

The BioComposites Centre **ANNUAL REPORT 2022**



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BEACON
From plants to products
O blanhigion i gynhyrchion



Llywodraeth Cymru
Welsh Government



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BC Annual Report 2022

Welcome and Introduction

Our focus for 2022 was on recovering from the pandemic and building on our successes. Catching up on delayed research projects, renewing our network of partners and securing new commercial projects were our top three priorities.

Successes have included the strengthening of our international links with our partners in Uganda and Malaysia and securing £1M worth of investment from Welsh Government for new equipment. Our international networks will help expand the impact of our research and the new equipment will improve our capacity for collaborative research.

At our Pilot Scale facility at Mona we have upgraded the control systems for the pressurised refiner, added new pumps and we hope to replace the steam boiler in 2023. With these improvements we attracted new project partners and expanded our offer to the forest product sector.

Our research areas continue to grow, we have expanded our links with Bangor University's Research Farm and in 2022 we had new projects in the Agritech sector. These have helped to increase the R&D for local companies in partnership with major UK businesses. Driven by the development of a UK fibre-based packaging sector aiming to replace plastic with cellulose fibres, we have seen an increase in pulp and paper research.

This year Bangor University was ranked No1 in the UK for its research impact in the Environmental sector and we helped to achieve this through our links to industry. Bangor University has one of the largest groups of environmental scientists in the UK and we are working together on a range of challenges from reducing microplastics in soils to Life Cycle Assessments (LCA) of wood-based materials.

In early October we faced a new challenge! The University had to take immediate action and close the building where our office and labs were based, ready for its demolition.

During the last three months of 2022 we were occupied with relocating our equipment, setting up new offices and

identifying new labs. This was achieved in a very short timeframe, and it is a great testament to our ability to work as a team. I would like to thank all the efforts of everyone involved; from packing glassware, to working with contractors and consultants and helping plan and coordinate all these tasks.

With our great team and new equipment, we will continue to develop and expand our research, we will increase our links with industry and work within the regions to help Wales and the UK deliver on its net zero carbon ambitions.

Dr Rob Elias, Director of the Biocomposites Centre



Dr Rob Elias: Director

National and International Funded Projects

Seed Treatments for a More Sustainable Future (Equippe)

A more sustainable and eco-conscious method of treating vegetable seeds is the focus of a multi-partner research project involving one of the UK's largest seed producers and Bangor University.

Tozer Seeds have linked up with the University's Biocomposites Centre to develop alternative seed treatments which are aiming to control disease as well as improve suitable characteristics for germination and crop establishment.

The 18-month project, funded via the UK Government's Farming Innovation Pathways programme, will see celery, parsnip, and coriander seeds treated with lasers and natural bioactive compounds.

The strategies are aiming to not only disinfect seeds of disease-causing pathogens, which can lead to large volumes of wasted crops, but improve the rate of germination, seeding establishment, growth rate, and crop yield.

Bangor University's Biocomposites Centre has assisted the development of the proposed treatments, with an

initial focus on optimising the strength of the bioactive compound and the power and treatment time of the laser. The laser seed treatment work is led by Dr Zengbo Wang's team at the School of Computer Science and Electronic Engineering.

The first round of testing and laboratory work is currently underway, with the most promising seed treatments to be evaluated by grower partners which form part of Surrey-based Tozer Seeds' supply chain.

Group research and development manager at Tozer Seeds Dr Matthew Walker showcases some of the seeds which will be treated with lasers and natural bioactive compounds by Bangor University's Biocomposites Centre as part of the research project.

Producers Medwyn's of Anglesey, G's Group, and Strawsons will contribute to the initiative, providing industry knowledge and growing space.

Group research and development manager at Tozer Seeds Dr Matthew Walker said:

"A plant is at its most vulnerable during the early stages of its development, and the application of an approved pesticide to the seed helps it through the germination process and can lead to a good seedling establishment and ultimately a higher crop yield.

"We are testing new methods of treating seeds, which can both improve plant growth and remove seed-borne diseases as well as having the potential to reduce our reliance on conventional pesticides.

"We look forward to working alongside Bangor University and the rest of our supply chain to ensure these innovations can be implemented across the board."

The treating of seeds, often utilising pesticides, is a common practice in commercial agriculture due to its effectiveness in fending off early-stage diseases and insects.

While the research is focusing initially on three crops, it is expected that if the treatment is successful, it may also be applicable to other seeds.

As part of the project, Bangor University has also worked with Medwyn's of Anglesey to gain access to additional research and development resources as part of the BEACON programme.

The initiative links Welsh universities with Welsh



Dr Radak Braganca (BC) with project partners inspecting new seedlings grown from seeds that had been treated during the project.

National and International Funded Projects

industry to develop a more sustainable Wales through the development of bio-focused products, services and technologies and is funded from the European Regional Development Fund through the Welsh Government.

Director of Bangor University's Biocomposites centre Dr Rob Elias said: "This is a project which needs every single link of the supply chain to pitch in; working alongside established industrial growers and producers to bring this to a reality is incredibly exciting.

"Increasing access to research and development for business is also important for this sector, particularly in Wales, and we are thrilled to have helped support this through the BEACON project. This is a great example of impact and helping to increase the level of R&D in Wales to back the bioeconomy sector and local producers."

For more information on Tozer Seeds, visit www.tozerseeds.com.

Down on the Farm-Potato Blight

An Interreg Atlantic funded project that has helped companies develop their bioactive compounds to replace conventional chemical interventions in agriculture concluded in December 2022. The four-year project, called NASPA, developed a network of field test locations across Europe enabling companies to test and validate their new products against a range of diseases.

The project lead was Dr Radek Braganca and he has helped set up a number of new networks that have helped the project partners test and validate their products. This has really helped the project partners gain some useful scientific data that can be utilised to develop their markets, explained Radek.



Dr Ahmad Al-Dulayymi preparing samples for spraying onto potato leaves.

Bangor's role in the project was as a test site for potato blight. Working with world expert Dr David Shaw and using the facilities of Bangor University's research farm our role was to test compounds for their effects against blight. During the project we evaluated over 20 different formulations supplied by the project partners. Using David's expertise our tests were undertaken first in the greenhouse, to identify lead compounds, and then taken through to field trials.

All tests were blind so coordinating the field trial treatments was critical to running of the project. Dr Ahmad Al-Dulayymi and Josh Davies worked on the farm under the close supervision of David along with Debbie Evans.

A key task was harvesting of the potatoes and the project had some bumper crops. At harvest time it really was all hands to the pump, explained Radek. We had some fantastic support from the farm staff helping to organise the planting and the harvesting. We needed to do this accurately so that we knew which potatoes belonged to which plot so we could calculate the yields of the potatoes against the different treatments. Results are



Planting potatoes at Bangor University's farm Henfaes

National and International Funded Projects

looking very promising, and the team hope to continue this work with InnovateUK funding working with some of the UK's leading potato farmers.

Note: The Atlantic Area is characterised by high rainfall and high humidity, conditions which increase crop fungal infection and leaching of inputs from soil (EEA, 2009). Crop growers counter these problems by applying high

levels of synthetic fungicides and fertilizers. However, heavy rainfall can render these applications ineffective and leach these chemicals into waterways, resulting in increased emissions of the powerful greenhouse gas, nitrous oxide (N₂O). The problem is compounded as many fungicides are toxic and face EU bans due to residue accumulation in food, which affects growers and retailers alike.

Cutting plastic waste by incorporating nanomaterials into food packaging

HiBarFilm 2 is an Innovate UK funded project that started in March 2022 and is expected to run for 30 months. Haydale Composite Solutions Ltd is leading the consortium of nine companies. BASF, Bangor University (BioComposites Centre), Cambridge Nanomaterials Technologies, Dunbia, Fre-Energy, Parkside Flexibles, Recycling Technologies and Wells Plastic. The project aims to develop the next generation of high barrier films for food packaging using functionalised nanomaterials.

The project has the ambitious objective to achieve the same barrier performance using a mono polyolefin film to replace the currently used multilayer barrier films. By manufacturing mono-materials flexible films the recyclability

of these materials will increase, and value will be added to nanomaterials incorporated in the films.

Project Contact

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HiBarFilm
High barrier mono-material flexible films for food contact applications

www.hibarfilm.co.uk
info@HiBarFilm.co.uk

Project website launched in July 2022
www.hibarfilm.co.uk. Cutting plastic waste.



Members of the HiBarFilm project team attending second quarterly meeting hosted by Wells Plastics.

National and International Funded Projects

Mushroom Stalks could Help Preserve your Food

SMARTCymru is supporting a collaboration between Pennotec and Bangor University to develop food-safe preservatives from mushroom stalks.

Pennotec is seeking to become a producer and exporter of a range of high-quality natural and food-safe preservatives from mushrooms to meet an increasing consumer demand.

Stalks and trimmings are an unavoidable by-product of production, with mushroom farmers disposing of tens of tonnes of trimmings every week. Fungi are a sustainable and vegan source of chitosans – natural fibres with anti-microbial and anti-fungal properties, which are mainly produced from crustacean shells in multi-thousand tonne per annum quantities.

A collaboration between Pennotec (Pennog Ltd), BC, the Centre for Environmental Biotechnology (CEB) and School of Natural Sciences (SNS) is researching environmentally sustainable methods for the preparation of high quality, food grade chitosans from mushroom trimmings. Dr Viacheslav Tverezovskiy and Dr Olga Tverezovskaya have strengthened the Centre's links with SNS, by working together with Dr Olga Golyshina (CEB, SNS) and Dr Katherine Steele (SNS). Through the application of sophisticated analytical techniques and expertise available at BC and CEB, the team seek to determine whether Pennotec's bio-refining techniques can produce chitosans that are free of compost residue.

If successful, the Trimchi project could bring new products to the market, increasing productivity and helping to reduce an economic and environmental cost to the mushroom industry.

From Sea Life to Shelf Life: An exciting new material that protects homes and the environment

An innovative new material, made from mussel shells, that protects homes is one step closer to being available on the market, thanks to collaboration between sustainable product company Pennotec (Pennog Ltd) and material research scientists at Bangor University's BioComposites Centre.

The company discovered that mussel shells have an ability to bind and release copper. Gradual release of copper from Pennotec's mussel shell-based composite material prevents the growth of green algae that cause unsightly staining of building surfaces. The product will also prevent the growth of moss on roofs and slime on wet surfaces, massively reducing the cost of home maintenance.

Steven Gallacher, Operations Manager at Scottish Shellfish Marketing Group, with whom the team are working, said "Mussel farming is one of the most sustainable methods of food production, but not all mussels meet the high-quality standards expected by consumers. This potential new outlet for out-graded mussels will help to further improve the sustainability of our industry."

Pennotec co-inventor, Dr Noel Roberts, an early career researcher and ION Leadership graduate from Bangor University, explains, "Conventional biocidal surface



Bag of mussel shells.

sprays that prevent growth of moss and slime last three years at most. This is expensive for homeowners and bad for the environment. Accelerated weathering tests at Bangor University predict that our product will prevent surface growth for up to 15 years, saving homeowners thousands of pounds and reducing the risk of roof damage by cleaning companies."

With such strong environmental credentials built into the material, Noel was keen to ensure that his product provided a truly circular solution.

"My invention replaces hazardous cleaning chemicals. Despite this, I knew that at the end of its useful life, my product could end up in landfill. I wasn't happy about that."

This led Noel to apply for DEFRA and UK Research and Innovation (UKRI) advice and support. UKRI's Interdisciplinary Circular Economy Centre for Mineral-

National and International Funded Projects

based Construction Materials (ICEC-MCM) - one of five £30million research centres focused on developing the UK Circular Economy - is now supporting a new, collaborative project to investigate the recycling of used mussel composite back into fresh product.

Noel, and his team at Pennotec, are collaborating with Dr Simon Curling, an expert in the life cycle and durability



Roof covered in moss.

of building materials at Bangor University's Biocomposites centre. Simon said, "Using our capability to simulate years of weathering in the space of a few weeks, we are helping Noel to test and validate the performance and durability of his recycled material."

Demonstrating that recycling is possible is only half the challenge in a construction industry that is notoriously linear in its use of materials. Construction generates more than a third of all waste hitting landfill sites.

"For my product to enter the market, new thinking is required on how building material manufacturers finance and manage the recovery and re-processing of products. By working with Circular Economy business and finance experts at ICEC-MCM, I hope to understand how the construction industry, banks, housing associations and homeowners can be motivated to support the recycling of building materials at the end of their useful life."

<https://www.bangor.ac.uk/news/12/a-protective-shell-an-exciting-new-material-that-protects-homes-and-the-environment>

Strong Partnership with Major UK Timber Firm Continues

One of the UK's largest timber suppliers has teamed up with Bangor University to pinpoint the full environmental impact of its products and help place sustainability at the forefront of its distribution activities.

Timber and materials supplier James Latham has partnered with the BioComposites Centre to create a carbon calculator to provide customers with transparency, knowledge, and awareness of the carbon impact of its products.

The calculator details the footprint of the entire process, from the carbon contained within the wood's structure to the manufacturing procedure, delivery, and storage in warehouses, with data provided for more than 70 per cent of Latham's goods.

The Biocomposites Centre is behind the development of the dataset used to calculate the actual carbon score, as well as supplying a certification as to the accuracy of the data used to provide the figure.

For example, peer-reviewed independent data from a manufacturer such as an environmental performance



The BioComposites Centre Life Cycle Assessment team, Campbell Skinner (left) and George Roberts (right), both worked on the project.

National and International Funded Projects

declaration will hold the highest accuracy scoring in the system, while publicly published yet unverified figures will hold a lower score.

With major industries like construction placing an increasing focus on carbon efficiency and footprints, as a distributor we need to be able to communicate directly and simply to all our stakeholders on the products we sell.

"Working with the BioComposites Centre, Bangor University on this carbon calculator has been immensely rewarding as they immediately understood not only the business aims of the project, but how to best gather and present the information in a manner which would be easily accessible." Ewa Bazydlo, Environmental and compliance manager, James Latham.

The BioComposites Centre Life Cycle Assessment team, Campbell Skinner and George Robert agree that *"Providing a clear message as to the level of confidence within the data will also help achieve two key aims of ours; encouraging those involved in the design process to use the most efficient products available, but also pushing the sector towards a higher standard of carbon measurement."*

Lead Life Cycle Assessment analyst at the BioComposites centre Campbell Skinner said: *"Working alongside industry is crucial to help identify areas where additional sustainability practices such as carbon monitoring or increasing energy efficiency in the production process can*

be implemented to further support the global shift to a net zero economy."

"Latham's calculator represents a great step forward as it allows customers to enjoy total transparency with regard to the carbon impact and scientific accuracy of what they are purchasing."

"By including a certification as to the accuracy and peer-acceptance status of the data, the calculator will also ensure that the impact is pinpointed to a much finer extent than using rough estimations, allowing for a better picture of the difference more sustainable products make on projects."

"This will benefit not only end users who will be able to research and select the most sustainable products, but it will also encourage suppliers to take greater steps to ensure resources and their carbon footprints are measured and peer-reviewed."

"It has been excellent to work alongside Latham's to produce this vital tool which will help inform customers from invoicing to delivery, and we look forward to working with them to continue to expand the goods covered over time."

James Latham is one of the UK's largest independent distributors of timber, panels, and decorative surfaces.

For more information on James Latham visit www.lathamtimber.co.uk.

Novel high-value products in seaweed species commonly found in southwest Wales

The Marine Energy Engineering Centre of Excellence (MEECE), part of Offshore Renewable Energy Catapult (ORE Catapult) is funding BC's research for SME from Wales, SeaWeedology. The primary purpose of this project is to analyse selected species of seaweed commonly found in southwest Wales (sugar kelp and others) and characterise useful and high-value compounds. The PI, Dr Tverezovskiy, is supporting further commercial development and exploitation of seaweeds in the nutraceutical and pharmaceutical sectors. This will ultimately allow innovative use of a newly licensed seaweed farm in Pembrokeshire, managed by Simon Pitt of SeaWeedology. Our newly appointed research technician, Laura Bischoff, has joined this exciting project.



*Kick off Meeting at Mona Biorefining Facilities.
Rebecca Jeffrey (MEESE), Simon Pitt (SeaWeedology),
Dr Viacheslav Tverezovskiy (BC)*

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The BioComposites Centre Continues its Work with the UK's Foundation Industries

As the Transforming Foundation Industries Hub (TransFIRe) moves it to the second half of the project BC researchers continue to work with the industries, including the pulp and paper sector to decarbonise and dematerialise. Two case studies, within the construction sector, have been developed, both with the intention of taking waste from one industry as an input to another.

Repulping and Recycling a Paper Whisky Bottle

Consumers could soon be pouring whisky out of a paper bottle, with a sustainable packaging project nearing completion. But what happens to that paper bottle after all the whiskey has gone? Can you reuse the paper fibres again?

The BioComposites Centre have partnered with global green packaging consortium Pulpex to design a paper bottle for use by a number of global consumer packaged goods companies, including Diageo.

Made from sustainably sourced, Forest Stewardship Council (FSC) certified wood pulp, the bottles have been designed to balance functionality and quality with recyclability. The intention is to create a resilient container which will allow for a long shelf-life and simple mass production.

The BioComposites Centre have worked alongside Pulpex since 2020 on the initiative. "Given the high carbon and energy cost which goes into making even a single glass bottle, it is critical more sustainable methods of packaging are developed to reduce costs and the global carbon footprint" said Dr Rob Elias.

"Working with industry is vital if we are to move forward to the next stage of innovation; the knowledge and support Pulpex has provided has proven invaluable to helping us research and optimise the ideal makeup of the bottle as well as scale up testing to provide more comprehensive results."

"It's been an absolute pleasure and advantage working alongside the talented individuals at Bangor University's

2022 saw the development and funding of a new TFI Demonstrator project which was influenced by the Hub. BONDIFI brings together past collaborators, Cambond Ltd, with hub members, Sheffield Hallam University and other industrial partners in the construction and foundry sectors. The aim is to develop a pilot scale resin production facility that will demonstrate the production of a bio-waste derived resin, primarily from bio-ethanol production and its use in the manufacture of board products and in the sand casting of metals.

BioComposites Centre. Their knowledge and experience in the field has become an indispensable extension of our team here at Pulpex." Scott Winston CEO, Pulpex.

To assess the recyclability of the bottles at the end of their life we used an industry adopted standard. This specifies the test method we need to use to determine if the bottle can be recycled in the waste-paper collection schemes. We repulp the bottle and screen the fibres using a special sieve called a Summerville Screen. We then grade the fibres by measuring the amount of reject fibres (too small or too big) and can then assign a pass or fail. "This is really important for the paper mills as they need to know that they can process the bottles in their mills" explained Sean.

Pulpex is a research and development collaboration between Diageo and Pilot Lite, a venture management company.



Bangor University materials technician Sean Baxter during the testing process of the BioComposites Centre's work with global green packaging consortium Pulpex to design a paper bottle for consumer use. Here we are focusing on the recyclability of the bottles at the end of their life.

National and International Funded Projects

PlantSea-Punnet: a versatile seaweed-based packaging

Building on our success in developing cutting edge, sustainable and compostable materials, the Centre is now working on the development of a PlantSea-Punnet, the first seaweed-based fully compostable, food-safe packaging concept for fresh produce. Here the aim to prevent 20,000 tons of plastic reaching landfill and polluting the environment. Dr Gianmarco Sanfratello, Chief Technology Officer (CTO) and co-founder of Plantsea is looking forward for to the project that is aiming to provide a functional solution that can make a significant impact in reducing plastic waste.

“The project is also a low carbon solution to plastic. Using our innovative approach and expertise in sustainable material production, PlantSea-Punnet could save up to 990,000 tonnes CO2 emissions per year” explained Gianmarco..

Dr Viacheslav Tverezovskiy, project leader, adds “PlantSea-Punnet provides an innovative, environmentally friendly solution to plastic packaging, with significant reductions in carbon footprint and plastic waste production.”

The collaborative research project, includes multinational packaging producer Tri-Wall. Their role in the project will be to ensure developments can be adopted and scaled for impact and exploitation.

Mike Valentine Projects Lead for the Tri-Wall Group says: “we are constantly challenging ourselves to better the industry offerings for more environmentally sustainable solutions, by working with experts in this team we hope to push the capabilities for us and the industry further.”



Meeting at Tri-Wall HQ in Monmouth, visit to the factory onsite.
Mike Valentine, Tri-Wall Projects Lead; Dr Viacheslav Tverezovskiy (BC).

Conferences, Workshops and Visits

Reducing plastic contamination in the global food supply chain.

Maximising crop yields by using silage, mulch and greenhouse films is an effective way to help feed the growing global population. But there is mounting concern about soil contamination and end of life solutions for the plastics used to make these films. BC has been working on solutions to address these concerns.

In March, Rob and Qiuyun made their first (post COVID-19) EU business trip to Barcelona, Spain, for the Agricultural Film conference organised by AMI. The conference brought together academics, researchers, raw material manufacturers, distributors, machinery manufacturers, agronomists and associations including public and private bodies involved in agriculture.

Supported by Innovate UK – Newton funded joint project

with China, Rob and Gary Ogden from project partner Wells Plastics Ltd, delivered an oral presentation on Novel agricultural mulch film developments for global applications.

The paper highlighted the idea of developing specific formulations for crops in different climatic conditions. Additionally, the paper described a novel method to characterise film biodegradation. The presentation received positive interest and feedback from the audience.

The three-day event highlighted the challenges of single use agricultural films and the need to use renewable materials for a better end of life solution.

Rob and Qiuyun made new contacts for future collaboration and the event provided important opportunities for understanding the current and emerging hot topics in the agriculture sector.



Dr Qiuyun Liu and Dr Rob Elias with Dr Gary Ogden (Technical Manager, Wells Plastics Ltd.) exhibiting at the AMI- Agricultural Film Conference March 2022, Barcellona.

Conferences, Workshops and Visits

International Composites Show – getting together again

In May, Dr Graham Ormondroyd spent three days at JEC World – the leading international composites show held annually in Paris. The show brings together composites' professionals from all over the world from major companies to innovative start-ups as well as experts, academics, scientists and R&D Leaders.

Industry Wales sponsored Graham to attend the show.

Graham helped to promote Wales by showcasing the R&D support the BioComposites Centre can offer existing companies and promoting Wales as a first class location for businesses.

"After so long away from shows and conferences due to the Covid-19 pandemic it was a fantastic opportunity to get back to in person events" said Graham. "I had several meetings with old and new contacts and am looking forward to building some exciting new project proposals with those companies in the near future."

ECWM10

Three of our team attended the European Conference on Wood Modification in Nancy, France, this April. Always an excellent event for networking and keeping up to date with rapid developments in the wood modification sector.

Carlo Kupfernagel, our PhD student, presented work from his previous internship project on timber fatigue and molecular rearrangements in modified wood in a talk "The effects of material fatigue on differently modified wood". This work was a precursor to (and complements) his

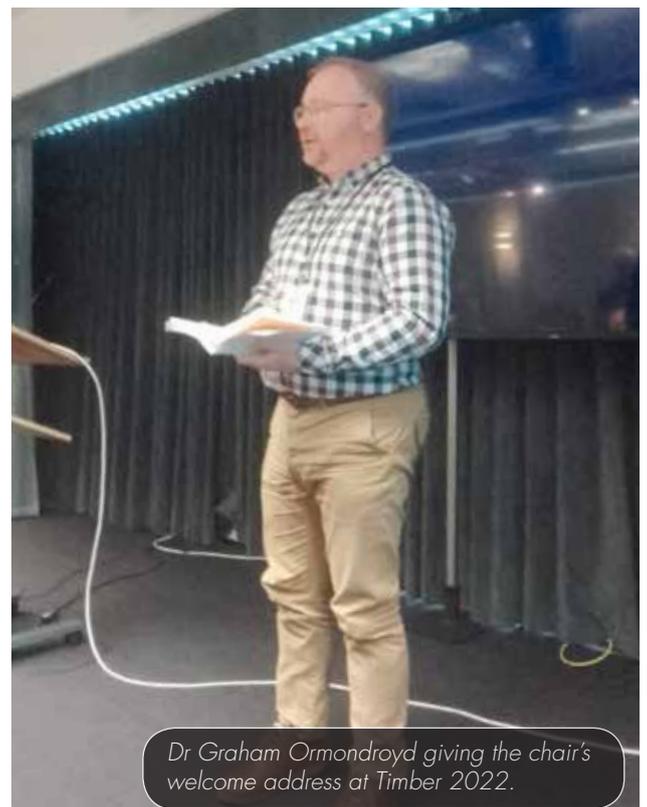
ongoing PhD studies on resin modification.

Dr Morwenna Spear gave a poster presentation on work with previous PhD student Md Ashaduzzaman "Use of DMA to evaluate the modification of tropical hardwood timbers by cashew nut liquid (CNSL) resin." Morwenna also presented work from a joint project with Coed Cymru on resin modification of timber for end grain cobbles. This novel application could combine the benefits of resin modification – durability and dimensional stability with the hard-wearing properties demonstrated in this paper.

Exciting Return to In-person Timber 2022 Conference

BC staff and students contributed three presentations at the Timber 2022 conference in London in July. The event, organised by the Wood Technology Group of the IOM3, was a great success, spanning the extremely broad range of topics covered by UK researchers in timber and wood science. It was also the final Timber conference at which Dr Graham Ormondroyd will be Chair of the board of the WTG of IOM3, as he steps down after a highly successful four-year term of office at the end of the year. This made the event all the more significant for the BioComposites Centre.

A highlight of the day was the keynote address by Matthew Caldwell and Natasha Watson, of Buro Happold, considering the challenges and opportunities of engineering with timber. Many other presentations prompted debate and discussion of future trends and needs within the industry.



Dr Graham Ormondroyd giving the chair's welcome address at Timber 2022.

Conferences, Workshops and Visits

Our KESS 2 funded PhD student Carlo Kupfernagel presented his work on widening the species mix for resin modification systems of wood. BC's Head of Materials Research Graham Ormondroyd posed a series of questions and challenges for decarbonising the timber industries and presented some areas where timber and paper have led the way towards a circular economy. Dr Morwenna Spear also provoked discussion on the topic of carbon accounting, carbon sequestration and displacement.



PhD candidate Carlo Kupfernagel giving his presentation at Timber 2022.

A Snapshot of Innovation, Successes & Next Steps – Smart Sustainable Plastics Packaging Challenge Workshop.

UKRI's Smart sustainable packaging challenge (SSPP) is working to make plastic packaging fit for a sustainable future. A £60 million five-year programme, it is the largest and most ambitious UK government investment to date in sustainable plastics research and innovation. It reflects the urgent need for action to reduce the environmental footprint of plastics and eradicate plastic pollution.

The event opened by Innovate UK presentations, followed by Unilever, PlantSea, BioComposites Centre and Fiberight. Dr Viacheslav Tverezovskiy represented BC and showcased key projects from the Centre that are related to the SSPP topic. At the end of his presentation, Viacheslav promoted BC's and Bangor University's capabilities for plastic packaging research and explained our vision on future challenges.

The event also included displays and BC's project partner PlantSea Ltd were on hand to demonstrate their seaweed based packaging pods. This project involves the work of newly appointed technician Max Clarkson.



Conferences, Workshops and Visits

Hi Tech Parks Helping to Kick Start the Bioeconomy in Ethiopia

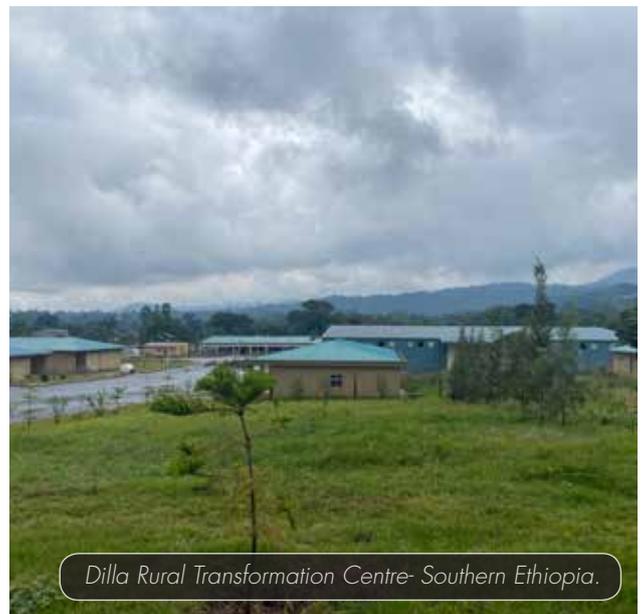
Adam Charlton visited Ethiopia in July 2022, at the request of the United Nations (UNIDO) to visit some of the country's Integrated Agro-Industrial Parks (IAIPs) and interlinked Rural Transformation Centers (RTCs.)



Dr Adam Charlton at the entrance to the Bulbula Integrated Agro Industrial Park (Central Ethiopia).

One of the aims of the field visit was to assess the potential to create added value from the agricultural crop waste generated by companies located at these IAIPs, by creating new value chains and biobased products from these residues.

A series of meetings were conducted with relevant stakeholders from both the public and private sectors



Dilla Rural Transformation Centre- Southern Ethiopia.

including; the Ethiopian Government Ministries, representatives from the Italian Government, which is supporting the IAIP programme, Regional Industrial Park Development Corporations, Universities and research institutes.

A review was undertaken which included the utilisation of agricultural crop residues in Ethiopia linked to commodities of interest in the IAIPs, key stakeholders engaged in the sector and pilot scale technologies for biobased product development.

"As a result of the visit we have prepared a report for UNIDO which identifies possible barriers and opportunities for the implementation of circular economy practices within the IAIPs, including actionable policy options" said Dr Adam Charlton. *"It was a good opportunity to draw on my experience of working in the BioComposites Centre on a variety of bio-based and circular economy projects, including the EU funded BEACON initiative and apply that knowledge to a different country."*



Roadside collection of pineapples near Dilla.

Conferences, Workshops and Visits

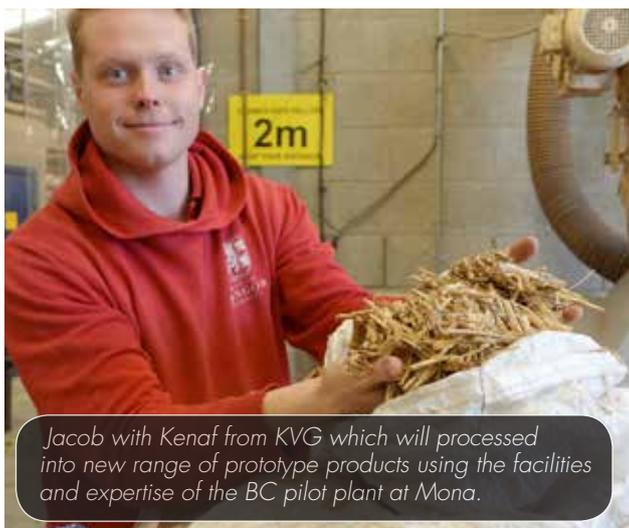
R&D Cooperation with Malaysia Strengthened

Kenaf Global Ventures (KVG) Sbn Bhd is one of the leading planters of kenaf in Malaysia. The company has an ambition to ensure that kenaf becomes Malaysia's third agriculture commodity. To help achieve their vision KVG has forged a series of partnerships with European Centres of Excellence and The BioComposites Centre was selected to help them develop a new range of MDF prototype products.

This partnership approach was celebrated with an online signing ceremony on the 20th of January 2022 where Centre Director Rob Elias signed a Memorandum of Understanding (MOU) with KVG.

"The MOU sets out the basis of the collaborative partnership" explained Rob Elias. "As a Centre of Excellence, we are at the forefront of research into crop-based materials, so it is great to be recognised as a leader in this sector. We will be using our pilot plant facilities to help KVG develop and scale up a new range of products. KVG's kenaf is a good quality biomass that is sustainably cultivated, harvested and processed so we are looking forward to working with this feedstock" added Rob.

In Dec 22 the KVG team had the chance to visit the Centre and discuss the next steps. At the meeting the team reviewed the pilot scale production process, agree the process parameters and inspected the kenaf delivered ready for the first set of trials.



Jacob with Kenaf from KVG which will be processed into new range of prototype products using the facilities and expertise of the BC pilot plant at Mona.



Jonathan, Jacob and Rob from BC being presented with gifts from Dr Noor Intan Saffinaz Anuar head of R&D at KVG and Mr Mohammad Syakir Che Mansor also of KVG during their visit to the pilot plant at Mona.

Public Engagement and Curious Minds

At the BioComposites Centre we understand the importance of increasing public awareness surrounding the climate crisis and how sustainable materials can play an important role moving forward.

On the 23rd of November 2022 BioComposites joined PlantSea Ltd and M-Sparc (Bangor University) at a STEAM event (Science, Technology, Engineering, Art, and Maths) hosted at Ysgol Dyffryn Nantlle secondary school. Students were separated into groups of ~10 and presented with a series of workshops throughout the day.

At the event Max Clarkson (Research Technician, BioComposites Centre) collaborated with Gianmarco Sanfratello (CTO, PlantSea Ltd) to host a workshop demonstrating the importance of reducing single-use plastic

packaging in favour of bio-based alternatives such as PlantSea's seaweed-based water-soluble shampoo pods.

Students were amazed to touch and feel the shampoo pods and demonstrated a curious approach to the new technologies being developed.

To challenge their scientific understanding, Max and Gianmarco presented the students with a challenge – to discuss and design a plastic free 'container for life' for PlantSea's soluble seaweed pods.

Students were stumped initially, realising just how many everyday objects are made from plastic because of its low price, ease of use, and durability.

However, with a little inspiration, students quickly thought up a myriad of ideas. Some on the creative side such as a shark that 'spits' out the seaweed-based pod, and some with

Conferences, Workshops and Visits

practical design in mind, such as twist activated dispensers - all made from natural long-lasting materials such as wood, rubber, and metal.

After the challenge, Max and Gianmarco briefly explained the importance of correct waste management and the small

changes we can all make as individuals to reduce climate impact.

Overall engagement at the event was outstanding, with school staff noting positive response among students - eager to share what they had learnt and show off their imaginative designs.

Keeping Warm at the Royal Welsh Winter Fair with Welsh Wool

The end of November saw Dr Graham Ormondroyd exhibit the new and novel products produced from Welsh wool as part of the Made with Wool project. The novel products included construction materials, sound insulation and composites, they were exhibited alongside work undertaken by research partners, Menter Môn and students

from Bangor University's Design School. The products were well received with much interest around how quickly we could get the products on the market and influence the value of Welsh wool.

The next steps for the Made with Wool project and the prototypes are to develop roadmaps to take the products to market, these roadmaps will then be offered to interested parties to take forward and develop businesses to manufacture the products.

Hardwood Silviculture – Excellence in Practice in Wales

In September 2022 Dr Morwenna Spear visited local woodland Broadleaf Wales near Abergele. 'It was so uplifting to visit a broadleaved woodland that is being so well managed' reported Morwenna about the award-winning woodland that is demonstrating excellence in hardwood silviculture practices.

Ruth Pybus and David Brown (an MSc Forestry graduate from Bangor University) are converting 20 hectares of mixed broadleaf plantation into productive continuous cover forestry in North Wales. Having established the woodland, they are committed to management practices such as high pruning to ensure their timber will be of high quality. They are already selling products from thinnings and demonstrating the benefits of good forest management. David and Ruth have also shared their skills and experience through running courses, mentoring and helping others plan their woodland management strategy.

'Much of the native broadleaf woodland in Wales and the UK is undermanaged, damaged by grey squirrels and prevented from regeneration by grazing pressures', explained Morwenna who is working on a project with Coed Cymru to promote hardwood timber produced from woodlands in Wales.

'Ruth and David are now selling a variety of hardwood products from woodland that is just 25 years old. Ash and cherry have been converted into planks, sweet chestnut has been made into fenceposts and palings, while larch

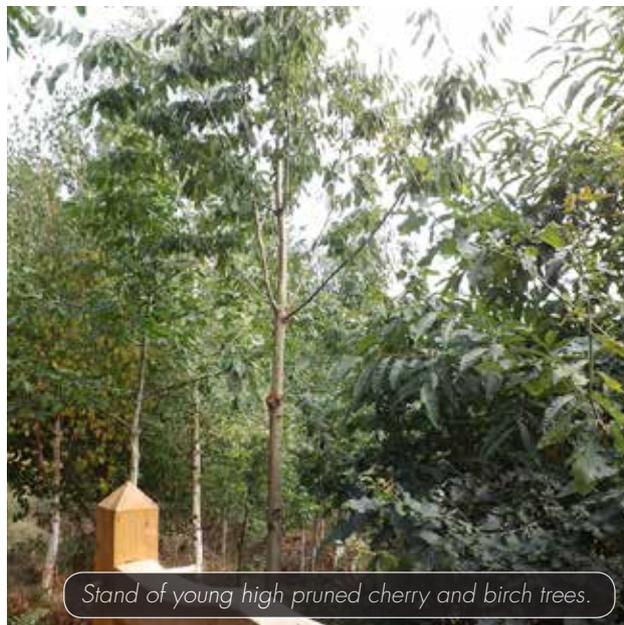


Sawn plank of Ash timber from thinning's taken from the woodland.

Conferences, Workshops and Visits

removed from the woodland has been converted into handmade gates and cladding. Their business model is well matched to their produce and will develop as the trees come closer to maturity' said Morwenna. 'This excellent model of hardwood silvicultural practice demonstrated what could be achieved, if simple measures were widely practised by other woodland owners. It demonstrated an excellent balance between production forestry and biodiversity.'

Developing products and markets for timber is one way to help encourage landowners of the value of planting trees on their land and thus help Wales achieve its planting targets. 'Looking at ways to add value to forest products is an area that the BioComposites Centre has been active in since we were established in 1989' said Dr Rob Elias, 'and it's great to see that interest in this area is returning as it has been a much-neglected area of research for too long'.



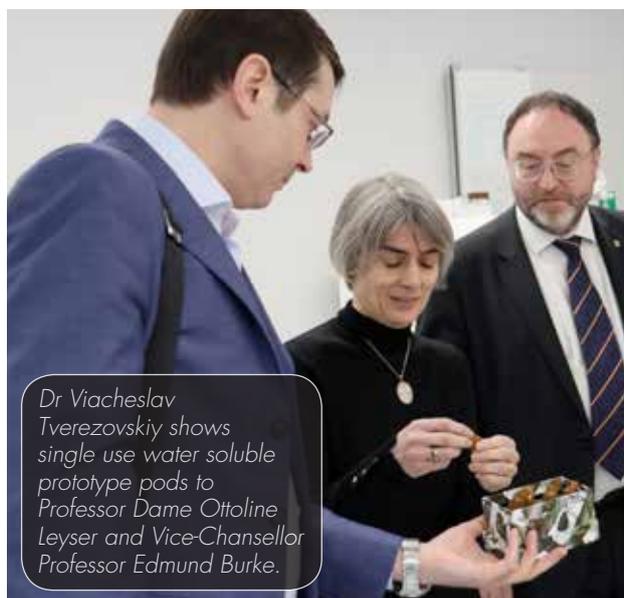
Stand of young high pruned cherry and birch trees.

Bangor University visited by Prof. Dame Ottoline Leyser, Chief Executive of UKRI.

Professor Dame Ottoline Leyser, visited the University on the 1st of December. Hosted by Bangor's Vice Chancellor Professor Edmund Burke and Pro Vice Chancellor Professor Paul Spencer, UKRI Chief meet with MSPARC tenants, including BC's project partner, PlantSea.

Dr Viacheslav Tverezovskiy explained to Dame Ottoline all about the Innovate UK feasibility project to produce single use water soluble pods for personal care applications such as shampoo pods.

At the end of her M-Sparc visit, Dame Ottoline said: "I was so impressed by the entrepreneurial community spirit at M-SParc. It was great to see so much variety under one roof, spanning high-growth sectors including low carbon technologies, VR, AR and many other digital technologies. I congratulate M-SParc and their tenants on their work."



Dr Viacheslav Tverezovskiy shows single use water soluble prototype pods to Professor Dame Ottoline Leyser and Vice-Chancellor Professor Edmund Burke.



Dr Viacheslav Tverezovskiy explains the process of novel polymer preparation from seaweeds to Vice-Chancellor Professor Edmund Burke and Professor Dame Ottoline Leyser.

Conferences, Workshops and Visits

BioBased Solutions can Help with Decarbonisation options

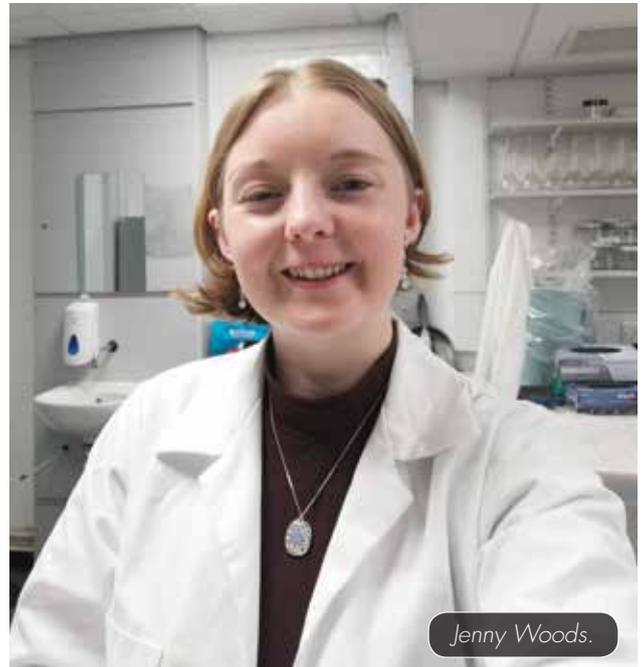
Research master's student Jenny Woods recently travelled to Dresden, Germany with supervisor Dr Qiuyun Liu to attend Jenny's first European conference at the Institut für Holztechnologie (IHD) on 6th-7th December 2022.

The focus of this pulp and paper conference was mainly on the fibre-based solutions that are being trialled and tested within companies. These solutions could be part of tomorrow's market for pushing sustainable alternatives and contributing to the circular economy.

There were many valuable opportunities to discuss several areas of interest, these being; bioeconomy of raw materials, decarbonisation solutions, cellulosic fibre coatings, polysaccharides and microencapsulation, barrier performance, alginate coatings and paper modification by plasma applications.

"The chance to travel to Germany" said Jenny "to partake in some really important discussions that are shaping the future of paper making and packaging was fantastic. It has given me an insight into the efforts researchers and companies are contributing to become a more sustainable, CO2 neutral industry".

Travel to the conference has helped give Jenny many new ideas about biobased coatings and testing practices to consider within her project. It has also helped enhance



Jenny Woods.

networking opportunities to have had the chance to talk with fellow researchers and make industry connections for the future.

Jenny is very thankful to have had the opportunity to attend her first conference and hopes there will be more to further expand her knowledge in the area of biobased coatings for paper application and maybe even present her own research one day!

Visiting Researchers

Sofia Gonçalves, a PhD student from the University of Porto in Portugal joined us for a four week visit in July. As part of her PhD Sofia was researching the use of lignosulphonate waste from the paper industry to make binders for the wood products industry. Working with BC scientists, Sofia used the Centre's board making equipment to manufacture and test medium density fibre boards (MDF) utilising these novel binders. This work ties in with the BioComposites Centre's work with novel board manufacturing technologies and the TRANSFIRE project looking at utilising difficult waste streams from the Foundation Industries. Sofia was able to visit BC due an STSM grant from the Lignocost COST action.



Sofia Gonçalves and Dr Simon Curling making experimental MDF boards.

Awards and Prizes

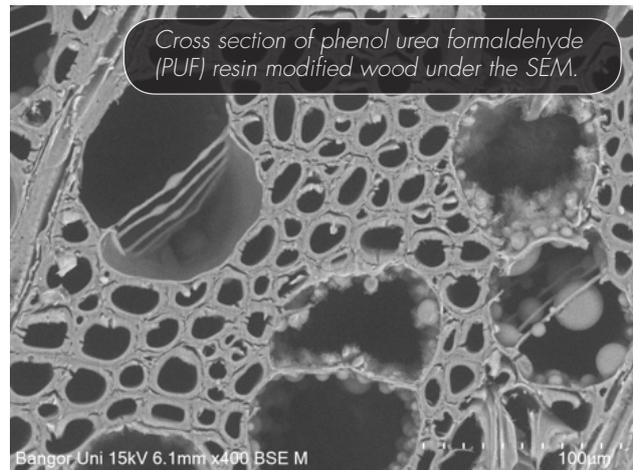
BC student takes first prize at European Wood Science and Engineering (WSE) conference

PhD student Carlo Kupfernagel travelled to Germany to attend a conference that took place from the 20st to 22nd September in Goettingen. It was the gathering of the "Northern European Network for Wood Science and Engineering" which was established in 2004 and includes 10 countries.

The overarching topic was 'Tackling the scarcity of resources in the wood industry under changing European forestry conditions'.

Carlo explained that "A day before the conference, we had a full-day workshop for approximately 30 – 40 PhD students and early career researchers. The topic of the workshop was 'Performance, potential, and limitations of European hardwoods'. Theoretical and practical lectures were given with a focus on; quality grading of sawn hardwood, chemical wood modification, gluing and finger jointing, outdoor performance testing".

Carlo picked up the first prize for his talk on "Cell wall diffusion of low molecular weight PUF resin studied by liquid- and solid-state NMR". "The chance to speak at a conference was a great learning experience and I was able to explain my work to look a sub-microscopic level the material transport of Phenol-urea-formaldehyde resin in wood during drying" added Carlo!



BioComposites Centre part of Winning Project Awarded \$3million by Alliance Prize

COtoCLEAN - an innovative multi-participant project by Nextek Limited – was announced as the winner of the Alliance Prize which aims to bring about change by incentivising transformative solutions that can help to address the plastic waste challenge.

Following a final pitch by five finalist teams at the New York Stock Exchange, Professor Edward Kosior, founder of Nextek, was awarded the prestigious prize of \$US3million

to fast-track COtoCLEAN's groundbreaking process to decontaminate post-consumer plastic films back to food-grade quality.

Bangor University's Biocomposites Centre will use its expertise to undertake life cycle assessment, examine process optimization and investigate scale-up, using its laboratory and pilot-scale CO₂ equipment. The project includes North Wales based Suprex Ltd, a spin out company from Bangor University that specializes in the development of applications of supercritical CO₂. Using CO₂ as a green solvent, the company can extract fine chemicals from a range of feedstocks. Suprex will take the lead in the

Awards and Prizes

design and construction of the new equipment that will assist in the large-scale trials of post-consumer films.

The event, that was presented live to global brand owners and investors, was the culmination of months of review by a panel of judges who whittled some 600 registrations down to 60 fully qualifying submissions and then down to five finalists.

COtooCLEAN aims to fill the gap in the recycling stream where food-safe post-consumer polyolefin films are currently missing. Their unique commercial process can be integrated into mechanical recycling operations and can treat printed and multi-layer films to make them much easier to recycle.

On winning the Alliance Prize, Professor Kosior commented, "We now have the potential to make a major contribution to the circularity of films in a global context."

Dr Qiuyun Liu project manager at the Biocomposites Centre said, "Bangor University are proud to be part of the innovative COtooCLEAN project, which aims to create

a solution to one of the world's pressing problems: that of plastic waste. By drawing on the expertise of our material science researchers in the BioComposites Centre and working in partnership with our industry partner Suprex Ltd, we can apply our knowledge to help increase the rate of plastic recycling. We are really looking forward to continuing to work with all the Nextek partners on this game-changing project."

Steve Sikra, AEPW VP Americas, Alliance to End Plastic Waste said, "The COtooCLEAN process offers an impactful solution for the high levels of flexible film waste growing around the world. By enabling food-grade film-to-film advanced mechanical recycling, the process will improve circularity of flexible films by diverting film waste from landfill and lesser value outlets.

"The relatively simple modification to the existing mechanical recycling process makes the potential impact of COtooCLEAN even greater because of its scalability to global adoption over time."



Other Activity

Pulp and Paper Training

Materials technician Sean Baxter, has this year attended two courses through PITA (Paper Industry Technical Association). Both courses were aimed at introducing the industrial papermaking process to those new to the sector. In March, Sean attended Modern Papermaking, a two-day course where attendees from papermills and suppliers discussed the step-by-step stages in papermaking machines.

In Decembers three-day Fundamentals of Papermaking course, the topics were elaborated on. Attendees took a

more detailed look into each stage of paper production from tree felling through to reel up of paper at the end of the machine. This also included a full tour of Pelter Medical Papers, where pulping, forming, pressing, drying, and reel up could all be clearly seen.

Sean said, *"The courses have been hugely informative and useful allowing me to understand the industrial processes involved in paper making outside of a pilot scale facility. This new knowledge feeds back into the work The BioComposites Centre can do in our pulp and paper lab."*

Paper laboratory expanded

The BioComposites Centres pulp and paper lab has this year been going from strength to strength. Working alongside Scitech Coatings we have been testing sustainable paper-based packaging for the next generation of food contact applications.

Paper packaging is already known to offer good recycling and sustainability credentials. However, paper has some undesirable barrier properties when used for wet and perishable products. Through the addition of biodegradable coatings on the surface of the paper-based packaging these barrier properties can be improved, which in turn can impact the recyclability of the product.

Coated papers have their oxygen and water vapour barrier properties tested using our automated MOCON barrier testing equipment. With data feeding back into the coating formulation process. A novel water holding method has been developed together with Scitech to better simulate some end uses.

Repulp testing take a vital role in the investigations, as novel barriers can lead to problems in the recycling process. The pulp and paper lab have been using a slightly modified Confederation of European Paper Industries (CEPI report to classify the recyclability of paper-based packaging using the rejected material after a screening process. Oven dried materials are pulped in warm water and then screened through 5 mm holes and 150 µm slots. The resulting rejected material mass is used to calculate the repulpability classification.

Since starting to carry out repulpability testing in the pulp and paper lab The BioComposites Centre have been able to work with the likes of Unilever, Wipak and Pulpex carrying out similar indicative testing.



Sean Baxter inspecting a pulp moulded beaker.



Selection of pulp moulded and bioplastic moulded packaging solutions.

Other Activity

All Change for BC Staff at the Institute of Materials, Minerals and Mining (IOM3)

The end of the year saw new leadership roles for BC staff within IOM3.

Dr Morwenna Spear was voted to the chair of the IOM3 Wood Technology Group following the end of Dr Graham Ormondroyd's tenure in the post. Dr Spear said, 'I'm very pleased to take on this new role as Chair of the Wood Technology Group (WTG) and I'm looking forward to building connections between WTG members, tapping into their skills and knowledge to grow the Group and ensure events and activities are interesting and relevant.'

Dr Graham Ormondroyd was appointed as Vice-President of the Institute and will join the executive as of 1st January 2023. Dr Ormondroyd said *'I am delighted to be elected as a Vice-President of the Institute, having worked all my life in sustainable materials, I am looking forward to driving the sustainability agenda across all facets of IOM3. As a Strategic Advisor I have welcomed the chance to interact with the Technical Communities outside of my direct area of specialism and I look forward to this continuing as I take up this new role. I look forward to the challenges ahead and being part of the team that will forge the future for the Institute and continue to develop the experience of members.'*

The two appointments strengthen the relationship between IOM3, the BioComposites Centre and the University as a whole, this relationship has already led to all KESS students and recent alumni been offered free Institute membership.



KESS2 Scholarships go From Strength to Strength



We currently have three Knowledge Exchange Skills Scholarships (KESS 2) students that we are supervising here in the BioComposites Centre. Bangor University leads this pan-Wales higher-level skills initiative supporting doctoral, MPhil and research master's degree qualifications.

"Carlo, Jenny and Josh are a fantastic addition to the research community here at the Centre." said Dr Morwenna Spear, one of their supervisors. *"The KESS2 programme is an excellent way to engage with Welsh companies and help exchange ideas and research techniques to help solve their specific problems".*

"The KESS 2 funded PhD and Research Masters opportunities we have been able to offer support Postgraduate Research designed and delivered in collaboration with a company partner, to meet an identified company need" said Penny Downey KESS2 Wales Manager. "This type of funded research project is a perfect fit with the BioComposites Center (BC). Over the years we have funded many collaborative research projects with BC through KESS 2 and we hope to continue to work together."

If you are interested in a scholarship or providing a placement, please visit the KESS 2 website: <https://kess2.ac.uk/>

Carlo Kupfernagel

Carlo Kupfernagel is in the third year of his PhD studying the chemical modification of wood with a low molecular weight thermosetting resin. The treatment renders low grade plantation timber dimensionally stable and imparts the ability to withstand wood destroying fungi and insects. Carlo studies the effect of different wood species and different processing conditions in this treatment. The project has allowed him to work with a broad selection of methods ranging from microscopy to thermoanalytical characterisations like dynamic scanning calorimetry (DSC). Carlo has presented his work at several national and international conferences winning an award for the best student presentation at one of them. So far, he has published one journal paper and submitted another one. *"I very much enjoy working with my supervisors and fellow students here at the BioComposites Centre"* said Carlo.



Carlo Kupfernagel during his presentation at the Northern European Network for Wood Science and Engineering.

<https://kess2.ac.uk/case-studies/wood-modification/>

<https://kess2.ac.uk/bangor-university-kess-2-researcher-carlo-kupfernagel-wins-award-at-wse-2022/>

Jenny Woods

Jenny recently graduated from Bangor University with a BSc in Environmental Conservation and joined the BioComposites Centre in July 2022. She is undertaking an MScRes under KESS2 East, and is working on a collaborative project with Wipak, a packaging company based in Welshpool. The project is looking at finding bio-based coatings for application onto paper packaging to replace the currently used synthetic polymers and to reduce issues related to accidental release of these polymers as packaging into the environment. Like many in the packaging industry, Wipak are striving to move away from plastic-based packaging towards sustainable paper materials.

Since joining us, Jenny has been able to create a bio-based solution and coat several paper substrates using the Centre's

coating technology. Jenny is looking forward to the next six months of the project, working within the BioComposites Centre and is excited to see what might be next after completing the MScRes.



Jenny Woods at packaging company Wipak in Welshpool.

People - New

Anneli Hopkins – Financial Assistant

"I joined BC in June 2022 as the Senior Clerical Officer. I have already had a thoroughly enjoyable and eye-opening experience meeting the team of friendly and welcoming scientists, who are working on a wide range of fascinating projects. My background in recent years has been training and working to qualify as a chartered accountant. I gained my Level 3 AAT Advanced Diploma in Accounting in November 2020, after which I had to pause this education due to the pandemic and all its challenges, including home schooling my two children. I intend to pick up where I left off in September 2023 with the Level 4 Professional Diploma in Accounting, then on to finish the qualification with Bangor University and become chartered.

Despite falling into finance and admin, my real passion is woodwork. Being a qualified joiner, it has been a happy coincidence to discover all the wood-based projects going on here in BC. I look forward to learning more about my profession from a scientific point of view from the fantastic people here and hopefully my experience and perspective on woodwork will also be beneficial to the departments research."



Anneli Hopkins.



Laura Bischoff enjoying graduation day after graduating with a first class masters in Chemistry from Bangor University.

Laura Bischoff – Research Technician

Growing up in Germany, my interest in chemistry became apparent when I chose chemistry to be my advanced subject during my A-levels. My journey has brought me to Wales, due to my now fiancé, and I have achieved a first-class master's degree in Chemistry from Bangor University. In July 2022, I started working at the BioComposites Centre as a research technician.

I am currently working on two different projects. The first deals with testing various lignin mixtures as a natural fire retardant. As lignin is classed as a waste product of the pulp and paper industry, the project explores this alternative way of reusing it. In the second project, I will make different extractions of the medicinal Lion's Mane mushroom and analyse them to achieve the most refined method with the maximum beneficial outcome.

Diving into different projects, not only caused me to learn a great amount about various interesting topics, but also made me use several different machines and techniques, which I was unfamiliar with. Another benefit of working for BC is that I can use and perfect the knowledge I have gained during my degree. As well as advancing my scientific skill

People - New

set, I have also developed other abilities as BC opened me up to the new world of business meetings and report writing.

My favourite aspect about BC is that this company, which I am now part of, is trying to make a difference in sustainability towards a brighter future for our planet.

Max Clarkson – Research Technician

After graduating BSc (Hons) Pharmaceutical Science at Staffordshire University, I gained experience within the Horticultural industry, where I developed a passion for the natural world and promoting sustainable practice.

I joined the BioComposites Centre in 2022 as a Research Technician on the Innovate UK funded 'PlantSea-Pack' project. Throughout my placement I have worked closely with the Bio-Tech start-up 'PlantSea Ltd' to help them test the chemical and physical properties of novel seaweed-based polymer film and develop a working prototype of shampoo-filled biodegradable pods – aiming to reduce the use of plastic shampoo bottles.

Working with the BioComposites Centre has proven an excellent pathway into the environmental sector, where the skills I have learnt can be applied towards the resolution of real-world issues.



Staff List

BioComposites Centre Staff List 2022-2023

Staff Category	Name
Research Staff	Adam Charlton
	Ahmad Al-Dulayymi
	Athanasios Dimitriou
	Campbell Skinner
	Ceri Loxton
	Graham Ormondroyd
	Morwenna Spear
	Olga Tverezovskaya (seconded)
	Paul Baker
	Qiuyun Liu
	Radak Braganca
	Robert Elias
	Simon Curling
	Viacheslav Tverezovskiy
Technicians and Research Support	Christopher Miles
	Debbie Evans
	Jacob Williams
	George Roberts
	Jonathan Nicholls
	Joshua Davies
	Laura Bischoff
	Llion Williams
	Sean Baxter
	Max Clarkson
Administration and Finance	Anneli Hopkins
	Judith Burgess
Student	Carlo Kupfernagel
	Jenny Woods
	Josh Fielding

Publications & Publicity

Journals

Baker P, **Charlton A**, Johnston C, Leahy JJ, Lindegaard K, Pisano I, Prendergast J, Preskett D, **Skinner C** (2022) A review of Willow (*Salix* spp.) as an integrated biorefinery feedstock. *Industrial Crops and Products*, 189: 115823. <https://doi.org/10.1016/j.indcrop.2022.115823>

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Hu, J., **Skinner, C.**, **Ormondroyd, G.**, Thevenon, M-F (2022) Life cycle assessment of a novel tannin-boron association for wood protection *Science of the Total Environment* 858: 159739

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Nath S., Waugh D.G., **Ormondroyd G.**, **Spear M.**, **Curling S.**, Pitman A., Mason P. (2022) Percussion Nd: YAG laser-incision of Radiata Pine: Effects of laser processing parameters and wood anatomy *Lasers in Manufacturing and Materials Processing*, 9: 153-192

Naziruddin, M. A., Kian, L. K., Jawaid, M., Aziman, N., Yusof, N. L., Abdul-Mutalib, N. A., Sanny, M., Fouad, H. & Tverezovskaya, O. A., "Development of encapsulated sage extract powder: Inter-comparison with commercially available powder for physical properties and metabolites composition", 2022, *Journal of Supercritical Fluids*. 184(1): 105571

Peng, Q. **Ormondroyd, G.**, **Spear, M.**, Chang, W-S (2022) The effect of the changes in chemical composition due to thermal treatment on the mechanical properties of *Pinus densiflora*. *Construction and Building Materials* 358: 129303 <https://doi.org/10.1016/j.conbuildmat.2022.129303>

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Publications & Publicity

Conference and Workshop Papers

United Nations Industrial Development Organisation- Operation and Sustainability of Integrated Agro Industrial Parks (IAIP) in Ethiopia- Inception workshop (on-line 28 November 2022) -Addis Ababa, Ethiopia. **Adam Charlton**: The Circular Bioeconomy at the IAIPs

Knowledge Transfer Network Agroforestry Innovation and Collaboration between the UK and Africa (webinar 16 November 2022). **Adam Charlton**: Seedling Wrap- a biobased film wrap to support Agroforestry in Uganda

Bioeconomy Ireland- Biowill -creating a Biorefinery for Willow Trees (webinar 21 October 2022). **Adam Charlton** – moulded fibre packaging produced from Willow

Eastern and Southern Africa Higher Education Centres of Excellence -Technical and Advisory workshop (on-line 9 June 2022) **Adam Charlton**- Industrial collaboration linked to circular bioeconomy research.

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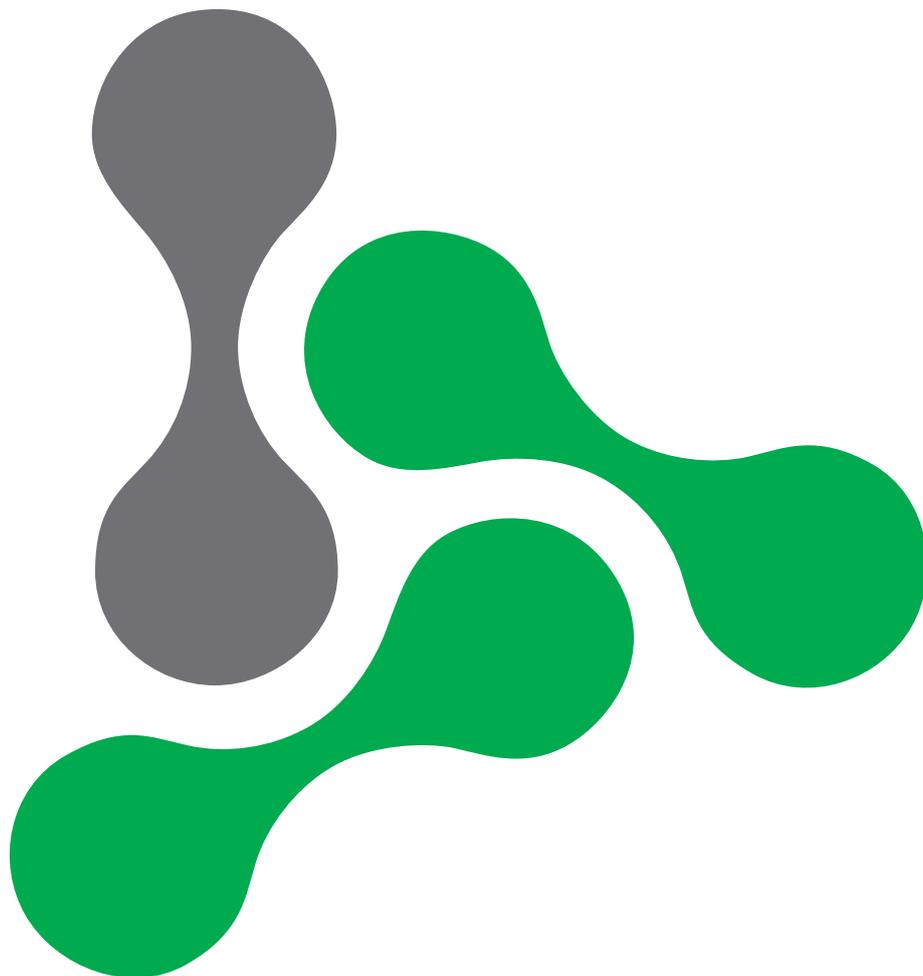
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