02	4.02E-02	2.08E-02
Hexaflouroethane	76-16-4	FSA	T2	61	3.50E-02	25	2.21E-02	1.75E-02	1.75E-02	1.75E-02	1.75E-02	3.80E-02	2.38E-02
Hexaflouroethane	76-16-4	FSA	T3	61	3.50E-02	0	1.75E-02	1.75E-02	–			1.75E-02	1.90E-02
Hexaflouroethane	76-16-4	F10	T1	61	3.50E-02	0	1.75E-02	1.75E-02				1.75E-02	1.90E-02
Hexaflouroethane	76-16-4	F10	T2	61	3.50E-02	0	1.76E-02	1.75E-02				1.75E-02	1.91E-02
Hexaflouroethane	76-16-4	F10	T3	61	3.50E-02	0	1.75E-02	1.75E-02	–	–	–	1.75E-02	1.90E-02
Hexaflouroethane	76-16-4	F10	T4	61	3.50E-02	3	1.81E-02	1.75E-02	1.75E-02	1.75E-02	1.75E-02	2.54E-02	1.90E-02
Hexaflouroethane	76-16-4	F10	T5	61	3.50E-02	2	1.78E-02	1.75E-02	1.75E-02	1.75E-02	1.75E-02	3.38E-02	1.98E-02
Hexaflouroethane	76-16-4	F10	T6	61	3.50E-02	0	1.75E-02	1.75E-02	–	–	–	1.75E-02	1.93E-02
Sulfur Hexafluride	2551-62-4	FSA	T1	61	8.00E-02	0	4.00E-02	4.00E-02	–	–	–	4.00E-02	4.37E-02
Sulfur Hexafluride	2551-62-4	FSA	T2	61	8.00E-02	0	4.00E-02	4.00E-02		–		4.00E-02	4.34E-02
Sulfur Hexafluride	2551-62-4	FSA	T3	61	8.00E-02	0	4.00E-02	4.00E-02		–		4.00E-02	4.59E-02
Sulfur Hexafluride	2551-62-4	F10	T1	61	8.00E-02	21	4.98E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	8.89E-02	5.42E-02
Sulfur Hexafluride	2551-62-4	F10	T2	61	8.00E-02	0	4.00E-02	4.00E-02				4.00E-02	4.35E-02
Sulfur Hexafluride	2551-62-4	F10	T3	61	8.00E-02	2	4.07E-02	4.00E-02	4.00E-02	4.00E-02	4.00E-02	8.04E-02	4.43E-02
Sulfur Hexafluride	2551-62-4	F10	T4	61	8.00E-02	0	4.00E-02	4.00E-02	–	–		4.00E-02	4.37E-02
Sulfur Hexafluride	2551-62-4	F10	T5	61	8.00E-02	0	4.00E-02	4.00E-02	–	–	–	4.00E-02	4.39E-02
Sulfur Hexafluride	2551-62-4	F10	T6	61	8.00E-02	0	4.00E-02	4.00E-02	–	–	–	4.00E-02	4.38E-02
Carbonyl Fluoride	353-50-4	FSA	T1	61	6.00E-01	0	3.00E-01	3.00E-01	–	–	–	3.00E-01	3.27E-01
Carbonyl Fluoride	353-50-4	FSA	T2	61	6.00E-01	0	3.00E-01	3.00E-01				3.00E-01	3.26E-01
Carbonyl Fluoride	353-50-4	FSA	T3	61	6.00E-01	0	3.00E-01	3.00E-01			–	3.00E-01	3.26E-01
Carbonyl Fluoride	353-50-4	F10	T1	61	6.00E-01	0	3.00E-01	3.00E-01				3.00E-01	3.27E-01
Carbonyl Fluoride	353-50-4	F10	T2	61	6.00E-01	0	3.00E-01	3.00E-01				3.00E-01	3.25E-01
Carbonyl Fluoride	353-50-4	F10	T3	61	6.00E-01	0	3.00E-01	3.00E-01			–	3.00E-01	3.25E-01
Carbonyl Fluoride	353-50-4	F10	T4	61	6.00E-01	0	3.00E-01	3.00E-01	–	–	–	3.00E-01	3.28E-01
Carbonyl Fluoride	353-50-4	F10	T5	61	6.00E-01	0	3.00E-01	3.00E-01	–		–	3.00E-01	3.25E-01
Carbonyl Fluoride	353-50-4	F10	T6	61	6.00E-01	0	3.00E-01	3.00E-01	–	–	–	3.00E-01	3.30E-01
Fluoromethane	593-53-3	FSA	T1	61	6.00E-02	3	3.28E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	6.60E-02	3.59E-02
Fluoromethane	593-53-3	FSA	T2	61	6.00E-02	2	3.05E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	6.12E-02	3.31E-02
Fluoromethane	593-53-3	FSA	T3	61	6.00E-02	2	3.05E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	6.58E-02	3.32E-02
Fluoromethane	593-53-3	F10	T1	61	1.10E-01	0	5.50E-02	5.50E-02	–	–	–	5.50E-02	5.95E-02
Fluoromethane	593-53-3	F10	T2	61	1.10E-01	0	5.50E-02	5.50E-02	–	–	–	5.50E-02	5.96E-02
Fluoromethane	593-53-3	F10	T3	61	1.10E-01	0	5.50E-02	5.50E-02	–	–	–	5.50E-02	5.96E-02
Fluoromethane	593-53-3	F10	T4	61	1.10E-01	0	5.50E-02	5.50E-02				5.50E-02	6.02E-02
Fluoromethane	593-53-3	F10	T5	61	1.10E-01	0	5.52E-02	5.50E-02			–	5.50E-02	6.04E-02
Fluoromethane	593-53-3	F10	T6	61	1.10E-01	0	5.50E-02	5.50E-02	–	–	–	5.50E-02	6.02E-02
Difluoromethane	75-10-5	FSA	T1	61	8.00E-02	0	4.00E-02	4.00E-02	–	–	–	4.00E-02	4.37E-02
Difluoromethane	75-10-5	FSA	T2	61	8.00E-02	0	4.00E-02	4.00E-02				4.00E-02	4.34E-02
Difluoromethane	75-10-5	FSA	T3	61	8.00E-02	0	4.00E-02	4.00E-02				4.00E-02	4.35E-02
Difluoromethane	75-10-5	F10	T1	61	1.50E-01	0	7.50E-02	7.50E-02				7.50E-02	8.17E-02
Difluoromethane	75-10-5	F10	T2	61	1.50E-01	0	7.50E-02	7.50E-02	–	–		7.50E-02	8.13E-02
Difluoromethane	75-10-5	F10	T3	61	1.50E-01	5	7.89E-02	7.50E-02	7.50E-02	7.50E-02	7.50E-02	1.58E-01	8.58E-02
Difluoromethane	75-10-5	F10	T4	61	1.50E-01	2	7.94E-02	7.50E-02	7.50E-02	7.50E-02	7.50E-02	1.40E-01	8.36E-02
Difluoromethane	75-10-5	F10	T5	61	1.50E-01	0	7.50E-02	7.50E-02	–	–	–	7.50E-02	8.23E-02
Difluoromethane	75-10-5	F10	T6	61	1.50E-01	2	7.63E-02	7.50E-02	7.50E-02	7.50E-02	7.50E-02	1.57E-01	8.35E-02
Trifluoromethane	75-46-7	FSA	T1	61	1.00E-02	0	5.00E-03	5.00E-03	–	–	–	5.00E-03	5.48E-03
Trifluoromethane	75-46-7	FSA	T2	61	1.00E-02	0	5.00E-03	5.00E-03			–	5.00E-03	5.43E-03
Trifluoromethane	75-46-7	FSA	T3	61	1.00E-02	0	5.00E-03	5.00E-03				5.00E-03	5.44E-03
Trifluoromethane	75-46-7	F10	T1	61	4.00E-02	0	2.00E-02	2.00E-02				2.00E-02	2.18E-02
Trifluoromethane	75-46-7	F10	T2	61	4.00E-02	0	2.00E-02	2.00E-02			–	2.00E-02	2.17E-02
Trifluoromethane	75-46-7	F10	T3	61	4.00E-02	0	2.00E-02	2.00E-02	–			2.00E-02	2.17E-02
Trifluoromethane	75-46-7	F10	T4	61	4.00E-02	0	2.00E-02	2.00E-02			–	2.00E-02	2.19E-02
Trifluoromethane	75-46-7	F10	T5	61	4.00E-02	0	2.00E-02	2.00E-02				2.00E-02	2.20E-02
Trifluoromethane	75-46-7	F10	T6	61	4.00E-02	0	2.00E-02	2.00E-02	–	–	–	2.00E-02	2.19E-02
Ammonia	7664-41-7	FSA	T1	61	9.00E-02	0	4.50E-02	4.50E-02	–	–	–	4.50E-02	4.91E-02
Ammonia	7664-41-7	FSA	T2	61	9.00E-02	0	4.50E-02	4.50E-02				4.50E-02	4.89E-02
Ammonia	7664-41-7	FSA	T3	61	9.00E-02	0	4.50E-02	4.50E-02				4.50E-02	4.90E-02
Ammonia	7664-41-7	F10	T1	61	1.50E-01	0	7.50E-02	7.50E-02				7.50E-02	8.17E-02
Ammonia	7664-41-7	F10	T2	61	1.50E-01	0	7.50E-02	7.50E-02	–			7.50E-02	8.13E-02
Ammonia	7664-41-7	F10	T3	61	1.50E-01	0	7.50E-02	7.50E-02			–	7.50E-02	8.13E-02
Ammonia	7664-41-7	F10	T4	61	1.50E-01	0	7.50E-02	7.50E-02	–		–	7.50E-02	8.20E-02
Ammonia	7664-41-7	F10	T5	61	1.50E-01	0	7.50E-02	7.50E-02				7.50E-02	8.23E-02
Ammonia	7664-41-7	F10	T6	61	1.50E-01	0	7.50E-02	7.50E-02	–	–	–	7.50E-02	8.20E-02
Carbon Dioxide	124-38-9	FSA	T1	61	–	100	5.41E+04	3.58E+04	5.31E+04	5.48E+04	5.56E+04	5.84E+04	5.90E+04
Carbon Dioxide	124-38-9	FSA	T2	61	–	100	5.29E+04	5.08E+04	5.23E+04	5.29E+04	5.37E+04	5.59E+04	5.74E+04
Carbon Dioxide	124-38-9	FSA	T3	61	–	100	5.27E+04	5.04E+04	5.19E+04	5.28E+04	5.34E+04	5.60E+04	5.73E+04
Carbon Dioxide	124-38-9	F10	T1	61	–	100	5.49E+04	3.98E+04	5.49E+04	5.56E+04	5.63E+04	5.85E+04	5.98E+04
Carbon Dioxide	124-38-9	F10	T2	61	–	100	5.38E+04	5.20E+04	5.30E+04	5.35E+04	5.42E+04	5.67E+04	5.81E+04
Carbon Dioxide	124-38-9	F10	T3	61	–	100	5.34E+04	5.13E+04	5.25E+04	5.33E+04	5.41E+04	5.65E+04	5.79E+04
Carbon Dioxide	124-38-9	F10	T4	61	–	100	4.93E+04	4.82E+04	4.88E+04	4.92E+04	4.96E+04	5.13E+04	5.30E+04
Carbon Dioxide	124-38-9	F10	T5	61	–	100	4.91E+04	4.74E+04	4.88E+04	4.90E+04	4.95E+04	5.17E+04	5.35E+04
Carbon Dioxide	124-38-9	F10	T6	61	–	100	4.90E+04	4.79E+04	4.84E+04	4.88E+04	4.94E+04	5.08E+04	5.36E+04

SI Table 7 summarizes canister analysis for selected VOC and fluorinated compounds not presented in Figure 3. These data were produced from same canisters presented in Table 4. The MDLs of the fluorinated compounds are considered approximations since the method is under development. Whereas FTIR produced detections for hexafluoroethane, this compound was not observed in canister data.

SI Table 7. Summary of fluorinated compound canister analysis, acquired at LA

Analyte Name	CAS Registry Number	Tests	Number of Samples (N)	MDL (ppb)	% > MDL (%)	Mean > MDL (ppb)
Toluene	108-88-3	T1-T6	6	0.00	100	1.35
Tert-Butanol	75-65-0	T1-T6	6	0.03	67	1.08
Isobutane	75-28-5	T1-T6	6	0.07	17	0.92
n-Pentane	109-66-0	T1-T6	6	0.01	100	0.77
Methylene Chloride	75-09-2	T1-T6	6	0.01	33	0.72
Tetrahydrofuran	109-99-9	T1-T6	6	0.01	100	0.69
Dodecane	112-40-3	T1-T6	6	0.05	17	0.60
Heptane	142-82-5	T1-T6	6	0.00	100	0.54
n-Decane	124-18-5	T1-T6	6	0.03	100	0.50
Undecane	1120-21-4	T1-T6	6	0.03	100	0.48
2-Hexanone	591-78-6	T1-T6	6	0.01	100	0.47
1,2-Diethylbenzene	135-01-3	T1-T6	6	0.03	100	0.41
n-Hexane	110-54-3	T1-T6	6	0.01	100	0.39
Iso-Pentane	78-78-4	T1-T6	6	0.01	83	0.37
Nonane	111-84-2	T1-T6	6	0.02	100	0.37
trans-2-butene	624-64-6	T1-T6	6	0.02	83	0.36
m-Xylene	108-38-3	T1-T6	6	0.01	100	0.31
p-Xylene	106-42-3	T1-T6	6	0.01	100	0.31
1,3,5-Trimethylbenzene	108-67-8	T1-T6	6	0.02	100	0.28
1,2,4-Trimethylbenzene	95-63-6	T1-T6	6	0.02	33	0.27
o-Xylene	95-47-6	T1-T6	6	0.01	100	0.24
Tetrafluoromethane	75-73-0	T1-T6	6	6.00	0.0	-
Difluoromethane	75-10-5	T1-T6	6	0.50	0.0	-
Hexafluoroethane	76-16-4	T1-T6	6	0.20	0.0	-
Fluoroform	75-46-7	T1-T6	6	2.00	0.0	-
Octafluoropropane	76-19-7	T1-T6	6	0.04	0.0	-
Tetrafluoroethylene	116-14-3	T1-T6	6	0.07	0.0	-
Hexafluoropropene	116-15-4	T1-T6	6	0.10	0.0	-
Hexafluoropropene Oxide	428-59-1	T1-T6	6	0.20	0.0	-
Heptafluoropropyl-1,2,2,2-t	3330-15-2	T1-T6	6	0.10	0.0	-
2H-Perfluoro-5-methyl-3,6-	3330-14-1	T1-T6	6	0.10	0.0	-
Pentafluoroethane	354-33-6	T1-T6	6	0.10	0.0	-
Perfluorohexane	355-42-0	T1-T6	6	0.10	0.0	-
Perfluoroheptane	335-57-9	T1-T6	6	0.10	0.0	-
1H-Perfluoropentane	678-26-2	T1-T6	6	0.07	0.0	-
1H-Perfluorohexane	355-37-3	T1-T6	6	0.10	0.0	-
1H-Perfluoroheptane	375-83-7	T1-T6	6	0.10	0.0	-
1H-Perfluorooctane	335-65-9	T1-T6	6	0.10	0.0	-

Note on Experiment design:

The original FTIR test design called for the controlled injection of small quantities of pure CF_4 and C_2F_4 indicator compounds into the front end of the pyrolysis unit to assist in understanding the C-F bond destruction potential of the pyrolysis/FLOX® system. The three-FTIR setup would allow the indicator compounds and other FTIR-measurable fluorinated PICs to be observed at various points in the process (LA, LB, LC), and used as a tracer to assess system leakage at LD and LE. With full method development, this indicator compound concept may help with comparison of C-F bond destruction efficacy across thermal and incineration technology classes. However, this first field trial of the indicator injection method was not performed due to potential safety concerns. Select FTIR results from LA are presented here.

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Pyrolysis processing of PFAS-impacted biosolids, a pilot study

Eben Thoma is a research physical scientist with EPA's Office Research and Development, Center for Environmental Measurement and Modeling in Durham, NC. His research focuses on characterization of difficult to measure air pollution sources and their impacts using next generation measurement approaches.

Robert S. Wright is a chemist with EPA's Office Research and Development, Center for Environmental Measurement and Modeling in Durham, NC. He is a quality assurance specialist with interests in PFAS and EPA traceability protocols for gaseous calibration standards.

Ingrid George is a research analytical chemist with EPA's Office Research and Development, Center for Environmental Measurement and Modeling in Durham, NC. Her research focuses on characterization of volatile organic compounds in source emissions and development of new instrumentation and analysis methods to characterize near sources impacts.

Max Krause is a research environmental engineer with EPA's Office Research and Development, Center for Environmental Solutions and Emergency Response in Cincinnati, OH. His research focuses on PFAS, landfills, and waste management topics.

Dario Presezzi is a Co-Founder and Chief Executive Officer of Bioforcetech Corporation in South San Francisco, CA. Since 2012 he has been working on developing and implementing systems to divert organic waste from landfills and transform them into valuable products.

Valentino Villa

Valentino Villa is a Co-Founder and Chief Operating Officer of Bioforcetech Corporation in South San Francisco, CA. Since 2012 he has been working on developing and implementing systems to divert organic waste from landfills and transform them into valuable products.

William Preston

William Preston is a chemist with Consolidated Safety Services in Durham, NC. He specializes in advanced gas chromatography and mass spectrometry for characterization of environmental samples.

Parik Deshmukh

Parik Deshmukh is a Principal Air Quality Engineer with AECOM in Raleigh, NC and was formerly with Jacobs Technology in Durham, NC. His research focuses on the development and implementation of innovative environmental technology and characterization of near-source impacts.

Phil Kauppi is the National Director of FTIR Services for Montrose Air Quality Service. He has 23 years of field experience utilizing Fourier transform infrared spectroscopy for characterization of combustion, chemical and many other air pollution sources and emission control technologies.

Peter G. Zemek is a Senior Vice President with Montrose's Research and Development Center for Emerging Technologies and Emerging Compounds in Fuquay Varina, NC and Boston, MA. His research focuses on characterization of difficult to measure air pollution sources, carbon capture technologies, and mitigation of forever chemicals from air, water and soil.

ABSTRACT

Concentrations of per- and poly-fluoroalkyl substances (PFAS) present in wastewater treatment biosolids are a growing concern. Pyrolysis is a thermal treatment technology for biosolids that can produce a useful biochar product with reduced levels of PFAS and other contaminants. In August 2020, a limited-scope study investigated target PFAS removal of a commercial pyrolysis system processing biosolid with the analysis of 41 target PFAS compounds in biosolids and biochar performed by two independent laboratories. The concentrations of 21 detected target compounds in the input biosolids ranged between approximately 2 µg/kg and 85 µg/kg. (ppb) No PFAS compounds were detected in the biochar. The PFAS concentrations in the biochar were assumed to equal the compounds' minimum detection limits (MDLs). The pyrolysis system's target PFAS removal efficiencies (REs) were estimated to range between >81.3% and >99.9% (mean >97.4%) with the lowest REs being associated with

the lowest detected PFAS concentrations and the highest MDLs. No information on non-target PFAS compounds in influent or effluent media or products of incomplete combustion was considered. Selected gaseous emissions were measured by Fourier transform infrared spectroscopy and gas chromatography time-of-flight mass spectrometry to provide additional information on air emissions after process controls. This limited-scope study indicated that additional research to further understand this process is warranted.*Implications*: Development of alternative approaches to manage PFAS-impacted biosolids is of emerging international importance. A commercially operating biosolid pyrolysis process was shown to lower target PFAS levels in produced biochar. Additional research is warranted to understand all potential PFAS transformation emission routes and optimal air pollution emissions control strategies for this technology class.

MELISSA CHESTER

Ms. Purdue asked some very good and relevant questions on March 7th. Among those was the previously mentioned sewer capacity. Also, PFAS, which was basically glossed over and ignored. She also addressed noise concerns.

1. The company stated distances from property owners (incorrectly, as we have measured those distances since) but also vegetation screen. The vegetation there is seasonal tree foliage from mostly poplar trees and some Maple and Oak trees sparsely scattered.
2. The company proposed no sound remediation of mention and this wasn't given a high impact declaration as it should have. They have a steel building with insulated panels- this is not a huge suppressor.
3. The board was also reminded that night that the current solo business in the park Hexion far exceeded the decibel levels alluded to in Town building code, and that (zero) enforcement has taken place even though multiple neighbors have reported complaints. I realize the planning board does not have enforcement duty here, but so should the planning board when considering the noise levels that will surely accompany this chipper.

Town Code is Fifty dB(A) (measured at the real property boundary line) between the hours of 10:00 p.m. and 8:00 a.m.;

100-5 Prohibited acts; exceptions.

4. Unnecessary noise. No person shall make, continue or cause or permit to be made any continued unreasonably loud or unnecessary noise, including any excessive or unusually loud sound which either annoys, disturbs, injures or endangers the comfort, repose, health, peace or safety of a reasonable person of normal and ordinary sensitivities.

This plant has proposed to run round the clock.

Met with Town of Kingsbury Code Enforcement officer about the wood chip (burning) plant in their industrial Park. Since 2015 there have been 15 written noise complaints for exceeding decibel levels in their code.

5 major fire calls to the chip facility as well.

He lives directly across Hudson River and expressed concerns about this project.

Submitted by Tracy Frisch

Assessment by research analyst with Defend Our Health, an environmental health organization in Maine:

At worst, PFAS does not break down with incineration but incineration has been documented to contribute to toxic releases in soil, water, and air (Bennington study). At best, PFAS may break down on incineration but there is (1) insufficient data to support this as an effective method and should not be recommended at this point (EPA technical brief), especially for land application where it is effectively entering the environment and human food systems, and (2) breakdown products such as hydrofluoric acid are toxic chemicals themselves.

Bennington College report at https://www.bennington.edu/center-advancement-of-public-action/environment-and-public-action/understanding-pfoa

"The soil and surface waters around Norlite [hazardous waste incinerator in Cohoes, NY] are laced with PFAS compounds commonly found in AFFF [aqueous fire fighting foam, which is made of a PFAS compound called PFOS]. The results of this preliminary research suggest the burning of AFFF at Norlite is not breaking down these dangerous chemicals so much as redistributing them into nearby poor and working class neighborhoods. Far from destroying the toxins, the Norlite facility appears to be a significant local and potentially regional source of PFAS contamination."

EPA Technical Brief: Per- and Polyfluoroalkyl Substances (PFAS): Incineration to Manage PFAS Waste Streams, 2019:

"EPA is currently considering multiple disposal techniques, including incineration, to effectively treat and dispose of PFAS wastes. EPA researchers are currently studying PFAS incineration, sampling and analytical methods development, and industrial field sampling. Research on thermal stability of PFAS compounds, the ability to fully capture and identify PFAS compounds and their thermal decomposition byproducts, and the efficacy of emission control technologies are areas of targeted research. [i.e., still ongoing and not yet definitive]. These efforts, in cooperation with states and industries, is aimed at proper disposal of PFAS-laden wastes without media-to-media transfer or environmental release [i.e., we don't know yet that this is a safe method for preventing media-to-media release]."

"PFAS compounds are difficult to break down due to fluorine's electronegativity and the chemical stability of fluorinated compounds. Incomplete destruction of PFAS compounds can result in the formation of smaller PFAS products, or products of incomplete combustion (PICs), which may not have been researched and thus could be a potential chemical of concern.

The most difficult fluorinated organic compound to decompose is CF_4, requiring temperatures over 1,400^{O}C, but is easily monitored, making it a potential candidate for destructibility trials. Tetrafluoromethane (CF_4) is a potent greenhouse gas that contributes to the greenhouse effect. It is very stable, has an atmospheric lifetime of 50,000 years, and a high greenhouse warming potential 6,500 times that of CO_2.

The stability of perfluorinated radicals leads to higher concentrations and correspondingly increased propensity to recombine, creating larger molecules that are products of incomplete combustion (PIC) and distinctive from the original fluorinated organics. These reactions are promoted by partial organic combustion resulting from insufficient temperatures, time, and mixing. In addition, the presence of catalytic surfaces, often metals, promotes further reaction and PIC formation in post-combustion regions. This scenario has been most studied related to the formation of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs/PCDFs) in the cool-down regions of waste incinerators.

The effectiveness of incineration to destroy PFAS compounds and the tendency for formation of fluorinated or mixed halogenated organic byproducts is not well understood. Few experiments have been conducted under oxidative and temperature conditions representative of field-scale incineration. Limited studies on the thermal destructibility of fluorotelomer-based polymers found no detectable levels of perfluorooctanoic acid after 2 second residence time and $1{,}000^{0}$C (Yamada et al., 2005; Taylor et al., 2014). Emission studies, particularly for PICs, have been incomplete due to lack of necessary measurement methods suitable for the comprehensive characterization of fluorinated and mixed halogenated organic compounds.
The extent to which PFAS-containing waste material in the United States is incinerated is not fully documented or understood. PFAS compounds are not listed as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) nor as hazardous air pollutants under Clean Air Act regulations, so they are not subject to the tracking systems associated with these regulations.

Incineration may spread, not break down PFAS, Chemical & Engineering News, April 27, 2020. https://cen.acs.org/environment/persistent-pollutants/Incincerators-spread-break-down-PFAS/98/web/2020/04

New data suggest that commercial incineration of per- and polyfluoroalkyl substances (PFAS) doesn't break down these hardy chemicals. Instead, it spreads them into surrounding areas.

"It's the very definition of foolhardy to try to keep burning these things," [David] Bond [Bennington College professor] says of PFAS. "By design, they resist thermal degradation."

Norlite, a company that makes a ceramic aggregate material, operates the Cohoes facility, burning hazardous waste to fire two kilns. Norlite has voluntarily stopped accepting and processing firefighting foam, pending research by the US Environmental Protection Agency.

The US military and nearby states have sent PFAS-containing firefighting foam to the Norlite plant. This facility is one of several across the US that environmental activists are asking a federal judge to shut down.

My name is Tracy Frisch. I am a resident of Argyle, and the founder and lead organizer of the Clean Air Action Network of Glens Falls. I enjoy helping concerned residents prevent and reduce pollution and find Zero Waste solutions, where possible. I do this work as an unpaid volunteer.

While I advocate for Zero Waste, my research indicates that some wastes, such as sewage sludge, are far too contaminated to have any beneficial use.

Tonight I will be speaking about per and poly fluorinated alkyl substances (PFAS) in relation to Saratoga Biochar. Saratoga Biochar claims that its process for making bioochar out of sewage sludge (burning in the absence of oxygen and then using thermal oxidation/incineration to burn off the gases released) will destroy the PFAS, but these claims are premature and are put into question by two recent peer-reviewed studies, an EPA research brief, and other documents I am submitting into the record.

Chemicals in the class known as PFAS contaminated the drinking water in Hoosick Falls, private wells in North Bennington, and due to the use of PFAS fire fighting foam, the drinking water supply at many military bases.

Residents' private wells in North Bennington were contaminated by PFAS emissions coming out of a factory smokestack. PFAS emissions fall to the ground where they then leach through the soil and into groundwater. PFAS chemicals also run off and end up in rivers, lakes, and ponds.

Whenever sewage sludge is tested for the PFAS class of chemicals, PFAS compounds are found as a contaminant. PFAS get into wastewater from consumer and commercial products such as cosmetics, floor cleaner, dental floss, and stain and water repellent coatings on carpets, clothing, food wrappers and other products. PFAS is hazardous to health at extremely low levels. NYS sets 10 parts per trillion as the drinking water standard.

The question I want to address is whether Saratoga Biochar's proposed facility in Moreau would emit PFAS out its stack.

First, let's consider PFAS in sewage sludge. We don't know how much PFAS is in our sewage sludge because NYS DEC has only begun testing it this year. In 2022, I have made 2 FOIL requests to NYSDEC but have not received any data yet. Sewage sludge continues to be spread on farmland in New York without knowledge of its PFAS content.

PFAS in sewage sludge is such a big problem because many PFAS chemicals are extremely persistent in soil and water, and in the bodies of people and other animals. They also bioaccumulate up the food chain.

PFAS chemicals are associated with cancer, both in lab animals and in epidemiological studies. PFAS compounds are also hormone disrupters and they depress the immune system, reducing the effectiveness of vaccines.

My knowledge about PFAS comes from various sources – a multiday conference on PFAS in Boston, webinars, reading. In March a national magazine published my long-form interview on PFAS with the Ohio attorney Rob Bilott, the person who revealed the existence of PFAS and its impacts on people and the environment to the world. Before he obtained important documents through discovery in an important lawsuit, only industry scientists knew much about PFAS chemicals.

By definition PFAS contain both carbon and fluorine atoms. The carbon-fluorine bond is extremely strong and is rarely if ever found in nature. PFAS chemicals were first synthesized after World War II in the 1940s. 3M and DuPont have been major makers of PFAS, but many other companies use them in manufacturing.

There are about 5,000 different PFAS chemicals, yet the common testing method for PFAS only can identify about 30 compounds. This makes accurate testing very difficult. If a facility's testing doesn't find PFAS, it still could be releasing it and polluting the land and water and harming people in the area.

In 2015, DuPont spun off the division that made PFAS into a new corporation named Chemours for liability protection. When the emissions at Chemours factory in NC were tested to determine its total organic fluorine emissions, more than 90% of the compounds detected could not be identified!

Also worth noting is that wells as far away as 25 miles have been found to be contaminated with PFAS from the Chemours factory in NC.

I am submitting 2 scientific studies of the fate of PFAS in the production of biochar from PFAS-contaminated sewage sludge. In both studies, published in peer-reviewed journals in 2020 and 2022, the researchers were unable to determine the fate of the PFAS. That is, they could not account for the total fluorine from the PFAS in the sewage sludge in air emissions, wastewater or the biochar. The fluorine had to go somewhere, but their methods for tracking and measuring it were not good enough. I am also submitting a write up interpreting these studies by an emeritus professor of geology at Columbia University.

In April, I had an hour-long conversation with the lead author of the 2022 paper. That study, by EPA research scientists, attempted to find out what happened to the PFAS from PFAS-contaminated sewage sludge at a commercial biochar facility in California. They scientists concluded that more research is needed. They had hoped to do a follow-up study at the biochar facility in which they would meter out a known amount of fluorine into the pyrolysis unit and then determine its fate, but they couldn't proceed because of safety considerations. Fluorinated chemicals are toxic and could harm the workers and area residents.

This scientist also told me that many details of the proposed biochar facility's design and operation would need to be evaluated to know if it could be effective at controlling PFAS. However the only way to definitively find out what happens to the PFAS and the fluorine in the PFAS would be actual monitoring of a facility. (A typical DEC air permit would not require sufficient testing to find out what is really happening to the PFAS during the biochar manufacturing process.)

The 2020 paper found that that the removal of PFAS in the sewage sludge biochar making process was very spotty and inconsistent. Some common PFAS compounds were removed at 98% efficiency from the biochar, whereas other closely related PFAS were only removed at 1%. These scientists determined that the scrubber waters had substantially increased their content of fluorotelomers, which are partial degradation products of PFAS that are suspected of being powerful toxic substances.

In light of these red flags and these important unknowns, the Moreau planning board should deny this application. If it approves the project, Moreau residents will have to rely on DEC to act.

But we cannot wait for our environmental agencies to protect us. EPA has known about the toxicity of PFAS since 2001, but has been very slow to act and has refused to regulate PFAS as a class. DEC stance is also disappointing. Two DEC officials recently stated that DEC is waiting for EPA's guidance on PFAS in sewage sludge and landfill leachate. They will need a lot of patience. Local residents cannot wait.

I'd like to raise one other concern. Besides PFAS, the presence of heavy metals in sewage sludge is another red flag. In test results I obtained in 2020 from the Glens Falls wastewater treatment plant, sewage sludge cake samples had elevated levels of cadmium (as high as 61.3 ppm in the sludge), lead (up to 174 ppm) and high levels of copper and zinc as well as mercury. Glens Falls closed its sewage sludge incinerator more than 5 years ago because it couldn't meet EPA's strengthened standards for mercury emissions.

If Saratoga Biochar were to make biochar with Glens Falls sewage sludge, would these heavy metals be released into the air or in wastewater, or would they be retained in the biochar? Heavy metals often bind with tiny particulate matter and thus get breathed in. In this way, they can enter the lungs, travel through the blood stream, and in some case, traverse the blood brain barrier. They can also land on soil and in water bodies. These metals accumulate in the soil and in people's bodies. Not a happy outcome.

Here is some info our research analyst pulled together. Hope this is helpful.

---------- Forwarded message ---------
From: **Roopa Krithivasan**

Roopa

PFAS and incineration -- for "biochar" land application

TL;DR - At worst, PFAS does not break down with incineration but incineration has been documented to contribute to toxic releases in soil, water, and air (Bennington study). At best, PFAS *may* breakdown on incineration but there is (1) insufficient data to support this as an effective method and should *not* be recommended at this point (EPA technical brief), especially for land application where it is effectively entering the environment and human food systems, and (2) breakdown products such as hydrofluoric acid are toxic chemicals themselves.

This source is probably the strongest evidence that **incineration will *not* render PFAS-containing waste safe** (firefighting foam, in this case):

- The report doesn't appear to have been published, but the data are available here: https://www.bennington.edu/sites/default/files/sources/docs/Norlite%20Water%20Results%204.25.20.pdf
- Here is a slide deck that's a bit easier to follow (slide 2 is especially helpful): https://www.bennington.edu/afff
- From bennington's summary of the study findings: "*The soil and surface waters around Norlite are laced with PFAS compounds commonly found in AFFF. The results of this preliminary research suggest the burning of AFFF at Norlite is not breaking down these dangerous chemicals so much as redistributing them into nearby poor and working class neighborhoods. Far from destroying the toxins, the Norlite facility appears to be a significant local and potentially regional source of PFAS contamination.*" From https://www.bennington.edu/center-advancement-of-public-action/environment-and-public-action/understanding-pfoa
- CEN coverage: https://cen.acs.org/environment/persistent-pollutants/Incincerators-spread-break-down-PFAS/98/web/2020/04
- If they haven't already reached out, the lead author of this study, **David Bond at Bennington College,** will likely be a helpful resource. He seems to have done the most comprehensive work to date on PFAS incineration, and while his work seems to focus on firefighting foam and air releases, I imagine he's also highly qualified to provide more information on the incinerated product as well. The primary site of his research is an incineration facility in NY (about 40 miles south of Moreau).

Support for taking a precautionary approach from this EPA source: https://www.epa.gov/sites/default/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf
"EPA is currently considering multiple disposal techniques, including incineration, to effectively treat and dispose of PFAS wastes. EPA researchers are currently studying PFAS incineration, sampling and analytical methods development, and industrial field sampling. **Research on thermal stability of PFAS compounds, the ability to fully capture and identify PFAS compounds and their thermal decomposition byproducts, and the efficacy of emission control technologies are areas of targeted research.** [ie, still ongoing and not yet

Petition to deny approval for Saratoga Bio Char Facility in the Moreau Industrial Park

Petition summary and background	Concerned Moreau citizens are in complete opposition to the Saratoga Bio Char proposal to erect a facility and produce Bio Char in in the Moreau Industrial Park
Action petitioned for	We, the undersigned, are concerned citizens who urge our leaders to act now to deny the application and/approval of the Saratoga Bio Char facility in Moreau

Printed Name	Signature	Address	e-mail	Date
MARCIA Boucher	Marcia Boucher	20 Hudson Dr	bouchmo43@gmail.com	4/15/22
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CHARLES GRANGER		11 MARION AVE S.G.F. NY	GRANGERCHARLES@outlook.com	4/15/2022
Stephanie Hodgson	Stephanie Hodgson	11 Sisson Rd. S.Gf. NY	518 338-2003	4/15/22
Sandy Mahoney	Sandy Mahoney	7 Sisson Rd. Moreau	518-361-2119	4/15/22
Michele Ostrander	Michele Ostrander	63 Winterberry Ft. Ed.	micheleostrander @rocketmail.com	4.15.22
Amy Dussault	Amy Dussault	48 Winterberry Lane Ft. Ed.		4.15.22
Randy Dussault	Randy Dussault	48 WINTERBERRY LN	RandolphDussault@Gmail.com	4/15/22
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Lindsey Barton	Lindsey Barton	46 Winterberry lane	lindseycote325@gmail.com	4/15/22
Lauralee Fisher	Lauralee Fisher	44 Winterberry Lane	lauralee_f hotmail.com	4/15/22
Louis Fisher	Lou Fisher	44 Winterberry LN	lou_f@hotmail.com	4/15/22

Printed Name	Signature	Address	e-mail	Date
Roger DeMarsh	Roger DeMarsh	13 Sisson Road		4-16-22
Kathi Bennett	Kathi Bennett	32 Sisson Rd		4-16-26
Gary Bennett	Gary Bennett	32 Sison Rd.		4/16
Cathy Lehmann		9 Robt Rogers Ave.		4/16/22
Tenora Rice		33 - Sisson R.D		4-16-22
Dave Michardi		33 - Sisson R.D.		4-16-22
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Walt Mykins	Walt Mykins	52 Sisson Rd		4/16/22
Nick Mykins	Nick Mykins	52 Sisson Rd		4/16/22
Vicki Hill		1 Michael Rd		4/16/22
Tommy DiDio		20 Park Dr.	(518) 932 5497	4/16/22
Sally Washburn	Sally Wash	78 Feeder Dam		4/16/22
Brian Washburn	Brian Washburn	78 Feeder Dam		4/16/22

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Printed Name	Signature	Address	e-mail	Date
Helen A Wolfe		17 Catherine St SGF NY 12533	hwgardenparty@gmail.com	4/18.22
Constance Bondzinski	C Bondzinski	57 Sisson Rd. SGF	pcbondzinski@gmail.com	4/18/22
Peter Bondzinski	Peter Bondzinski	57 Sisson Rd. SGF	" "	4/18/22
James J. Dorsey	James J. Dorsey	58 Sisson Rd. Moreau	dolphins3374@gmail.com	4/18/22

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Printed Name	Signature	Address	e-mail	Date
Jessica Shiels	Jessica Shiels	8 Winterberry	Jshiels@ymail.com	4/16/22
Dan Shiels		8 winterberry lane	Shiels40@gmail.com	4/16/22
CARRIE TRZASKOS	Carolyn Trzaskos	61 Winterberry Ln.	Carrieinforteduard@gmail.com	4/16/22
Michael Trzaskos	Michael Trzaskos	61 WINTERBERRY LANE	TKos20@hotmail.com	4/16/22
Alison Stidd		28 Sage Lane	alirroberts_19@yahoo.com	4/16/22
Brian Stidd		28 Sage Lane	bstiddcpa@yahoo.com	4/16/22
Bradlee Stidd	Bradlee Stidd	28 Sage Lane	stiddb@sgfcsd.org	4/16/22
Jocelyn Edens	Jocelyn Eden	29 Winterberry Lane	jocelynphy28@gmail.com	4/16/22
Jordan Edens	Jordan A Eden	29 Winterberry Lane	jedens014@gmail.com	4/16/22
Carolyn Maxam	Carolyn Maxam	30 Winterberry Lane	carolyn.stein91@gmail.com	4/16/22
Michael Maxam		30 Winterberry Lane	michaelk.maxam@gmail.com	4/16/22
Eric L Paust	Eric L Paust	9 Sisson Rd	epaust@twc.com	4/18/22

Petition to deny approval for Saratoga Bio Char Facility in the Moreau Industrial Park

Petition summary and background	Concerned Moreau citizens are in complete opposition to the Saratoga Bio Char proposal to erect a facility and produce Bio Char in in the Moreau Industrial Park
Action petitioned for	We, the undersigned, are concerned citizens who urge our leaders to act now to deny the application and/approval of the Saratoga Bio Char facility in Moreau

Printed Name	Signature	Address	e-mail	Date
JAson Hamiston		35 Winterberry Lane Fort Edward 12828	jhamiston10@gmail.com	4/15/2022
Caitlin McIntyre	Caitlin McIntyre	35 Winterberry Lane 12828 FE	cjm_08@yahoo.com	4/15/22
Chris Supernant		21 Winterberry ln. 12828 FE	ChrisSupernant@hotmail.com	4/15/22
Kristin Supernant		21 Winterberry Ln 12828	Kristinleell22@hotmail.com	4/15/22
Roo Padron		19 Sisson Rd 12828	rosie_720@yahoo.com	4/15/22
Jorge Falcon		19 Sisson RD 12828	jefcorp@gmail.com	4/15/22
LISA TOUX	Alison Toux	39 Michael Rd 12828	touxhouse@yahoo.com	4/15/22
Brian Toux	Brian Toux	39 Michael Rd 12828	touxbrian@yahoo.com	4/15/22
AMANDA TOUX		39 MICHAEL RD 12828	amandatoux@yahoo.com	4/15/22
Paige Toux	Paige Toux	39 Michael Rd 12828	paigemarietoux@yahoo.com	4/15/22
Gary Mattison	GARY MATTISO	85 Sisson Rd. FORT Edward 12828		4-16-22
Maria A Pourt	Maria A Pourt	9 Sisson Rd Fort Edward 12828	Bamas@TWC.com	4-18-22

Petition to deny approval for Saratoga Bio Char Facility in the Moreau Industrial Park

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Petition summary and background	Concerned Moreau citizens are in complete opposition to the Saratoga Bio Char proposal to erect a facility and produce Bio Char in in the Moreau Industrial Park
Action petitioned for	We, the undersigned, are concerned citizens who urge our leaders to act now to deny the application and/approval of the Saratoga Bio Char facility in Moreau

Printed Name	Signature	Address	e-mail	Date
Tonya Haywood		3D Sand Hill drive	TonyaHaywood61@gmail.com	5/7/22
Dave [illegible]		Barnmaster Dr	DADMYZ@yahoo.com	5/7/22
William Murphy		2 Jackson RD	wmurphy34@gmail.com	5/7/22
Nikia Eastman	Nikia Eastman	2 Jackson Rd	Nikiamarie@me.com	5/7/22
Vesper McCindle		388 Gurn Springs	VWAKERS3[illegible]@aol.com	5/7/22
Heath McCindle		"	Heathdouglas1274@gmail	5/7/22
[illegible]		2 Balsam Dr. Queensbury NY	dlgking52@icloud.com	5-7-22
John Farrell		68 Helen Dr Queensbury	FARRELDOG6980@GMAIL.COM	5·7·22
Chad Reinemann		254 Gurn Springs Rd Gansevoort	CREINEMAN@GMAIL.com	5/7/22
D Athelan		11 Fernwood Rd	Athelstanpaintings@gmail	
Lynn Atherton		11 Fernwood. Rd	Lynnatherton@gmail.com	5/6/22
Patrick Cronin		13 Balsam Lane	patrickpsu03@yahoo.com	5-7-22

Printed Name	Signature	Address	e-mail	Date
Megan Quinn		202 Reservoir Rd Moreau NY	megquinn89@gmail.com	5/7/22
Nicholas Quinn		" "	" "	5/7/22
[illegible]		53 [illegible] Rd Gansevoort		5/7/22
Emily Boucher		10 Sisson Rd Ft Edward	eboucher118@gmail.com	5/7/22
Matthew Boucher		10 Sisson Rd Moreau		5/7/22
Brad Mosher	Brad I [illegible]	8 Myron Rd S. Glens Falls	—	5/7/22

Petition to deny approval for Saratoga Bio Char Facility in the Moreau Industrial Park

Petition summary and background	Concerned Moreau citizens are in complete opposition to the Saratoga Bio Char proposal to erect a facility and produce Bio Char in in the Moreau Industrial Park
Action petitioned for	We, the undersigned, are concerned citizens who urge our leaders to act now to deny the application and/approval of the Saratoga Bio Char facility in Moreau

Printed Name	**Signature**	**Address**	**e-mail**	**Date**
Melissa Chester	Melissa Chester	1462 Rt 9 SGF, NY 12803	Melisches@yahoo.com	5/9/22
Tara Weaver	Tara Weaver	24 Jacobie Rd SGF, NY 12803	tlweaver222@gmail.com	5/9/22
Lisa Corlew		27 Jackson Rd. South Glens Falls, NY	corlewlisa@yahoo.com	5/19/22
Priscilla Tyner	Priscilla Tyner	58 Blanchard Rd Gansevoort		5/9/22
John Hanlon		461 Gansevoort Rd Fort Edward NY 12828	jcarmyfamily@gmail.com	5/9/22
Cassandra Hanlon		461 Gansevoort Rd Fort Edward NY 12828		5/9/22
Michele Morgan	Michele Morgan	440 Wilton Gansevoort Rd Gansevoort NY 12831	[illegible]5 @ Yahoo	5/9/22
Denise Murphy	Denise Murphy	15 John St. South Glens Falls NY 12803	dfrettdosc@hotmail.com	5/9/22
Marla Jo Nichols	Marla Jo Nichols	31 Hilton Dr. South Glens Falls NY 12803	freespiritmy23@gmail.com	5/9/22
Jennifer Bean	Jennifer Bean	625 Gansevoort Rd SGF NY 12803	jenandjeff04@mail.com	5/9/22
Shelley A. Dion	Shelley A. Dion	5 Mtn. View Dr, SGF		5/9/22
Rebekah Ripley		47 Sweet Rd Gansevoort	ripleybekah@hotmail.com	5/9/22

Printed Name	Signature	Address	e-mail	Date
Beth Parodi	Beth Parody	11 Middleton Dr		5/9/22
DAVE TAFT	David Taft	205 Waite Rd HF		5/9/22
Cindy Hazelton	Cindy Hazelton	567 Gansevoort Rd.		5/9/22
Tina DiBastol		25 Hudson Rd S69		5/9/22
Kevin Hammond		1810 OLD [illegible] RD		5/9/22
Todd Hark		31 Ferry Blvd		5/9/22
Shane Walsh	Shane Walsh	13 Pine Rd SGF		5/9/22
CARY Chamberlain	Cary Chamberlain	16 McGregor Ld 14 SGF		5/9/22
Thomas Cosey		20 John St SGF		5/10/22
TOBI IRWIN		36 BAKER AVE, SGF		5/10/22
Michelle Johnson		45 Gansevoort Fort Edward		5-10-22
Kristie Hooper	Kristie Hooper	2 Woodland Dr. Gansevoort		5/10/22
CHAD MITCHELL		25 PHEASANT WAY		5/10/22
Karen Gladstone	Karen Gladstone	3 Cherry Tree Gansevoort, NY.		5/10/22
Sonja Cormier		8. Preston Ct Wilton		5/10/22
Jennifer Wolfe	Jennifer Wolfe	374 Gurn Springs Rd Gansevoort NY		5/10/22

Printed Name	Signature	Address	e-mail	Date
TANYA TESSITORE		275 White Birch ESTATES FORT EDWARD, NY 12828	tanyatessitore@Yahoo.Com	5/11/22
Tom Knapp		5 Edens Way Gansevoort, NY 12831	AMR2455@yahoo.com	5/11/22
Michael Kelleher		25 Bakerhurst Dr Gansevoort, NY 12831		5/11/22
Stacey Cardinale	Stacey Cardinale	5 Spruce St So. Glens Falls, NY 12803		5/11/22
Anthony Demarco		127 Koren Lane Gansevoort NY 12831		5/11/22
Alyssa Rose	Alyssa Rose	18 Pheasant way South Glens Falls, NY 12803		5/11/22
Marisa Tyree	M Tyree	15 Dorrer Ave South Glens Falls NY 12803		5/11/22
Michael Terry	Michael Terry	186 Petts Rd Gansevoort NY 12831	Mit1777@gmail.com	5/11/22
Leslee Chadwick	Leslee M Chadwick	1550 Route 9 Fort Edward, NY 12828	LmChadwick1@gmail.com	5/11/22
Doreen Kirk	Doreen Kirk	6 Mitten Rd NY So. Glens Falls 12803		5/12/22
Ken Chester	Ken Chester	1662 Rt 9 SGF, NY 12803	Kches2@gmail.com	5/12/22

Printed Name	Signature	Address	e-mail	Date
DEREK Tay	D. Tay	13 WINTERBERRY Ln Morea,	dctaylor8@me.com	4/18/22
Ashley Albrecht	Ashley Albrecht	5 Winterberry Ln Moreau	adoyle1208@outlook.com	4/18/22
Breanne Taylor	Breanne Taylor	13 Winter berry Lane Moreau	breanne.taylor81013@yahoo.com	4/18/22
STEVE MONK		155 HATCHERY GANSEVOORT	docmonn@gmail	4/18/22
Sean Macfarlane		31 Winterberry Ln	SMACFAR@[illegible].com	4/18/22
JORDAN EDDOWS	Jordan Eddows	29 WINTERBERRY LN	n/a	4/18/22
Nan Allen	Nan Allen	15 Michael Rd		4/18/22
Janet Haeger	Jane Hagg	1269 Saratoga Rd.		4/18/22
BRUCE FLAYER	Bruce Flayer	289 Burt RD		5/12/22
VIRGINIA LIVSEY	Virginia Livsey	289 BURT RD		5/12/22

Printed Name	Signature	Address	e-mail	Date
Dianne Sante	Dianne Sante	Qsby 10 Pinion Pine Lane	dbsant@gmail.com	4/15
Sophia Dubrowski	Sophia Dubrowski	171 Sanford Street Glens Falls	SophiaDubrowski@gmail.com	4/15
Osaunia Harr		49 Finch way Queensbury NY 12804	osauniaharr@yahoo.com	04/15/2022
Alexa Quinn		38 Bayview Ave S. Glens Falls NY 12803	alexa.rclarr@yahoo	4/15
Jennifer Markowitz	Jennifer Markowitz	171 Sanford Street Glens Falls NY	jmarkowitz@rocketmail.com	4.15
Bruce Markowitz	Bruce Markowitz	171 Sanford Street Glens Falls NY 12801	ptbruce2@yahoo.com	4/15
Tiger Ling		6 Reginald Dr. Qby NY 12804	tiger.clevin97@gmail.com	4/17
Leora Havel	Leora Havel	639 Saw mill hill rd wells VT 05774	reneeleora12@icloud.com	4/17
Madison Collins	Madison Collins	52 Hendrick St Lake George NY 12845	MadisonMWCollins@gmail.com	4/17
Aydan Cook	ACook		aydanalexis@gmail.com	4/17
Suzy Chhim-Peris			suzanna.chhim@gmail.com	4/17
Lorraine Rosati	Lorraine Rosati	36 Stewart Ave SGF	catails4@yahoo.com	4/18
Bonita Hagan	Bonita Hagan	122 Hunter St. Glens Falls 12801	bbjh62@gmail.com	4/18
Rosann Putnam	Rosann Putnam	94 Byrne Ave Glens Falls, NY		4/18
Susan Ireland	Susan Ireland	36 Sherman Ave GF, NY 12801		4/18
Karen LaVine	Karen LaVine	24 Lupine Lane Queensbury, NY	karenllavine@ hotmail	4/18

Josscelyn Hadden	Joscelyn Hadden	27 Sisson Rd Ft. Edward, 12828	" @yahoo.com 4/18
Peg Kuttner	Peg Kuttner	6 Robertson Ave. 4/18	
John Smith		26 Sisson Rd Ft Edward	
Peter Corlew		7 West Mason Ave	
Roy Waddell		3 Tina Ln Queensbury	
SEAN Sheehan		292 Clark rd GANSEVOORT	
Dan Levo		163 Reynolds Rd	
Chris Johnson	Chris Johnson	5 Deer Run	
Holly Johnson	Holly Johnson	5 Deer Run	
Jennette Hubinger		5 Deer Run	
Laurie LaFord	Laurie LaFord	3 Oakwood Drive, SGF Town of Moreau	
Diane Collins	Diane Collins	33 Thornberry Dr Glens Falls 12801	
Vince Spencer		163 Ft Ed Rd	
Alison Lattimore	Alison Lattimore	6 Iris Ave SGF	
Sherrie Murray	Sherrie Murray	4 Thornapple Drive Gansevoort 12831	
Lawrence Finn		27 [illegible] park	
Deb Siem		PO B 135 Ft Edward NY 12828	

Petition to deny approval for Saratoga Bio Char Facility in the Moreau Industrial Park

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Printed Name	Signature	Address	e-mail	Date
Megh Howard		131 Feeder Dam Rd So Glens Falls	Megh247@hotmail.com	4-23-22
Mike Howard		131 Feeder Dam Rd So Glens Falls	Mdavid@erbessd-instruments.com	4-23-22
Trish Myott		33 Jackson Ave. SGF	trishmyott@gmail.com	4/23/22
Tom Myott		33 Jackson Ave. SGF	tmyottart@gmail.com	4/23/22
Jen Butler	JButler	36. Wynnefield Dr. SGF	jennifer.butler.lmt@gmail	4/23/22
CAHILL BUTLER		" "	CAHILL.BUTLER33@GMAIL	4-25-22
Aliesha Narduzzo		48 Jackson Ave SGF	alieshanarduzzo@gmail.com	4-23-22
Hannah Wilson	Hannah Wilson	48 Jackson Ave SGF	alieshanarduzzo@gmail.com	4-23-22
Britt Creel		522 Gansevoort Ft Edward	brittcreel12@gmail.com	4/23/22
JEFF DONOHUE		14 MERRITT Rd SGF	jdonohue125@gmail.com	5/7/22
Rebecca Towle	Rebecca Towle	1687 W. River Rd	beckylummis@gmail.com	5/7/22

A meeting of the Planning Board for the Town of Moreau, Saratoga County, State of New York was held at the Moreau Town Hall, 351 Reynolds Road, Moreau, NY 12828 on the 12nd day of May 2022 at 7:00 pm.

Attachment 2

The applicant promotes this project as an environmentally friendly means of disposing of municipal sewage.

The project is the first of its kind and will be built by a company that has never built such a facility.

If it works, it might be great. If it doesn't work, it could be awful.

Once permitted, it may be difficult to reverse and may not be monitored as closely as we would hope.

The project warrants careful review to ensure that we don't jeopardize our community's health and that the community can rely on our findings.

The prior negative SEQR declaration was made without the benefit of independent expert advice despite the complicated nature of the project and its potential negative impacts.

So, I move that the Board:

> Determine to rescind the prior negative declaration issued by the Board based on new information;
>
> Notify the other cooperating agencies and applicant of that recission and allow the applicant an opportunity to respond; and
>
> Retain an independent expert to assist it in consideration of this project and the need for an EIS.

The new information in support of this motion consists of the following:

> The excessive wastewater capacity to be used by the Project – 16% of the town's total capacity according to the engineering report dated March; The project also uses significant water capacity in relation to typical water users.
>
> The potential fire risks associated with the storage and handling of biochar on site as noted in the water engineering report dated March and the applicant's revised air emissions permit application.
>
> That the DEC may require additional modifications to the project, such as the increase in the height of the stack from 75 to 100 feet.
>
> Omissions on the applicant's EAF - the emission of 100 tons/year of Nitrous Oxide and the storage of Liquid Nitrogen on site shown now on a drawing in the revised air emission permit application.

There may be other information that could be found in recent project documents that also warrant consideration. The assistance of an expert would be helpful in reviewing that information.

I understand that the applicant is trying something new and credit them for their innovation.

But, at the end of the day, we live here and need to see that the project is done the right way.