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BIOTECH DRIVES THE WATER PURIFICATION INDUSTRY TOWARDS A CIRCULAR ECONOMY

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Abstract
Rising populations and pollution levels mean that water purification is now more crucial than ever before. However, much of the industry is still using water treatment methods that originated over 100 years ago. “Coming from biotechnology, I’m really surprised about how little innovation we find in the water industry, since it’s the world’s largest natural resource… and it’s the world’s third largest market. Only oil and energy, as far as I know, have a larger revenue number than water treatment. Biotechnological methods of water purification are considered in this article.

Keywords: wastewater; adsorption; biological treatment; nanoparticles contents, water treatment, man-made chemicals.

Introduction

These outdated methods are unsustainable in the long term, particularly in developing countries. To make water purification sustainable, a handful of companies are developing new technologies that aim to make water consumption part of a circular economy, which is designed to minimize and eventually eradicate waste and pollution, keep products and materials used in industry in use, and to continually regenerate natural systems.

“As a planet, we need to address the water-energy-food nexus and think of how we can sustainably provide compact solutions that fit in an increasingly urbanized, highly populated world,” says Henrik Hagemann, CEO of Puraffinity. This London-based biotech company (previously known as CustoMem) is developing technology to remove toxic compounds from water.

While the circular economy is an admirable goal, officially endorsed by the European Commision in 2020, we have a long way to go before we have a truly circular system. Water use, purification and reuse can play an important role in making the circular economy a reality. Industrial wastewater is currently a massive source of pollution around the world; biotech solutions can be used to remove contaminants and reduce wastewater.

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Main part

Targeting waste with enzymes

"Water treatment for us is a very interesting space. It's obviously been around for decades and in itself is a biological process. And yet, there's very little in terms of biological or biotechnology solutions. We treat water with chemistry", VP Marketing, Industrial Biosolutions at Novozymes. This Danish giant of industrial biotech applications has started developing water treatment solutions in recent years.

An important focus for Novozymes is improving so-called 'sludge management'. In other words, managing the solid sewage material deposited at wastewater treatment plants. Current systems are expensive and can pollute the environment.

"What they're often doing when they're trying to dry down sludge and remove water is they're adding polymers, which is another word for plastic," said Klingenberg. "Our view is quite strongly that if you can use biology versus using something that might not be an organically erodible material, we prefer to see biology in there."

Fig.1. Sewage treatment plant

Novozymes uses enzyme technology to improve sludge management by drying out the biomass in the water more than can be achieved using conventional methods. This not only reduces costs, but also can reduce the use of polymers by up to 20%.

"Management of sludge as a whole can be as much as 50% of the operating costs for some of these wastewater treatment plants," explained Klingenberg.

Another advantage of using enzymes is that they can help anaerobic bacteria in the water to feed more quickly as the biomass breaks down. These bacteria then produce methane, which can be captured and used as a biogas. "Now you're actually creating more of a closed-loop biotech system that's enabling you to really turn a waste product into a value product," says Klingenberg.

Swedish water treatment company Pharem Biotech also has a focus on enzyme-based water treatment, but focuses on removing pollutants rather than breaking down biomass. The company has access to libraries of different enzymes that can be tailored for different purposes, for example, neutralizing drug residue from sewage water.

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"We have developed a flexible technology to treat unwanted organic micropollutants, or other organic substances, in various water and process environments. The product itself is a porous, sand-like material with enzymes bound to it".

"Comparing our technology to older technologies I would say that Pharem's solutions are more flexible, easier to use and more cost-efficient."

While Pharem can customize the enzymes to target specific pollutants, the company also produces a standard 'plug and play' module that targets common pollutants. Pharem provides this module free of charge to wastewater treatment plants as an incentive to try the enzymatic method over older and more conventional methods.

Decontaminating water with synthetic biology

Wastewater is a massive environmental and health problem. With increasingly strict regulations following on from recent knowledge about the harm the pollutants found in wastewater can do, new solutions are desperately needed.

Microbe-based removal is one way to target these unwanted chemicals. One example is nitrates, a wastewater chemical commonly appearing in the form of ammonia and urea. "In Denmark, we pump a lot of nitrates out from wastewater plants, which obviously has very significant negative effects in terms of essentially nitrifying oceans, driving less oxygen and causing real problems in terms of those ecosystems".

Although much of this pollution is just left to flow out, some places use techniques such as ion exchange to remove the nitrates. "The problem with ion exchange is you end up with a lot of salt". "So now there's a cost associated with getting rid of that salt brine."

It's early days, but Novozymes is working with as yet undisclosed partners to develop contaminant removal technology using microbes that can be used to remove pollutants such as nitrates and phosphorus.

The company Puraffinity also works on contaminant removal, but with a focus on removing per- and polyfluoroalkyl substances (PFAS) from water rather than nitrates or phosphorus. PFAS are man-made chemicals, used to produce materials such as teflon, that do not degrade naturally. Exposure to PFAS has been linked to a number of health problems including high cholesterol, cancer, and autoimmune diseases. Some research has also shown exposure to these chemicals can reduce vaccine efficacy.

"Conventional water purification tools like granulated activated carbon have done a great job at tackling the bulk of contaminants as a blunt instrument to broadly safeguard drinking water quality since the 1940s. We now need to respond to more recent challenges that arise because of human, current and past, activity," said Puraffinity CEO Henrik Hagemann.

"We developed the initial thesis for Puraffinity at the 2014 iGEM competition where we genetically engineered cells to produce functionalized bacterial cellulose to selectively capture micropollutants. We have since progressed beyond only using bacterial cellulose and now have a suite of materials to address micropollutant water treatment needs."

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Puraffinity is not the only company targeting PFAS. US-based Allonnia launched at the end of 2020 as a spinout from Ginkgo Bioworks with a goal of engineering microbes to target pollutants in wastewater and soil. 'Forever' chemicals such as PFAS are one of the key targets of its microbes.

Nature's water filter

Aquaporin proteins are nature's water filter. These proteins channel water into and out of the cells of many life forms. The discovery of aquaporins in the 1990s led to not just a Nobel Prize for Peter Agre in 2003, but also to the founding of the Danish company Aquaporin.

Based on Agre's work, Aquaporin founder and CEO Peter Holme Jensen decided to create large-scale water filters using a combination of aquaporin proteins and traditional water filters. More than 10 years down the line, the company has a drinking water filter on the market.

"We have a membrane that gets rid of all pesticides, all bacteria, all viruses. And it takes out a certain amount of the salt and minerals that are in the water, but not all. If it's drinking water, then you still need some of the minerals and salts. I think that is one of the big advantages compared to more classical reverse osmosis membranes."

The company has also just received approval from the US FDA for an osmosis membrane that can be used to concentrate food and drink substances, and is developing a reverse osmosis membrane for desalination.

Notably, the company has a partnership with NASA to develop a water filter for use in space.

"The most obvious track is the one where we extract water from urine by osmosis into a sugar and salt solution that could essentially be a Coca Cola concentrate," explained Jensen. "Then you can extract 95% of the water from the urine into the sugar solution and you end up with a beverage you can drink and concentrated urine."

Although the technology is still in development, Jensen has high hopes for it. "If we want to have something working in 10 years time to go to Mars, we have to start now. Otherwise, we will be lacking these water treatment technologies and that will be the limiting factor stopping us going into deep space exploration."

This technology also has other applications that will have a positive impact on the environment here on Earth.

"When you can extract water from human urine, then you also have technology that can extract water from other wastewater streams we use the same technology to focus on textile wastewater streams, because it's one of the biggest polluters of wastewater in the world".

Calculation

So can biotech companies focusing on water treatment and purification help us achieve the goals proposed as part of a true circular economy? Of course, achieving a circular economy will involve many other industries, but water is the world's most abundant natural resources, so it's a good place to start. Enzyme technology, specialized microbes and bio-based filters all help to minimize sludge and remove pollutants from water. But water is also a resource. Once clean, it can be used for drinking, or for

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growing crops. Valuable byproducts can also be extracted during the treatment process such as biogas or chemicals.
“What’s exciting about this field is that you can move from an initial phase of ‘capture, concentrate, and destroy’ to the second phase of ‘capture, concentrate, and reuse’ when dealing with targeted capture of high industrial utility compounds”.

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