CRC for
Water Sensitive Cities

Resource recovery from wastewater

Location:
Brisbane, Queensland

Case Study — Prepared by Cooperative Research Centre for Water Sensitive Cities, November 2019

Australian Government
Department of Industry, Innovation and Science
Business
Cooperative Research Centres Programme

Insight

A new wastewater treatment technology can generate products for Australia's $5 billion fertiliser market and $1 billion aquaculture market

Project description

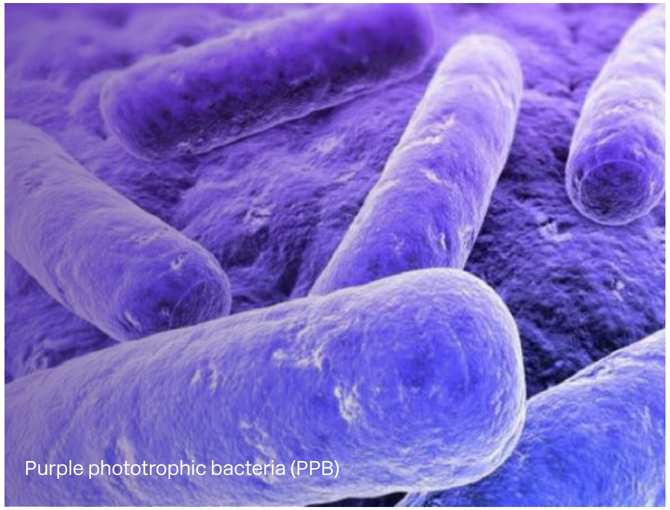
The project developed a new way of recovering energy, water and valuable nutrients (phosphorous, nitrogen and potassium) from wastewater (treated sewage). The aim was to develop a suite of technologies that, together, can supplement or even completely replace existing domestic and industrial wastewater treatment systems at different scales.

Traditional wastewater treatment technology uses aeration to convert resources in wastewater, such as nitrogen and organics, into atmospheric carbon dioxide and nitrogen gas. It is expensive (costing around $200 per person each year) and energy intensive. It is also wasteful of resources. It does not capture any of the resources present in wastewater, and so does not unlock the value of this waste.

The project concept focused on using low energy infrared light to enable special non-pathogenic photosensitive organisms—purple phototrophic bacteria (PPB)—to remove contaminants through microbial growth rather than reactive removal.

As the project developed, the scope expanded to include production of valuable products, particularly single cell proteins. This process has the potential to generate valuable fertilisers and fish feeds from suitable domestic and industrial wastewaters. Australia's fertiliser market is worth $5 billion and fish feed is the largest input cost to Australia's $1 billion aquaculture market.

The project involved testing bulk replacement of fishmeal with PPB microbial biomass in a large scale barramundi trial. The use of PPB biomass was economically viable, though with reduced fish weight at varying fishmeal replacement levels, up to complete substitution of fishmeal.



Purple phototrophic bacteria (PPB)

What does this case study demonstrate?

Each case study has been selected to demonstrate specific solutions, benefits or enabling structures that support the creation of water sensitive cities. This case study focuses on:

Wastewater management and recycling

The project enables resource recycling and recovery at all levels. Nutrients and carbon can be captured from domestic and industrial sources and used on-site and remotely.

Ecosystem health

High-environmental footprint feeds such as wild caught fish meal can be substituted with low-cost waste derived resources.

Leadership and influence

This project has established new avenues for research, which now has multiple competing and collaborating research from industrial groups in Australia and internationally (North America, Europe, China).

The drivers

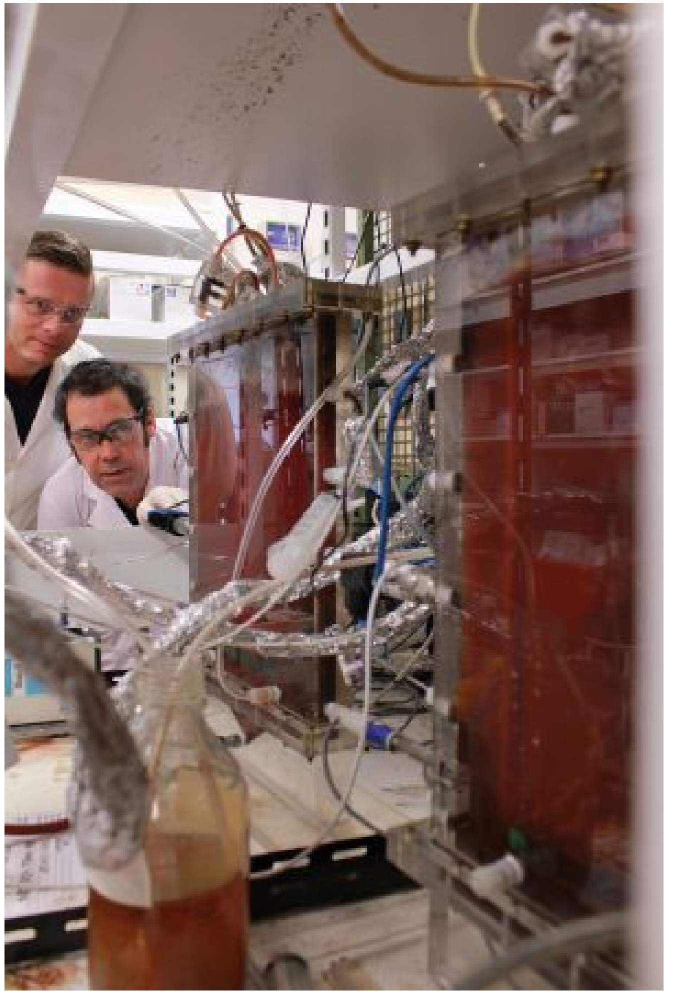
Desire to re-examine current methods of treating wastewater to extract valuable nutrients and save on energy costs

- Increased world population, population shifts to megacities and the vulnerability of conventional crop production to climate change prompted a re-examination of current methods of treating wastewater.
- Current wastewater treatment technologies do not harvest useful nutrients (phosphorous, nitrogen, potassium) from wastewater, and are very resource intensive. They also impose a financial cost on the community, who do not benefit financially from the treatment process.
- Industry and researchers recognised the need to recover nitrogen and other resources from wastewater. Recovering these valuable nutrients could offset the environmental and financial costs of energy intensive industrial nitrogen fixation and mined phosphorous.
- Animal production wastewater treatment and animal feed production have both become more profitable in recent years. This is particularly true of aquaculture, which worldwide has grown on average by 8% each year since 1961, and now supplies 47% of all food fish.
- Aquaculture is the fastest growing animal food production industry, now producing 50% of all food fish. However, aquaculture feeds depend on fishmeal derived from capture fisheries, which must be reduced for continued sustainable growth.

The innovations

Creation of a novel wastewater treatment platform that uses purple phototrophic bacteria (PPB) to simultaneously remove organic material, nitrogen and phosphorous, without destroying these valuable nutrients

- **Purple phototrophic biofilms**—These films are attached to submerged infrared illuminated surfaces. Biofilms grow extremely quickly and outcompete other organisms which may otherwise grow on the surface. This process enables a consistent, easily harvestable material stream.
- **Light-sensitive bacteria extracts nutrients from wastewater (treated sewage), converting them into solids**—These nutrients (potassium, phosphorous and nitrogen) are highly valued as fertilisers by the agricultural sector, and currently are in short supply. The project scope expanded to allow for the production of byproducts, particularly single cell proteins, which can then be used for feed or feed additives in aquaculture.
- **Pilot units of varying sizes, from 160mL to 1000L**—Much of the original concept development was done at very small scale, and then scaled up to produce enough biomass for a large scale barramundi trial. It has been trialled with natural lighting at piggeries and chicken processors.
- **Pilot units treating a variety of wastewaters**—The project has been trialled using domestic wastewater (both fresh and saline water), as well as agri-industrial streams (such as pig manure, poultry, red meat and dairy processing effluents).



↑ Early experiments with purple phototrophic biofilms

The outcomes

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• The PPB treatment process meets or exceeds the technical performance capability of existing technologies, but in a single stage bioreactor. Via this project, it became clear that the correct balance of organics and nitrogen was a factor, so the project was reorientated to resource production, rather than domestic wastewater treatment.	• The treatment process is cost neutral or positive, when value in the product can be realised as organic fertiliser or animal feeds.	• This new treatment process also has some aesthetic benefits. Wastewater treatment can generate methane, carbon dioxide and odours. By contrast, the PPB process produces almost no odours or greenhouse gas emissions, and the biomass is a purple colour, rather than the usual brown.	• The complete capture of nutrients allows for societal recycling of nitrogen. Currently from fertiliser factory to plate, only approximately 16% of the nitrogen produced ends up available for human consumption. The PPB process can close this balance and completely capture nutrients, particularly from agricultural sources.	• PPB efficiently yield biomass from wastewater with high product homogeneity and a relatively high protein fraction, making it a useful ingredient for fish feed.

Business case

The business case shows the PPB process is not economically viable for treating domestic wastewater, but is viable for treating commercial and industrial wastewater, especially from the agri-industrial sector.

The business case depends on the type of product being extracted, for example bioplastics or fishmeal. In general terms, **the business case relies on the product being worth around $1000–2000 per dry tonne**. At this level, the project is economically viable through product generation, rather than reducing the cost of treatment.

This project is a practical example of how water research is adding to the circular economy.

While first focusing on a novel method to treat wastewater, it is now emerging as an environmental biotechnology and resource recovery method. **It is converting negative value waste into positive value and sustainable inputs for the highly profitable food and agricultural sectors.**

The lessons

- Willingness to shift the project focus over time has provided a much better economic case than simply recovering elemental nitrogen and phosphorous. In particular, the project expanded to include substantially new lines of inquiry, including the capacity to generate new and value added outputs, such as animal feeds, fertilisers, and in the future, bioproducts such as plastics.
- Involvement of industry partners resulted in research that is directly useful to industry. It also gave industry confidence that the resource can be successfully implemented. This resulted in substantial forward funding to develop products from waste-derived purple bacteria, and better use the resources in wastewater.

Transferability

The project eventuated in a new platform for resource recovery, rather than simply a new way to treat domestic wastewater. This bioproduction platform has been used immediately to generate novel products such as animal feeds, but has broad applicability to gas stream desulfurisation, and the generation of biopolymers, high value chemicals and biochemicals.

The research has had strong impact internationally, with multiple groups in Spain, Belgium, Denmark, China, USA and Canada all competing and collaborating with the UQ team. It is being applied across the waste production, wastewater treatment and food production sectors.

The project has also led to further research development in the new Blue Economy CRC (the Sustainable seafood energy production project), which is investigating generating fish feed in remote areas.

Project collaborators

- Queensland Urban Utilities
- Melbourne Water
- South East Water
- Barwon Water
- GHD
- Aquatec Maxcon
- Ridley (Fish feed)
- Blue Economy CRC

Awards

2019 Engineers Australia, Fonterra Award Nominee

2018 Australian Water Association Research Innovation Award

2018 Tim Hüelsen, Advanced Queensland Innovation Fellowship

2017 Queensland Water Association Research Innovation Award

2015 Damien Batstone, Vice Chancellor's Teaching and Research Fellowship

More information

- 2018 National Water Award winners: where are they now?
- Waste not, want not
- Wastewater resource recovery project wins a 2018 Australian Water Award
- A kinetic model based on utilization of purple phototrophic bacteria for nutrient recovery
- Effects of carbon source in nutrient assimilation of purple phototrophic bacteria
- Low temperature of domestic wastewater by purple phototrophic bacteria: performance, activity, and community
- Domestic wastewater treatment with purple phototrophic bacteria using a novel continuous photo anaerobic membrane reactor