Excerpts: How to dissolve a tree

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The following excerpts from the article *How to dissolve a tree* have been selected for 11–14 students to support the talking heads and evaluation activity. Read the article in full at the Education in Chemistry website: rsc.li/3k4Vuyg

Ask a biologist and a chemist what the term ‘biomass’ means and you’ll get two very different answers. A biologist will tell you that biomass is the weight of all living organisms in a given area or ecosystem, but a chemist will tell you that biomass can be a fuel, a bio-friendly polymer or a feedstock for industry. ‘This is because chemists are being a bit lazy with their language,’ jokes Tom Welton of Imperial College London who has a fascination with biologically-derived materials and what can be done with them.

Using lignocellulosic biomass is certainly not a new idea: ever since man made a fire with wood we’ve been using it as an energy source. Carbon based polymers found in crude oil can be used to make plastic products but this is not an infinite resource and has a negative environmental impact. So, researchers, like Tom, have been looking again at what we can usefully do with lignocellulosic biomass, apart from just burning it.

What’s in wood?

Three biopolymers form the majority of woody plants like trees, shrubs and grasses: cellulose, hemicelluloses and lignin. Cellulose makes up the majority of lignocellulosic biomass, and is best known for the manufacture of paper, but making use of the other components is much more difficult.

One of the big issues with working with lignin or cellulose is getting the biopolymer into solution, so it can be separated from the other components of biomass. Nature has deliberately created materials these biopolymers to resist dissolution, otherwise trees would come down in the briefest shower of rain.

‘The problem with both of these materials is they are both really hard to dissolve. And hard to get back out of solution without doing a transformation on them,’ Tom Wlton explains. ‘But I’m really interested in solvents and getting things to dissolve, and I liked the challenge.’

“So far we’ve made fibres and we’re interested in using cellulose as a precursor to carbon fibre. The problem is that there’s not a lot of carbon in cellulose, but if we could make a composite of [the more carbon rich] lignin with cellulose then that might be a way to up the carbon content,’ he says.

Tom is also interested in using cellulose–lignin composites to replace the microplastics that are added to shampoo and cosmetics. ‘If we could get rid of those [they have been banned by law] and replace them with something like cellulose then that would be amazing. You can just wash that into the sea with no concern – it will biodegrade.’

Small molecules

Someone who has also encountered the problem of separation when trying to break down lignocellulosic biomass is Herbert Sixta of Aalto University in Finland. ‘At the moment, when cellulose is extracted from chipped wood for things like paper manufacture, the lignin and hemicelluloses are dissolved in water. That’s not easy and it’s even more difficult to get them out of solution again so, typically, this waste solution is just concentrated down by evaporation and sold as an energy source to be burned. What we would like to do is to be able to use all of the material usefully,’ Herbert explains.

He continues: ‘The ultimate aim is to replace crude oil with biomass.

‘The hemicelluloses transform into sugars like xylose, which can be converted to xylitol – an alcohol that’s often used as a non-calorific sweetener. We can make furans too, which can be used in the manufacture of Lycra.’

Silver bullet?

Naturally sourced, potentially biodegradable materials from completely sustainable sources. It seems that biomass could be the silver environmental bullet that humanity has been waiting for, right? Well, there are two sides to every story.

Early biomass fuels got a justifiable slamming from environmentalists. Huge swathes of rainforest were cleared for plantations of single species, like sugar, devastating the biodiversity in the process. This is something that both Herbert and Tom are adamant cannot happen again if we are to rely on biomass in the future.

‘It would be self-defeating,’ Tom says. ‘But there are sources of lignocellulosic biomass that don’t have to be grown like that. When we plant forests, we thin out the weaker trees to let the stronger ones grow and that’s all excellent biomass. And we have the recycling capacity in place to take old wood and cotton and use that too.’

Herbert has similar thoughts: ‘Consider a piece of wood. First, we use it as furniture and when that furniture has outlived its usefulness we can use that biomass as a polymer for things like fibres in textiles – maybe several times over. After that we can make the small molecules from it like sugars and furans. That’s a lot to get from a single piece of wood.’

On a more immediate timeframe, Tom’s group has been experimenting with cellulose and lignin blends to make food packaging, but the current Covid-19 restrictions have caused a momentary halt to proceedings. ‘Traditionally, coffee cups are lined with plastic, and that’s what makes them non-biodegradable. But lignin is also hydrophobic, it’s naturally sourced from biomass and biodegradable,’ he says.

So one of Welton’s students went on to make a film of 10 per cent lignin in cellulose that could have just the right properties to help solve the single-use packaging problem. But we’ll have to wait to see. “That sample is currently sitting in a locked cupboard in a department that’s not yet reopened because of social distancing guidelines,” he says. “It’s very frustrating!”

But patience could pay off, and chemists could just make biomass into much more than fuel. As a potential replacement for crude oil, and the place where humanity could get all of its carbon-based chemicals and materials, the future for biomass is of colossal importance.

Glossary

lignincellulosic	a material made from a combination of lignin and cellulose
polymer	a material made of long, repeating chains of molecules. There are both natural and manmade polymers.
crude oil	a fossil fuel mixture which can be separated into different petroleum products
lignin	a natural polymer that makes up the rigid and woody parts of plants
(hemi) cellulose	a plant material that makes up plant cell walls
biopolymer	a polymer that occurs in living organisms
solution	a mixture composed of a dissolved solid in a liquid solvent
dissolution	the process of dissolving
dissolve	when a solute goes into solution
composite	a material made of at least two materials which improves on their individual properties
microplastics	very small pieces of plastic that can cause environmental issues
biodegrade	to break down or decay naturally
hydrophobic	molecules that repel or do not mix with water