Plastics Eating Fungus

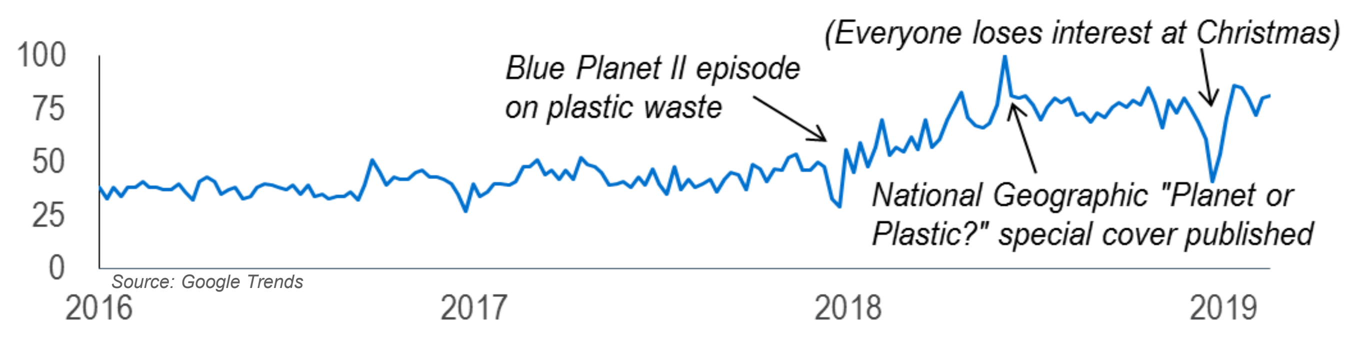
The solution to the problem of waste plastic?

Nexant

Fungus, the organism that causes worrying black patches in bathrooms, the petri-dish mould Alexander Fleming famously extracted penicillin from, the magic ingredient that makes blue cheese, truffle oil and soy sauce so delicious, is increasingly being lauded as a potential solution to the problem of plastic waste

Plastic waste and its adverse health and environmental impact is currently receiving considerable media attention. A National Geographic special cover and a Blue Planet episode directed by Sir David Attenborough has raised public awareness and the number of google searches for “plastic waste” has more than doubled in the last year.

Google searches for “plastic waste” worldwide (search numbers represent search interest relative to the highest point of peak popularity, which is 100)



China’s plastic waste import ban created disposal problems in the United States and other Western countries, demonstrating how ill-equipped most countries are to deal with their plastics life-cycle.

Negative public sentiment and the economic burden of waste disposal have influenced many governments to introduce legislation to curb plastic consumption. This trend is not limited to well-developed countries. For example, Kenya introduced a ban in August 2017 threatening imprisonment or fines of up to $40 000 for anyone producing, selling, or carrying, a plastic bag. A year on, the success of the Kenya ban has influenced other east African nations to develop similar legislation.

Proactive development of cost-effective solutions to excessive plastic waste should be a key strategy of plastic producers to sustain the beneficial uses of plastics in the longer term

Proposed solutions include substitution of conventional plastics with biodegradable plastic, effective recycling programs, chemical recycling(1), incineration and packaging redesign. These ideas are being pursued with varying degrees of success(2), but there are two fundamental problems:

- Plastics derived from petrochemicals are relatively cheap to produce in the current oil environment, making it difficult for alternative bio-based polymers to compete without subsidies.
- The very properties which make plastic useful, such as robustness and longevity, unfortunately make them intrinsically challenging to recycle or biodegrade.

The quantity of waste plastics entering the marine environment continues to increase as we struggle to find ways of slowing it down.

(1) See Plastics to Fuel and Chemicals, Nexant TECH Report 2017
https://www.nexantsubscriptions.com/node/45031
(2) See GPCA-Nexant_Circular economy and plastics, April 2018
https://training.nexant.com/blog/the-overarching-vision-of-the-circular-economy-plastics/

Plastics “eating” fungus is an attractive idea as it offers a simple way to get rid of all the plastic currently cluttering up our cities, landfills and oceans, without developing complicated recycling programs or technologies

In 2017, when a team of scientists discovered a novel “plastic-eating” fungus called *Aspergillus Tubingensis* in a rubbish heap in Pakistan(1) which disintegrated polyester polyurethane (PU) in just eight weeks under ambient conditions, it made headlines.

The discovery was significant as analysis suggested the fungus has evolved specifically to use polyester polyurethane as an energy source and eight weeks is considerably quicker than the typical biodegradation time for plastics in a landfill (which ranges from months to years).

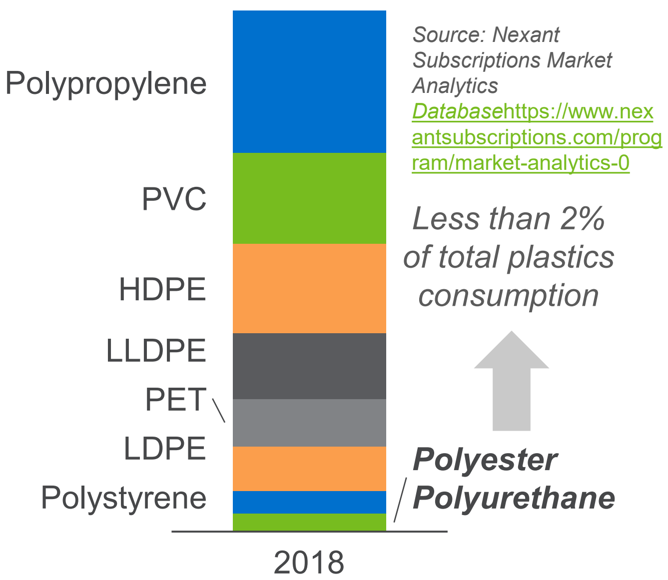
The secret behind *A. Tubingensis’* biodegradation performance was hypothesised to be a combination of the physical strength of the fungus mycelia, which helps break apart plastic film, and enzymes secreted from the fungus, which biodegrade the fragments. Mycelia are branching thread-like structures that help the process of biodegradation of wood in forests, and it is therefore unsurprising that they can break down hard substances like plastics into smaller fragments. Enzymes are protein molecules which are used in a variety of biotechnological processes as biological catalysts to speed up chemical reactions, which may allow plastics to be broken down at lower temperatures.

For plastic producers, a plastics-eating fungus is a ground-breaking idea, offering the possibility of following a strategy of “business as usual” until commercially viable alternatives to hydrocarbon-derived plastics are developed. However, what is its immediate impact on the plastics industry?

Putting the discovery into context, the “plastic eating fungus” at the centre of all the media attention has been tested with only one type of plastic so far: polyester polyurethane film.

Polyester polyurethane is a class of polymer mainly used in paints, coatings, adhesives, insulation and plastics, which only accounts for a small segment of the total consumption of plastics. So does this mean the discovery of A. Tubingensis was overhyped? Perhaps. However, the real significance of the finding is that it suggests fungi deserve further investigation, and new research may yield strains which can biodegrade or recycle a wider range of plastics.

Consumption of Major Plastics (*ktons*)



(1) Sehroon Khan et al. "Biodegradation of Polyester Polyurethane by Aspergillus Tubingensis." Environmental Pollution 225 (2017): 469-80. doi:10.1016/j.envpol.2017.03.012. https://www.sciencedirect.com/science/article/pii/S0269749117300295

Is plastic-eating fungus commercially feasible?

Considering the typical development stages of new technologies, after the initial discovery of *A. Tubingensis*, the next step is to define the concept and evaluate the market requirement.

Speculative ideas include inoculating rubbish heaps with *A. Tubingensis* or biodegrading polyester polyurethane waste in a liquid phase bioreactor using the active enzyme in the fungus.

These ideas are not outlandish as citric acid production using fungus is a well-established technology in the food industry and *Carbios*, a green chemistry company, has successfully scaled a process using enzymes to recycle PET plastic up to pilot scale[(1)].

Therefore, the active enzyme and fungus spores could potentially be produced in scaled-up solid-state or liquid fermentation bioreactors. However, even if successfully demonstrated at lab scale, further analysis would still be required to assess if the plastic eating fungus is commercially feasible [(2)].

Key Questions at Concept Definition Phase

- How would the fungus be applied to waste?
- How would the fungus/enzymes be produced at scale?
- Can *A.Tubingensis* treat mixed waste, or waste containing high levels of impurities?
- What by-products would be produced from biodegradation?
- Would any toxic or environmentally harmful by-products be produced?

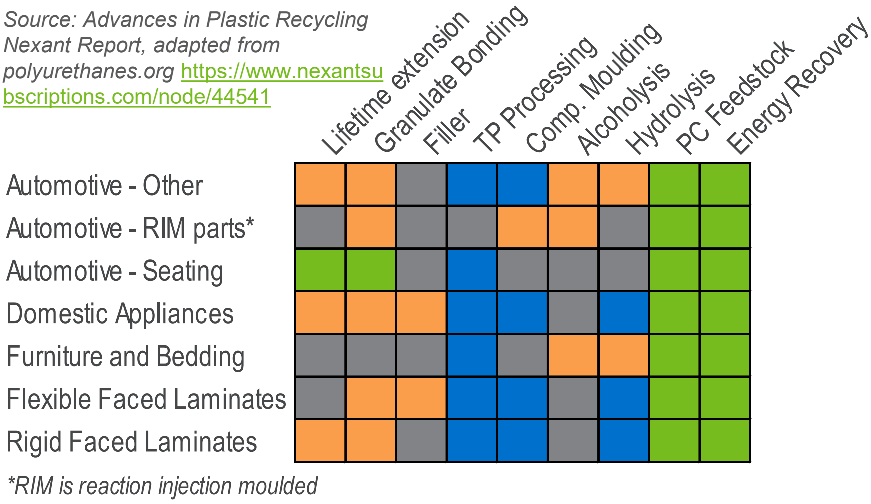
Key challenges to address in initial concept development

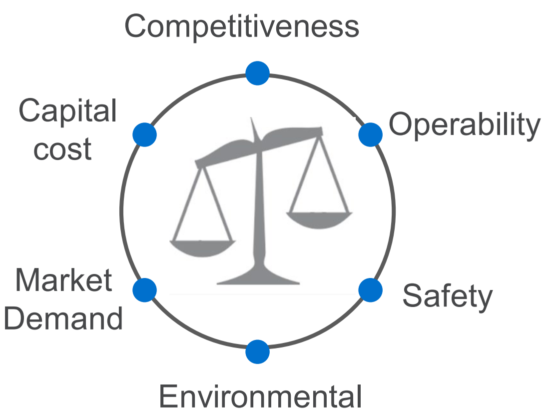
The environmental credentials of any proposed solution to plastic waste would be critical, and a life cycle analysis (LCA) would be essential to show benefits compared to the alternatives of landfill and incineration. Also, the by-products from biodegradation must be tested, as if they are toxic or environmentally damaging, this could prevent commercialisation.

Even once the milestone of "proof of concept" is achieved, producing spores or enzymes in a bioreactor may prove to be too costly to be commercialised, and so estimates of the economics of the process would be essential to assess its long-term prospects. For the case of polyester polyurethane, the economics of disposing or recycling waste using fungus must be improved over existing options for recycling (see below). Until then, it's too early to say if plastic-eating fungus will ever be technologically and commercially feasible.

Typical Recovery Options for Various Polyurethane Applications and Desirability Criteria

Source: Advances in Plastic Recycling Nexant Report, adapted from polyurethanes.org https://www.nexantsubscriptions.com/node/44541





(1) *Plastics to Fuel and Chemicals, Nexant TECH Report 2017* https://www.nexantsubscriptions.com/node/45031
(2) *Project Scale-up, Nexant TECH Report 2012* https://www.nexantsubscriptions.com/node/41849

Conclusion

Fungus eating plastics is a disruptive idea, but no concept for commercialisation has been defined yet, and the idea is still at the research phase. Critical questions still need to be answered before the commercial and technological feasibility can be assessed. Because our Blue Planet cannot wait, the successful commercialisation of other solutions to plastic waste, such as biodegradable plastics or mechanical/chemical recycling, are thought to be vital.

"It is one world. And it's in our care. For the first time in the history of humanity, for the first time in 500 million years, one species has the future in the palm of its hands. I just hope he realises that that is the case" – Sir David Attenborough

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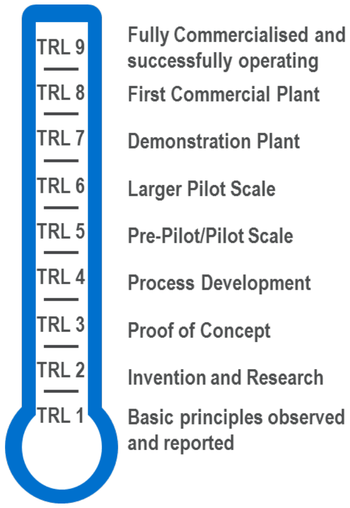

Nexant's Technology Evaluation Methodology covers every phase of technological development

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