ENVIRONMENTAL BIOTECHNOLOGY NETWORK

Biochars for Pollution Prevention WG

[Biochars for Pollution Prevention](#) (Biochar WG)

Led by [Dr Meredith Barr](#), London South Bank University

With the current surge in interest for environmental applications of biochars, the establishment in late 2023 of a group looking at their microbial interactions was timely.

This working group aims to foster knowledge exchange and pathways to impact for academics working on state-of-the-art technologies related to the use of biochar for pollution prevention and environmental remediation – particularly as applied to microorganisms, either in terms of removing, killing, or preventing release of harmful microorganisms, or in terms of seeding bioremediative microorganisms for the purpose of pollutant degradation.

Activity Synopsis

This WG led with a webinar on *[Biochar in Environmental Biotechnology](#)*, with presenters Dr Meredith Barr, London South Bank University; Prof Fred Coulon, Cranfield; and Distinguished Prof Andy Ball of RMIT, Melbourne, Australia.

EB Network Biochar Working Group Inaugural Webinar Slides - 13 Feb

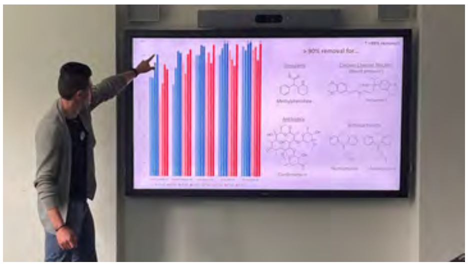
EBNet supported two WG members to attend the 10th International Conference on Engineering for Waste and Biomass Valorisation (WasteEng2024), where they presented their research and promoted the WG, including a session chaired by WG Lead Dr Barr.

This subject area is popular amongst EBNet's Early Career Researchers, with 21 presentations on biochar-related topics at our ECR conferences. In 2022 Dr Anjali Jaykumar, a WG member who also chairs EBNet's ECR Committee, won the overall award for Best Presentation, and used her prize money to attend the AquaConSoil 2023 conference in Prague, Czech Republic.

As part of its networking activity to facilitate knowledge sharing and methodology exchange, the WG organised a laboratory visit to Heriot-Watt University, hosted by Prof Tony Gutierrez.

Activity Synopsis ctd

An article by Lidia Krzynowek and David Vaughan on Biochar, AD and Digestate was published in AD & Bioresources News. Dr Barr also represented the WG at the Environmental Biotechnology and Social Sciences WG's event Exploring The Past, Present and Futures of Environmental Biotechnology as a Field, and gave an invited Provocation putting forward a vision for the future of the field.



WG meeting – presentations and brainstorming for animation

EBNet funded two POCs associated with this WG area in 2020 and 2024.

POC202008 *Bio-engineering of biochar for enhanced remediation of contaminated land*
POC202409 *Elucidating mechanisms of bacterial adsorption to biochar by 3D X-ray image analysis*

On behalf of the group, Dr Szabolcs Pap attended the 2024 European Biosolids Conference, to capture progress in the water sector related to advanced thermal conversation (ATC) technologies and biochar production, and applications for different purposes. His report is available on the EBNet website, and was used to inform plans for a subsequent major workshop.

The WG ran a very successful 2-day workshop on *Integration of thermal, thermochemical, and biological conversion technologies* in London in February 2025. The workshop was jointly funded by EBNet and our sister Network BBNet, with added administrative support from BBNet, and was attended by more than 50 participants. The workshop outcomes will be used to inform research funders and policymakers.

Workshop attendees at a Networking Dinner

Dr Meredith Barr,
London South Bank University
POC202409

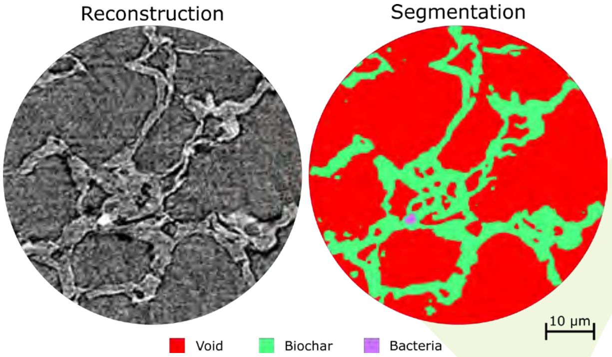
Elucidating mechanisms of bacterial adsorption to biochar by 3D X-ray image analysis

AIM

The environment is a major reservoir for the spread of antimicrobial resistance (AMR). Resistant human pathogens enter the environment via wastewater, which can be untreated due to combined sewer overflows and other bypass events. To avoid resistance spreading in hotspots like combined sewers, and in the environment more broadly, high-risk wastewater (such as that from hospitals) can be filtered using biochar, which adsorbs microorganisms.

Biochar is a carbon-rich material produced from inedible biomass. Its porous structure enables biochar to adsorb bacteria effectively, making it a valuable tool for wastewater filtration while aligning with sustainability goals. This is just one way biochar can interact with microorganisms to reduce pollution. It can both remove harmful microorganisms from, and add helpful microorganisms to, the environment. Biochar can not only filter pathogens from wastewater, but also selectively adsorb them from soil and waterways. It can also seed and promote growth of microorganisms that degrade chemical pollutants or outcompete pathogens.

This project used a 3D imaging technique called X-ray nanotomography to investigate the mechanisms of bacterial adsorption onto biochar. High-resolution imaging enabled detailed characterisation of biochar morphology and its relationship to adsorption of resistant human pathogens. A significant outcome of the project was the development of an innovative image analysis pipeline. Using machine learning-based segmentation tools, the pipeline accurately distinguished bacterial clusters from biochar structures and mapped their spatial distribution. The distinct X-ray attenuation properties of bacteria enabled precise identification of bacterial adsorption patterns within biochar particles.



Results and presentations

RESULTS

The research revealed that specific features of local biochar structure play a critical role in promoting bacterial adsorption. Larger bacterial clusters were primarily found between (rather than inside) plant cell structures in biochar, where porosity was lower and tortuosity higher. This suggests either that larger clusters became lodged in smaller pores, or that they formed by agglomeration following adsorption of smaller clusters in these regions. In either case, results suggest that a mixture of pore sizes relative to the target adsorbate is preferable, ideally with larger openings towards biochar particle surfaces.

The findings provide a clear pathway for enhancing biochar's performance in wastewater filtration and other microbial adsorption applications. By optimising production parameters — such as pyrolysis temperature, feedstock selection, and pre- and post-treatment methods — manufacturers can design biochar with tailored pore structures that maximise bacterial adsorption. These targeted improvements can enhance the efficacy of biochar-based filtration and other adsorption systems, providing sustainable and cost-effective methods to prevent and remediate water and soil pollution.

Dr Tony Gutierrez
Heriot-Watt University
POC202008

Bio-engineering of biochar for enhanced remediation of contaminated land

"Through the synergy of biochar and microorganisms, we can implement a sustainable alchemy, transforming oil-spill impacted soils into fertile grounds, where nature's resilience meets low-carbon solutions for a thriving Earth. It's not just a remedy: it's a testament to our dedication to coexist harmoniously with the planet, nurturing a greener, healthier future for generations to come".
Prof Frederic Coulon, Cranfield University – Co-Investigator

AIM

Based on a 2016 House of Commons report, there are ~300,000 contaminated sites in the UK with an economic value >£1 billion. Meanwhile, progress on remediation technologies has lacked momentum. This project proposes an innovative systematic approach that will marry specific physicochemical properties of biochar with selected bacterial species for enhancing the bioremediation of soils contaminated with persistent priority pollutants.

Our focus is on polycyclic aromatic hydrocarbons (PAHs) and toxic heavy metals (i.e. Ni, Cr, Cd), including the metalloid arsenic (As). These are recognised as some of the most common and important contaminants in UK and European soils. Our approach will lead to new microbe-biochar composites that are tailor-made for the targeted and enhanced bioremediation of polluted soils.

Specifically, this work represents the first synthesis approach taken to evaluate a range of waste feedstock source materials to matchmake biochar with microbes for soil pollution remediation, with state-of-the-art techniques used to characterise the biochar materials to identify which are best suited for colonisation of specific bioremediation microbes.

Efficacy of bioamendments in reducing the influence of salinity on the bioremediation of oil-contaminated soil Atai, E., Jumbo, R.B., Cowley, T., Azuazu, I., Coulon, F., Pawlett, M., 2023. Sci Tot Env, 892, p.164720; Bioengineering remediation of former industrial sites contaminated with chemical mixtures Atai, E., Jumbo, R.B., Andrews, R., Cowley, T., Azuazu, I., Coulon, F. and Pawlett, M., 2023. J Hazardous Materials Advances, 10, p.100319. Evaluating different soil amendments as bioremediation strategy for wetland soil contaminated by crude oil Jumbo, R.B., Coulon, F., Cowley, T., Azuazu, I., Atai, E., Bortone, I. and Jiang, Y., 2022.. Sustainability, 14(24), p.16568.

RESULTS

Several methods were tested using different biochars amended with/without specific microbial species, and it was found that wheat straw biochar combined with two hydrocarbon-degrading bacterial species showed promise in terms of achieving substantial total petroleum hydrocarbon (TPH) reduction. Overall, the study demonstrated how specific combinations of biochar and bacterial strains influenced soil remediation efficiency, particularly in scenarios of recurrent oil spills.

By examining the microbial response and the dynamics between environmental variables, the study provided valuable insights into tailoring effective strategies for managing and remediating oil-contaminated soil in areas prone to repeated spills. Additional experiments are ongoing with a view to produce a generic, bespoke microbe-biochar composite material for the targeted and enhanced bioremediation of polluted soils.

This work endeavours to take a scientific leap in demonstrating biochar as a cheap and effective, carbon negative matrix to marry with microbes for tailored and enhanced bioremediation of contaminated land, which may form the basis of sustainable business opportunities in the UK, Europe and elsewhere on land reclamation.

"There is growing interest in the use of biochars for soil applications including, but not limited to, remediation of contaminated soils. Involvement in this research project is of value to ERS to evaluate the potential technical benefits of biochar-based bioremediation over established bioremediation approaches" .
Dr Tom Aspray, ERS Ltd

Summary of the Integration of Thermal, Thermochemical, and Biological Conversion Technologies Workshop hosted by EBNet's Biochars for Pollution Prevention WG

On 25-26 February 2025, the EBNet Biochar working group led by Dr Meredith Barr hosted a workshop co-funded by EBNet and BBNet to explore how thermal, thermochemical, and biological conversion technologies may be integrated to improve environmental and economic outcomes of waste and biomass valorisation processes. This is a broad topic of growing interest, for which the workshop successfully identified priority areas.

Workshop participants at the networking dinner

Workshop Content

The two-day workshop consisted of three conference-style sessions, each with an introduction by an expert chair, three to four invited talks, and a consensus building activity following a "Café Delphi" format, in which open discussion functioned as the first round of the Delphi process, to identify consensus pathways subsequently ranked by participants according to perceived potential impacts and TRLs.

The 3 session topics were:

1. **Biological pretreatment of thermal and thermochemical feedstocks**, chaired by Prof Jhuma Sadhukhan (University of Surrey, EBNet Co-I, Process Integration and Sustainability Assessment WG lead)
2. **Biochar for microbiome engineering**, chaired by Dr Mark Gronnow (Biorenewables Development Centre Process Development Unit leader, BBNet board member)
3. **Thermal and thermochemical technologies in anaerobic digestion and fermentation**, chaired by Dr Andy Ross (University of Leeds, Institute for Chemical Technology)

Dr Meredith Barr (left), Marc Buttmann of TerraNova Energy (centre), and Prof Ondrej Masek of the UKBRC (right)

The workshop also included a networking dinner on the first night to encourage collaboration-building and concluded with an industry panel discussion used to gather data on existing progress, feasibility, and industrial interest in the different pathways discussed throughout the workshop. The industry panel included representatives from Unyte Group, Inspro, and Colorifix, with additional industry representation among speakers and delegates including Severn Trent, TerraNova Energy, Yorfuel, Anaero Technology, Mono Carbon, ICMEA UK, and Straw Innovations.

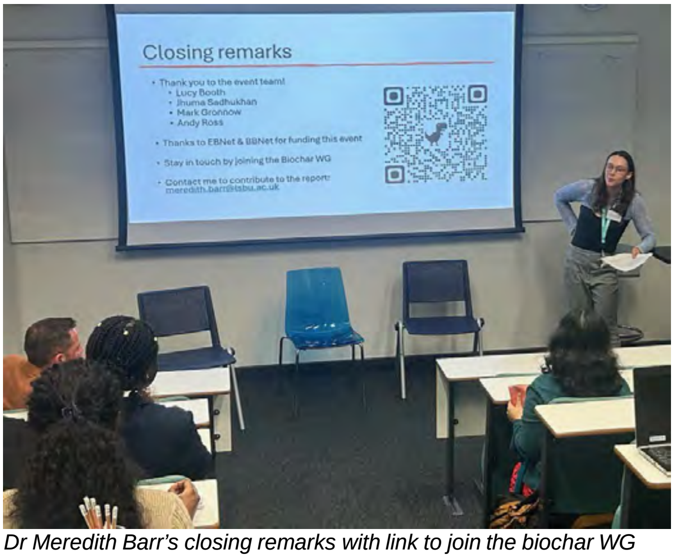
Dr Tony Gutierrez (left) and the industry panel (right)—Jamie Bartley (left), Richard Small (centre), Chidinma Angela Tennison-Omovoh (right)—chaired by Dr Meredith Barr

Preliminary Results

The consensus pathways identified in each session, and highlights of the associated survey results are detailed below. Consensus was built from the contributions of 52 workshop participants, including the host, 16 invited chairs, speakers, and panellists, and 35 competitively-selected delegates whose expertise was judged relevant to the workshop scope.

Session	Consensus Pathways	Survey Highlights
1	Anaerobic digestate hydrothermal carbonisation	Largest market disruption
	Fermentation residue hydrothermal carbonisation	
	Anaerobic digestate pyrolysis	Largest market size, ecological benefits, and waste valorisation potential; highest TRL
	Enzymatic hydrolysate advanced thermal conversion	
2	Contaminated soil bioremediation	Greatest ecological benefits
	Wastewater treatment (including biofiltration)	Largest market size and market disruption
	Anaerobic digestion	Greatest waste valorisation potential; highest TRL
	Agricultural soil microbiome amelioration	
3	Hydrothermal pretreatment for anaerobic digestion	Largest market size and waste valorisation potential; highest TRL
	Digestate thermal conversion	
	Syngas fermentation	Largest market disruption
	Bio/hydro-char in anaerobic digesters and fermenters	Greatest ecological benefits

The industry panel identified overwhelming interest from both industry and academic participants in feeding into the regulatory environment for waste valorisation processes, as well as a desire for more straightforward opportunities for knowledge exchange and research co-production between the two sectors.



Dr Meredith Barr's closing remarks with link to join the biochar WG

Feedback

Thus far, 100% of participants have rated the workshop 5/5 for overall experience and for their likeliness to attend future EBNet and/or BBNet events. Highlights include:

"…an excellent and fruitful exchange of inter-sector views across academia and industry. I hope it broadens in scope and becomes a regular event that can only help the sector grow." -Richard Small, Managing Director and Founder at InsPro

"…such an interesting range of speakers, covering such diverse subject matter whilst bringing academic and industry minds together to identify and discuss the challenges and opportunities in this exciting field of development." -Samuel Dilcock, Director at YorFuel

Future Plans

A report detailing the scope of this field including identified priority areas for research funding, enterprise investment, and regulatory focus will be published in 2025. This will include full analyses of the consensus activities and detailed conclusions of the industry panel discussion. This report will be used to engage funding bodies and policymakers in discussions about the future of integrated conversion technologies.

This workshop identified a strong demand for further events on the topic, especially those focusing on industry engagement, regulatory impact, and enterprise opportunities.

Dr Meredith Barr

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On behalf of the workshop participants

Environmental Biotechnology Network www.ebnet.ac.uk

Biomass Biorefinery Network www.bbnet-nibb.co.uk

European Biosolids & Bioresources Conference & Exhibition

Report for the Working Group: Biochars for Pollution Prevention

Dr Szabolcs Pap, University of the Highlands and Islands

In Brief

I recently represented the Environmental Biotechnology Network's 'Biochar' Working Group (BWG) at the annual European Biosolids & Bioresources Conference & Exhibition (https://european-biosolids.com). The conference took place on 19-20 November 2024 in Manchester. It covered a broad range of topics, within the fields of biosolids management, circular economy, advanced thermal conversation (ATC) technologies and biochar, with more than 300 attendees from the bioresource and biowaste processing sector (both industry and academia) from Europe, North America, Australia and Asia. My main interest was to capture progress in the water sector related to ATC and biochar production, and applications for different purposes. Biochar is recognised as a greenhouse gas removal technology and it has been suggested that application of biochar to agricultural soils may provide agronomic benefits alongside carbon sequestration.

The benefits of this Conference for EBNet cannot be overstated. I strongly believe that this conference helped me and EBNet to develop new links and collaborations with researchers and industry representatives worldwide, facilitating broader benefits to the wider EBNet community. The conference summarised much of the ongoing UK research in the field of ATC technology and biochar, and the general conclusion was that immense progress had been achieved in the past few years, and that industry/stakeholders are keen to implement ATC within their biosolid management. Additionally, biochar is gaining momentum in the UK, which is reflected through its implementation not only as a soil amendment but as an adsorbent in water treatment, and its use in construction/building materials..

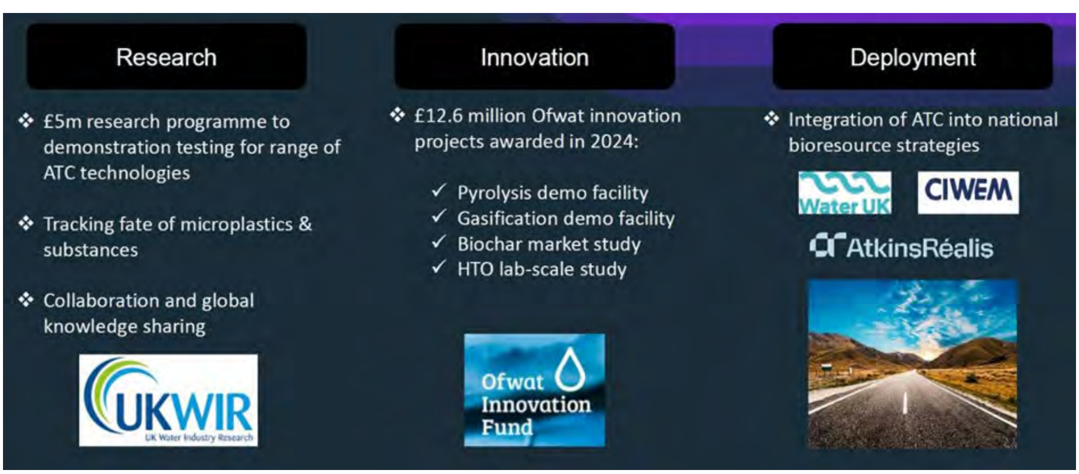

Figure 1. UK outlook for ATC and biochar (source: Stephen Riches, Atkins Réalis)

The conference content has also informed and acted as a preparatory base for the Biochar WG joint workshop which explores how thermal, thermochemical, and biological conversion technologies may be integrated to improve environmental and economic outcomes within waste and biomass valorisation processes.

Main Takeaways (1)

During the two-day conference, the following key points were noted:

FIDRA stated that current agricultural use of biosolids is not managed in an entirely safe and environmentally beneficial way. UK and EU regulations must be updated urgently. Biosolids are expensive to handle/destroy, regulations are tightening, and there is too much volume. One major concern related to the fate of persistent organic pollutants such as flame retardants (PFAS and PFOS) and microplastics. Up- and down-stream biosolids solutions were required, with ongoing commitments to invest in research and innovative new technologies which will achieve safe and clean biosolids or products from it (i.e., biochar). ATC technologies were one of the major topics discussed throughout the conference.

Oda Svennevik from VOW (world-leading Norwegian company in biomass and waste conversion) concluded that pyrolysis without anaerobic digestion (AD) represents the most eco-friendly treatment for biosolids because of its climate change benefits, C-storage (through biochar), energy benefits and potential to reduce contaminants and ecotoxicological impacts. It was highlighted that pyrolysis ≥ 600 °C decomposed flame retardants and that a biochar can also act as an effective PFAS sorbent. Findings are published in the following papers:

- *Sewage sludge biochars as effective PFAS-sorbents* By Katinka M. Krahn *et al.* In Journal of Hazardous Materials. Volume 445, 5 March 2023, 130449.
- *Eco-toxicological and climate change effects of sludge thermal treatments: Pathways towards zero pollution and negative emissions* By Marjorie Morales *et al*. In Journal of Hazardous Materials. Volume 470, 15 May 2024, 134242.

Bill Barber from CAMBI (leading global provider of thermal hydrolysis solutions for biosolids and organic waste management) challenged the ATC processes for their high energy demand and carbon footprint and stated that direct land application of sludge cake from thermal hydrolysis had multiple environmental benefits, including increased digester throughput, boosted biogas production, and minimal waste and operational costs. Also, he highlighted that by moving away from land application, the intrinsic value of biosolids is lost. An interesting point was raised during the discussion, namely that PFAS does indeed pose health concerns in drinking water, however, PFAS in biosolids is very low (when compared to other everyday materials such as food containers, paper products, carpets, sports equipment, electronic components, etc.) and therefore, the strong focus on PFAS in biosolids is unjustified.

The FIREFLY project (funded by the OFWAT Innovation catalyst) outlined the potential use of biosolids for simultaneous aviation fuel and biochar production using hydrothermal liquefaction (HTL). The process successfully reduced PFAS levels in the produced biochar.

Christian Wieth from AquaGreen (a Danish engineering company, specialising in biosolid pyrolysis) made an interesting statement about biosolid-based biochar production costs. Alongside the rapid evolution of pyrolysis units in the past few years (which has driven production costs down), if biochar is used for water treatment (e.g., PFAS removal from water through filtration), further cost reductions could be achieved because biochar could replace expensive activated carbons (which can cost up to £4000/tonne). This could lower the effective 'cost' of biochar production 10-fold.

Cont…

Main Takeaways (2)

Ross Wilson from Scottish Water and Grant Hemple from Atkins Réalis presented data on the new Alloa based Resource Recovery Facility operated by Scottish Water. The facility aims to ask if new technologies can be retrofitted to WWTPs and will assess the benefits, impacts and market for the recovered resources. The facility focuses on 5 different materials/technologies.

- Screenings – project with Carbogenics (pyrolysis to biochar).
- Grit – project with Brewster Brothers (no technical intervention required).
- Cellulose – project with Purgatoria and Icabus (fermentation to green chemicals).
- Algae – project with Greenskill Environmental Technology and James Hutton Institute (photobioreactor for algae production).
- Biocrude Oil – project with Circlia (HTL technology) and Strathclyde University.

The Microplastics & Advanced Thermal Conversion Project also presented. This project is part of the Chemical Investigations Programme (CIP) and is funded by UK water and sewage companies. CIP is administered by UK Water Industry Research (UKWIR), which is responsible for facilitating and shaping a research agenda, developing the programme, the management of research, and the dissemination of findings. The project is part of CIP4, which builds on research from previous investigations, specifically the observation that 99% of microplastics within wastewater effluents partition into sewage sludge.

The project aims to enhance understanding of ATC, to explore the ability to remove microplastics and other key substances (such as flame retardants), from all outputs and develop understanding of the wider environmental impact from a transition to ATC strategies and away from currently deployed strategies. Additionally, in 2024, OFWAT awarded four ATC-themed projects a total of £12.6 M in Round 4 of the Innovation Challenge. Figure 1 shows the structure of these projects.

Finally, DEFRA recently carried out an evidence assessment of the impacts of biochar application to UK agricultural soils. This was a follow up to a report published in 2009. It concluded that biochar is an effective method for sequestering C in a stable form and may be used as a GHG removal strategy, however, in temperate regions (such as the UK), there is limited evidence that biochar can improve soil quality and crop yield. Effects are variable dependent upon application rate, soil type and chemical and structural properties of the biochar. Further research on ATC processes and biochar is needed.

Cite as: Szabolcs, P., 2025. European Biosolids & Bioresources Conference & Exhibition - Report to the EBNet Working Group: Biochars for Pollution Prevention https://ebnet.ac.uk/wg-details/wg-biochar/.

Contact:

Biochar WG https://ebnet.ac.uk/wg-details/wg-biochar

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Representing EBNet Biochars for Pollution Prevention WG at the 10th International Conference on Engineering for Waste & Biomass Valorisation

Introduction

Two members of the EBNet Biochars for Pollution Prevention Working Group (WG) attended WasteEng2024 in Sendai, Japan where they gave two oral presentations, chaired a session, and presented a poster for a third working group member who could not attend.

Report from Dr Meredith Barr

Dr Meredith Barr, who coordinates the working group, presented her research on "Lignocellulosic and Poultry Litter Biochars as a Two-Pronged Approach to Plant Nutrient Regulation". This work focuses on controlling nutrient concentrations in soil using a combination of animal-waste-derived biochars as a slow-release fertilizer and plant-waste-derived biochars as a sorbent material. Adsorbing excess nutrients from soil and releasing them only as required by plants prevents pollution of waterways by excess nutrients from agriculture. Nutrient pollution results in algal blooms that shade and kill submerged plants, whose decomposition alongside that of the algae itself consumes oxygen vital to the survival of all aquatic organisms. Some algal blooms also produce toxins that threaten human health. Regulating soil nutrients controls the growth of aquatic (micro)algae in order to preserve the aquatic ecosystem critical to maintaining water security and aquacultural productivity.

Moreover, controlling nutrient concentrations in soil facilitates engineering the soil microbiome, ensuring plant health, agricultural productivity, and thereby food security.

The work Meredith presented considers how pyrolysis conditions affect the selectivity of nutrient leaching and sorption. Her group is investigating how the way in which biochars are produced affects which nutrients they release and immobilise in soil, which in turn affects their influence on the soil microbiome.

Poultry litter, being readily available on farms, is itself widely used by farmers as a fertiliser (in some cases so excessively as to be responsible for severe nutrient pollution in nearby waterways). When converted to biochar, nutrient release is not only slowed, reducing the risk of nutrient pollution, but poultry litter is also sterilised, neutralising the threat of pathogen pollution. Introducing pathogens from animal waste to agricultural land is a hazard to plant and human health with long-term effects on the soil microbiome. By pyrolysing this natural fertiliser, Meredith's research group engineers the composition of the soil microbiome by allowing symbionts to outcompete the far smaller concentrations of pathogens naturally introduced by wildlife. This work fits squarely within the EBNet Pollutants and Media theme, incorporating elements of engineering microbial systems at the Water-Wastes-Soil nexus. The research aims to prevent both soil and water pollution by valorising waste via control of environmental microbiota.

Outreach

Meredith also chaired a session on waste and biomass gasification. She invited the audiences of both her presentation and this session to join the EBNet Biochars for Pollution Prevention working group. Attendance of this conference as enabled by the travel bursary generously provided by EBNet has resulted in the discussion of several new collaborations as well as identification of a future conference of potential interest to working group members (Bio-Char IV).

Representing EBNet Biochars for Pollution Prevention WG at the 10th International Conference on Engineering for Waste & Biomass Valorisation

Report from Dr Paul-Enguerrand Fady

In August 2024, I travelled to the WasteEng2024 conference held Sendai (Japan) thanks to a generous travel bursary provided by EBNet. I was fortunate enough to be selected to present an interdisciplinary research project which arose from a collaboration between three members of the EBNet-funded "Biochars to Prevent Pollution" working group, led by Dr Meredith Barr. WasteEng2024 proved an excellent vehicle for disseminating our findings, as well as connecting with international experts in the fields of waste engineering and biochar applications.

The work in question concerns the design and development of bespoke biochars derived from waste lignocellulosic biomass, to create novel wastewater filters which remove both antimicrobial compounds and multidrug-resistant bacteria. This is an exciting application of technology to biological waste streams which contributes to the remediation of bacterial antimicrobial resistance (AMR). Bacterial AMR is a very serious health threat, directly responsible for 1.27M deaths/annum and linked to almost 5M deaths (as of 2019). The costly and inefficient development of new antimicrobials will not suffice to stem the rise of AMR, and novel solutions such as the one developed and tested by the three working group members are key to tackling this threat.

I presented our findings, which show (among other things) that upwards of 95% of specific drug-resistant clinical bacterial isolates and 91% of clarithromycin (an antibiotic which drives AMR development) can be removed from wastewater through inline filtration with our system. This was a fairly unique presentation at WasteEng, which was attended by few microbiologists and even fewer colleagues with clinical expertise. The presentation was well received and acted as a good catalyst for discussions around precision applications of biochars.

This project links applied microbiology (using patient-derived clinical strains) with engineering and systems optimisation of biochars from agricultural waste. Our work on fine-tuning the ability of biochars to sequester bacteria has a range of exciting applications at the water-wastes-soil nexus, including this preventative application but also developing a better understanding of the production conditions which could be employed in remediative soil applications (e.g. soil microbiome seeding). WasteEng2024 provided an excellent sandbox for exploring these thoughts with colleagues from all different disciplines.

Contact

Dr Meredith Barr, LSBU

BIOCHAR, AD AND DIGESTATE

Biochar has the potential to boost AD production, sequester carbon, improve soil health and increase crop yield. **Lidia Krzynowek** and **David Vaughan** introduce this ancient yet modern material.

The use of biochar can be traced back to ancient civilisations such as the Amazonians, who practiced slash-and-char agriculture. Today it is enjoying a renaissance and being hailed across a raft of applications.

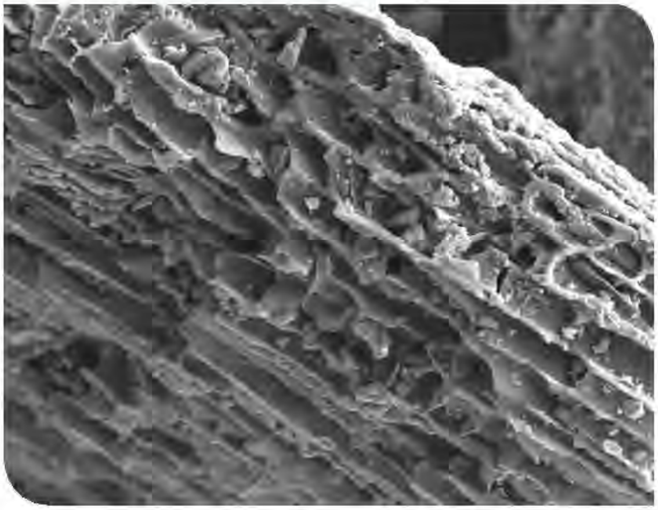
Biochar is a special kind of charcoal made from organic materials like wood chips, agricultural waste and secondary biomass products. It is made through a process called pyrolysis, which involves heating the organic material in a zero-oxygen environment to produce biochar and renewable energy.

The physiochemical properties of biochars can vary dependent upon different parameters e.g. feedstock and production temperatures. This means not all biochars carry the same characteristics and can, therefore, be produced to be optimal for a given application. Quality and customisation are paramount in harnessing the full potential of biochar, to meet the distinct requirements of various applications and ensure consistent quality.

Biochar is perhaps best known for its ability to improve soil health and fertility. Among the key physicochemical properties of biochar are its porous structure and high surface area. Typically, biochar boasts a surface area of 100-500m^2/g. As such, a single gramme of char has roughly the same surface area as a tennis court.

When added to soil, it helps retain moisture, nutrients, and beneficial microbes, which can enhance plant growth. It also helps reduce greenhouse gas emissions by sequestering carbon in the soil, which can contribute to combating climate change.

The carbon in biochar is highly stable and can endure in soils for thousands of years without being degraded by microorganisms. When produced to meet quality standard i.e. European Biochar Certification (EBC standard) biochar represents a long-term CO_2 sink that can sequester carbon in the soil virtually indefinitely. This makes biochar a promising Carbon Dioxide Removal (CDR) technology that can contribute to the mitigation of climate change and help work towards net zero goals.



Biochar, after organic material has been treated in a patented drying and pyrolysis oven known as PyroDry

At the time of writing, one tonne of biochar-based carbon fetched between €100 and €500 on the voluntary carbon trading platform Puro.Earth. The additional income from carbon credits can enable biochar makers to offer their product at a lower price, thereby contributing to the economic viability of the biochar industry.

Biochar and AD

As AD is often likened to tending an animal, it is perhaps telling that biochar is already in use as a feed additive for a range of farm animals including cows, pigs and poultry, where it can prevent or treat digestive problems. This leads to improved feed conversion and hence to faster weight gain and better meat quality.

Continued>>

BOOSTING MICROBIAL COMMUNITIES IN AD

There is lots of ongoing research around how biochar mediates several bio-electrochemical interactions, including in the AD process, especially by mediating and even accelerating (bio)-electrochemical interactions such as Direct Interspecies Electron Transfer (DIET).

DIET is a microbial interaction mechanism in which different species of microorganisms exchange electrons directly between each other as part of their metabolic processes. In microbial communities, DIET enables the transfer of electrons from one microorganism to another without the need for intermediary molecules such as hydrogen or formate.

In DIET, certain microorganisms possess the ability to form conductive structures, such as pili or nanowires, which facilitate the transfer of electrons between cells. These conductive structures act as conduits, allowing electrons to move from the electron donor microorganism to the electron acceptor microorganism.

DIET is particularly significant in anaerobic environments, such as those found in sediments, wastewater treatment systems, and the gastrointestinal tracts of animals, where microbial communities play crucial roles in biogeochemical cycling and organic matter degradation.

By facilitating direct electron transfer between different microbial species, DIET enables more efficient energy metabolism and enhances the overall metabolic capabilities of microbial communities. This mechanism has implications for various biotechnological applications, including bioenergy production, bioremediation, and wastewater treatment.

Understanding and harnessing DIET could lead to the development of novel strategies for sustainable energy production and environmental management. **Dr Anjali Jayakumar** *Lecturer in Chemical Engineering, Fellow of the Higher Education Academy, Deputy Degree Program Director MSc Sustainable Chemical Engineering, Newcastle University*

Similarly, biochar of high quality and designed to meet key specifications can enhance the performance of anaerobic digestion (AD) plants in several ways:

Improving Digestion Efficiency: Adding biochar to the AD process can increase the surface area available for microbial colonization. This provides a habitat for beneficial microorganisms that help break down organic matter more efficiently, thus enhancing digestion rates and overall biogas production.

Buffering pH Levels: Biochar has a neutral to slightly alkaline pH, which can help stabilize pH levels within the AD system. This buffering capacity can mitigate fluctuations in pH that may occur during digestion, maintaining optimal conditions for microbial activity and biogas production.

Reducing Inhibitory Compounds: Biochar has been shown to adsorb or immobilize certain inhibitory compounds present in the feedstock or produced during digestion, such as ammonia and fatty acids. By reducing the concentration of these inhibitory substances, biochar can improve the stability and performance of the AD process.

Enhancing Methane Yield: Studies have indicated that the addition of biochar to anaerobic digesters can increase methane yield per unit of feedstock input. This improvement in methane production efficiency can result in higher biogas yields and greater energy generation from AD plants.

Finally, **Enhancing Nutrient Recycling:** Biochar acts as a carrier for nutrients and helps retain essential elements like nitrogen, phosphorus, and potassium during the digestion process. This nutrient retention capability of biochar can improve the quality of the digestate produced, making it a more effective fertilizer for agricultural use. It could also have the potential to reduce leaching of nutrients when digestate is added to soils, but this will require additional biochar incorporation after the digestion process. The production parameters may not need to be as specific as for the AD process-enhancing char.

Overall, incorporating biochar into anaerobic digestion systems has the potential to optimize process efficiency, increase biogas production, and improve the quality of digestate, thereby contributing to the sustainability and effectiveness of AD operations (see Boosting Microbial Communities in AD).

Future options

Biochar is an old material, but a relatively young market, with extensive research being conducted into its possible uses. Due to its diverse attributes, biochar has found itself connected to a lot of potential markets.

One line of research being carried out is on circular economy approaches such as the Sequential Biochar Systems, where several thermochemical and biological pathways are efficiently integrated to valorise waste biomass. These include the use of biochar in water or air purification followed by its use in AD. Ultimately, at the end-of-life, the spent biochar finds application in soils, ensuring that the biochar from each step is tailored for the next. This not only generates more revenue strands, but also reduces the carbon footprints of each application.

In a recent EB Network webinar on biochar, hosted by the Biochars for Pollution Prevention Working Group, Distinguished Professor Andy Ball from RMIT University (Royal Melbourne Institute of Technology) outlined a study which showed that the addition of biochar generally enhanced the removal of petroleum hydrocarbons from contaminated soils, but that the biochar pyrolysis temperature, biochar application dose and fertiliser dose affected the hydrocarbon removal efficacy. The study has been demonstrated at pilot scale in Singapore.

ECOCHAR FROM DIGESTATE

At the time of going to press, Carbogenics announced it had won Innovate UK funding to undertake research into a new product derived from the pyrolysis of digestate, EcoChar (Emission Control Organic-Char). The project seeks to validate the potential for EcoChar to be used as a low-cost, efficient and eco-friendly alternative to traditional Anaerobic Digestion (AD) lagoon cover materials.

The Clean Air Strategy aims to tackle emissions from open slurry and digestate stores, mandating the use of emission abatement measures, particularly for lagoons currently exposed to the elements.

While new constructions will require fixed covers, existing infrastructure can utilise various options, including organic layers of lightweight aggregates. Biochar is one, which can not only suppress emissions but can also serve as a fertiliser and soil conditioner, contributing to carbon sequestration.

Professor Fred Coulon of Cranfield University explored the bioremediation concept further by describing work they are doing using biochar from sewage sludge pellets and wheat straw pellets which had been dosed ("bioaugmented") with microbes, including *Bacillus sonorensis* and *Pseudomonas aeruginosa*. These were applied to remediate soil contaminated with crude oil. They found that the bioaugmented biochars degraded the total petroleum hydrocarbons (TPH) more effectively than the plain biochar.

As with any new product, some of these applications will need to overcome legislative hurdles and it remains to be seen under which scheme that biochars will be certified in the UK. Biochar is a growth industry and is set to play a large role in tackling climate change, the race to net zero and carbon sequestration.

Lidia Krzynowek is COO-Cofounder and David Vaughan R&D Director at Carbogenics.

INTERESTED IN BIOCHAR?

Join the Environmental Biotechnology Network Biochars for Pollution Prevention Working Group, led by Dr Meredith Rose Barr, Lecturer, Division of Chemical and Energy Engineering, London South Bank University. Read more about the working group here https://ebnet.ac.uk/wg-details/wg-biochar, where you can also view research papers and view our webinars and upcoming events.

INTERESTED IN FINDING OUT MORE ABOUT USING BIOCHAR IN YOUR DIGESTER?

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