TOWARDS RESOURCE RECOVERY

Biosolids from wastewater treatment is an energy- and carbon-rich resource that in many cases is going completely to waste. John Andrews and Daniel Gapes from Scion discuss the need for better biosolids management and a new way to 'make poop pay'.

The sewage that cities and towns have to deal with daily is a source of energy and nutrients that cannot be ignored. Innovative technology that reduces biosolids volume and increases resource recovery is well on its way to commercialisation in New Zealand.

People poop. Lots of people produce lots of poop. Every day, Australia has to dispose of some 3,600 tonnes of biosolids produced by treating wastewater and sewage; New Zealand, with its smaller population, only has to cope with 1,100 tonnes.

Australia is fortunate to have a farming industry that is willing to accept biosolids, with about two-thirds being recycled to agriculture and other uses on the land, and nearly a quarter stockpiled or sent to landfill. In contrast, the majority of municipal biosolids in New Zealand are sent to landfill, with only 30 per cent reused on the land (see www.biosolids.com.au).

Agricultural reuse or land rehabilitation attempts to recover the total nutrient value of biosolids, but it comes with a cost. For example, between 30 and 90 per cent of the total cost of treatment and beneficial reuse of biosolids occurs in the disposal phase. Transport is the largest component of this cost. Typical transport distances in Australia are 200–300 km from the point of generation (DSEWPaC, 2012), often requiring heavy vehicle movement through urban areas.

THE NEED FOR BETTER BIOSOLIDS MANAGEMENT

The centenary of the commissioning of the world's first activated sludge plant will be in 2016. Ninety-nine years ago the new technology delivered impressive improvements in public health and environmental protection.

Wastewater and sludge treatment has continued to evolve, but there is still an emphasis on treatment. Opportunities exist for moving beyond wastewater treatment functions like basic sanitation to resource recovery and more.

The biosolids from the wastewater treatment are an energy- and carbon-rich resource that contains recoverable nitrogen and phosphorus. Extending value recovery further, biosolids could be used to source materials in the production of chemicals, bioplastics, biofuels and the recovery of trace metals (Figure 1). Bioplastics such as polyhydroxyalkanoates (PHA) have already been synthesised and extracted from treated wastewater-derived biosolids (Chua *et al.*, 2003).

Technologies for biosolids management currently in use vary in their costs, their effectiveness at reducing solids volume and biohazard, and in the extent of value recovery. Energy is often recovered through incineration or by using the biogas generated by anaerobic digestion.

Incineration reduces volume but is expensive and has a negative public perception. The high moisture content of biosolids can make it challenging to achieve self-sustaining combustion in an incinerator, and supplementary fuel is often required.

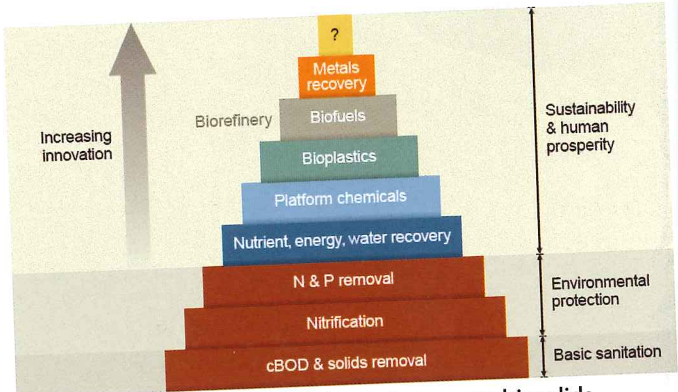

Figure 1. Increasing levels of disruption moves biosolids treatment from basic sanitation towards resource recovery (redrawn from a CH2MHILL diagram).

Anaerobic digestion is a conventional and mature technology. It is relatively inexpensive but only moderately efficient in reducing hazards and biosolids volume; value recovery is also moderate. The end product (digestate) is subject to the challenges discussed above regarding land or landfill disposal.

One alternative processing technology is wet oxidation. This process utilises wet combustion through the addition of the biosolids along with an oxidant (usually oxygen) into a vessel operated at elevated temperatures (180–374°C) and pressures (30–90 bar). Under these sub-critical conditions, carbon and nitrogen can be converted and retained as acetic acid and ammonia.

NEW TECHNOLOGY DEVELOPED

An innovative process to extract value from sewage sludge has been developed at Scion. The target of the TERAX™ process is maximum recovery of energy, carbon, nitrogen and phosphorus components. The heart of the process is a biological fermentation stage combined with a hydrothermal (sub-critical wet oxidation) second stage. This hybrid configuration provides a synergy whereby the strengths of one process mitigate the weaknesses of the other. An outline of the process is shown in Figure 2.

Thickened raw primary and secondary solids are fed to an anaerobic fermenter. The sewage sludge is held at 35–55°C and, over a period of four to six days, it undergoes hydrolysis, acidogenesis and acetogenesis, producing acetic acid and other short-chain organic acids.

The residence time is relatively short for an anaerobic process, allowing the reactor volume to be minimised with the flow-on effect of reducing capital costs. Approximately 30% of the suspended solids are dissolved during this stage and the vast majority of the carbon is retained within the solid and liquid phases.

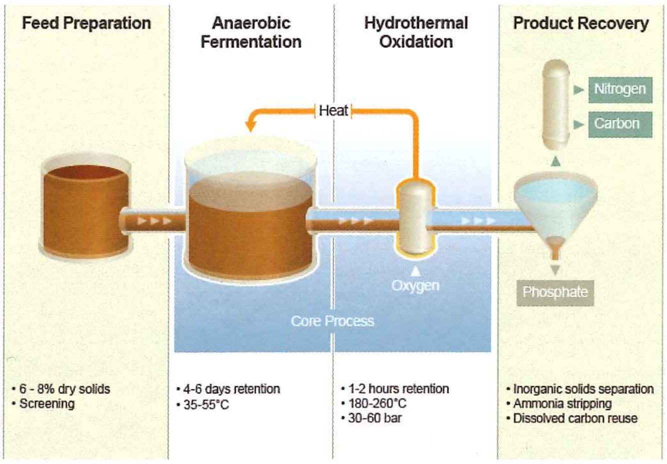

Figure 2. A simplified process diagram of the hybrid TERAX technology.

The second, wet oxidation stage is a continuous, oxidative hydrothermal process that is completed in one to two hours. The remaining organic suspended solids from the fermentation stage are rapidly degraded, with >95% destruction. The few solids that remain (mostly the inorganic component of the solids) are sterile and rich in phosphorus. Under the sub-critical conditions in the hydrothermal reactor, the acetic acid concentration rises as the organic matter is broken down. Approximately 50 per cent of the carbon entering the process is lost as CO_2 during wet oxidation, but the remainder is retained in solution, principally as acetic acid. The biosolids transformation process is shown in Figure 3.

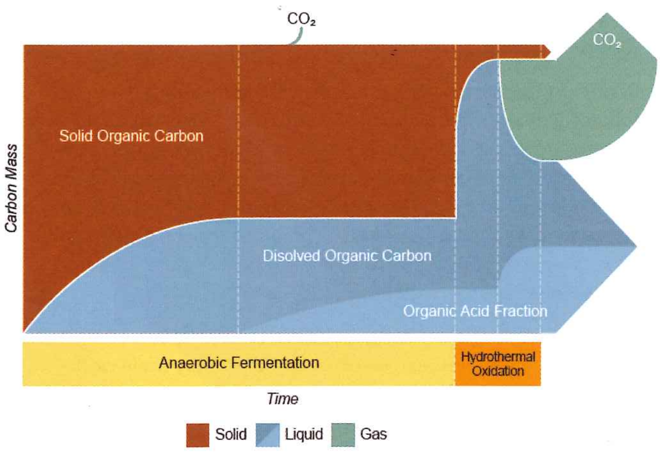

Figure 3. A simplified diagram showing the destruction of biosolids (brown) and conversion to breakdown products.

Wet oxidation can be likened to burning in water. This is important as it means that, unlike incineration, biosolids do not have to be extensively dewatered before treatment to make it effective. Chemical oxidation reactions occurring in the aqueous phase produce sufficient energy to make the process autothermal. Energetic self-sufficiency means that once the process has started, no external energy inputs are required. This includes the heat requirements for the anaerobic fermentation stage.

USING RECOVERED RESOURCES

Carbon

Acetic acid is the main carbon compound recovered in the Terax process. It can be used in a number of beneficial ways.

Organic carbon is often the limiting substrate in biological denitrification systems. Wastewater treatment plant (WWTP) operators add extra carbon in the form of methanol or ethanol to stimulate nitrogen removal. Acetic acid can be used as a supplementary carbon feedstock in denitrification. With a high ethanol price, supplementing this carbon source with acetic acid can achieve significant operational cost savings.

An alternative use for the acetic acid is to convert it to energy via methane. Acetic acid is an intermediary compound in methanogenesis and it is converted to methane more rapidly than raw wastes that first need to undergo microbial hydrolysis.

Sewage sludge deconstructed to basic molecular building blocks such as acetic acid also has the potential to be used as feedstock for new industrial processes. With its high carbon content the TERAX liquor would make a suitable feedstock in the production of high-value PHA bioplastics, for example.

Nitrogen

Nitrogen as ammonia can be recovered through the new process. Using an ammonia recovery unit operation the ammonia that accumulates in the reactor during the hydrothermal stage can be retrieved as an ammonium sulphate solution.

There is an existing market for ammonium sulphate in agricultural applications and it can readily fit into the existing supply chains. As a liquid fertiliser of known concentration, the ammonium-sulphate solution can be applied to crops in a controlled manner. Recovered ammonium sulphate from wastewater treatment is a way to displace traditional fertiliser manufacturing routes that rely heavily on natural gas.

Phosphorus

Technologies to recover phosphorus are urgently needed, as fossil phosphorus resources are finite. WWTPs are a source of phosphorus that should be seen as a resource. More than 95 per cent of the phosphorus entering the TERAX process is collected in the solid (ash) phase of the TERAX process. The phosphate content of the ash (~30%) is comparable to rock phosphate used for fertiliser production. The solid product, as with the liquid product, is in a form that can easily enter existing supply chains for fertiliser manufacture and distribution.

THE NEED FOR THE TECHNOLOGY

The first full-scale plant incorporating the TERAX process is targeted to be commissioned in 2016 in Rotorua, New Zealand. The district as a whole contains 18 lakes (Figure 4), and the town is located on a lake that has had issues with nutrient accumulation and eutrophication. As a consequence, low consent limits for nitrogen and phosphorus are in place.

Biosolids treatment and disposal costs the Rotorua District Council (RDC) approximately AU$1M per year – a large sum relative to its low population of 75,000 equivalents. Understandably, the council has been looking for a more sustainable long-term disposal option for the town's biosolids.

Rotorua's WWTP currently generates approximately 10,000 tonnes per annum of biosolids. Using the new process to extensively break down the organic component would leave 500–1000 tonnes per annum of solid material to be recycled into fertiliser.

One-third of the current operating costs at the Rotorua WWTP relate to the use of ethanol in biological nutrient removal (BNR). Significant savings could be achieved by using acetic acid from the TERAX process to substitute around 40 per cent of the WWTP's ethanol requirements.

The technology is considered to be the most cost-effective option for achieving the district council's objectives around

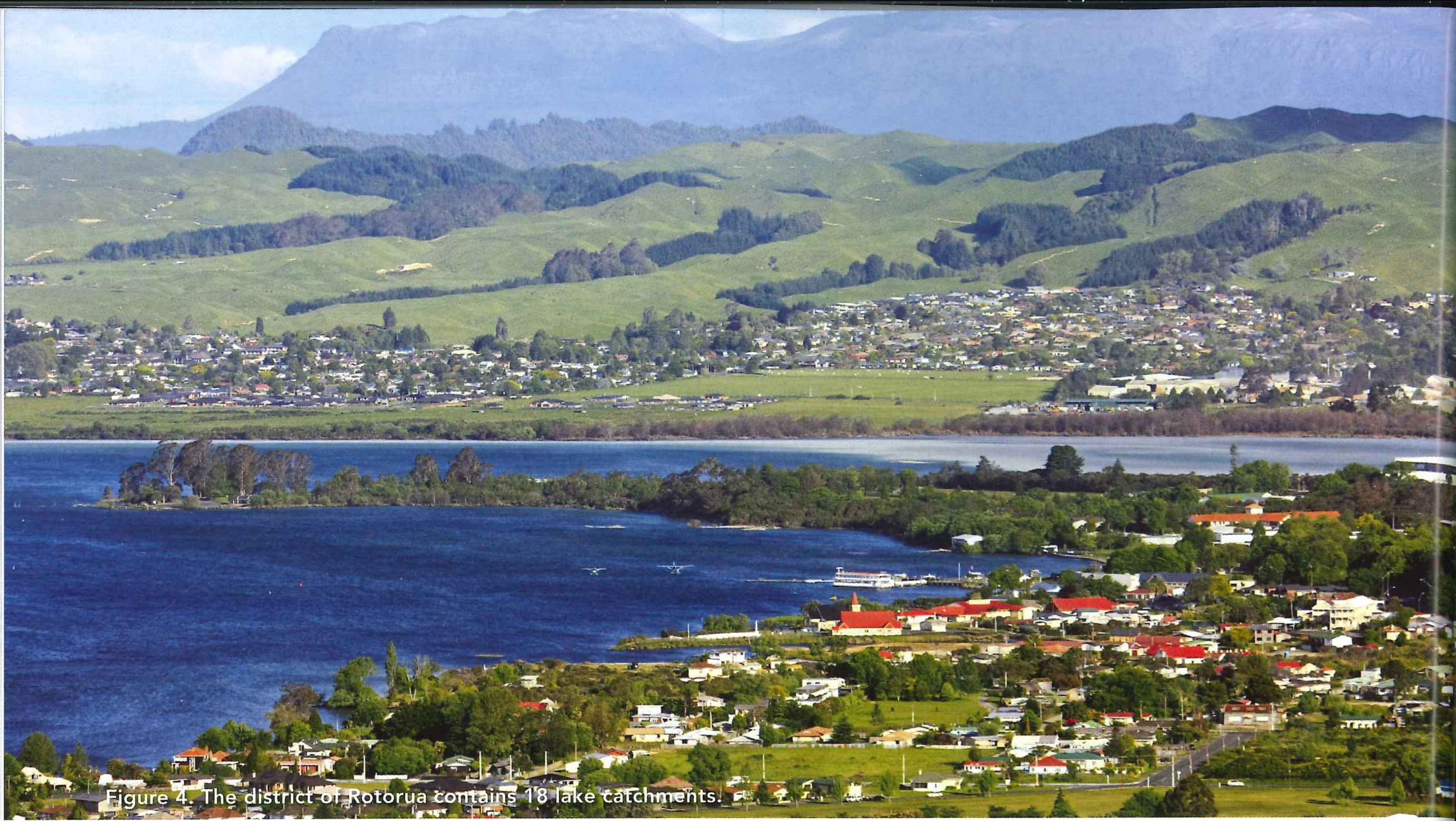

Figure 4. The district of Rotorua contains 18 lake catchments.

sustainable disposal of biosolids from the WWTP, and to comply with increasingly stringent environmental protection requirements.

The business case for the Rotorua plant has been accepted and validated through a review process. Global engineering contractor, WorleyParsons, has been selected for the engineering and project management of the full-scale plant. Construction is expected to be completed in early 2016, followed by plant commissioning and operator training prior to handover (Figure 5).

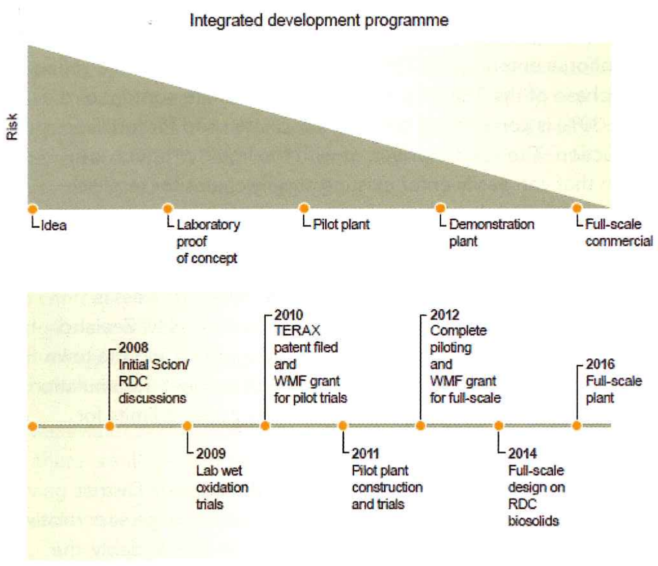

Figure 5. The technology development timeline.

COMMERCIALISING THE TECHNOLOGY

The new technology was conceived in 2006. At the same time as improved waste management technologies for the pulp and paper industry were being investigated by researchers at Scion, conversations were taking place with municipal wastewater treatment professionals in Rotorua about the issues they faced with biosolids disposal. A combination of the two sets of needs led to a convergence of technology, research and market forces.

After preliminary laboratory experiments were used to prove the technical feasibility of the work, funding was needed to improve the initial concept and develop economic models to underpin the business case for further investment. At that time, New Zealand government policy had a focus on reducing organic waste disposal at landfill. With this environmental driver and the Waste Minimisation levy as a funding mechanism, further development of the process was possible.

The technology was trialled on a pilot scale at the Rotorua council's WWTP in 2011, an experience that has proved immensely valuable. Having a tangible asset at a pilot plant scale meant that laboratory results could be replicated on a larger scale, and that stakeholders could see the technology working and have confidence in further scale-up.

Running the process on a pilot plant scale revealed the mechanical, instrumentation and control problems that could occur during full-scale operation. While the problems were frustrating, they provided key learnings that have been carried over into the detailed design of the full-scale plant. Overall, the results from the pilot stage provided sufficient justification to proceed to the initial engineering and business case phases of building a commercial-scale demonstration plant at the Rotorua WWTP.

The development process has not been linear. Aspects of the technology were frequently refined by laboratory-scale work. Ensuring models and costs were up to date, and adapting to changes in regulatory environment and investment priorities over the lifecycle of the technology development, also resulted in process changes.

The final, and perhaps most important, factor in the success of the project thus far has been the people involved. Decision makers that committed appropriate resources to mitigate risks, champions within the Rotorua council, sound project management and individuals with perseverance and passion have all contributed immensely to the progress of the process development.

BEYOND 2016

Future opportunities for the technology lie beyond biosolids. The high oxidation potential of hydrothermal processing can be applied to other organic waste streams. Primary industry wastes such as those from pulp and paper, dairy, meat and fruit processing, as well as municipal solid waste, are all potential resource streams in Australia and New Zealand. The TERAX process, utilising diverse waste streams and conserving society's resources will constitute a major paradigm shift towards more sustainable treatment systems. We are looking forward to a waste-free, resource rich future.

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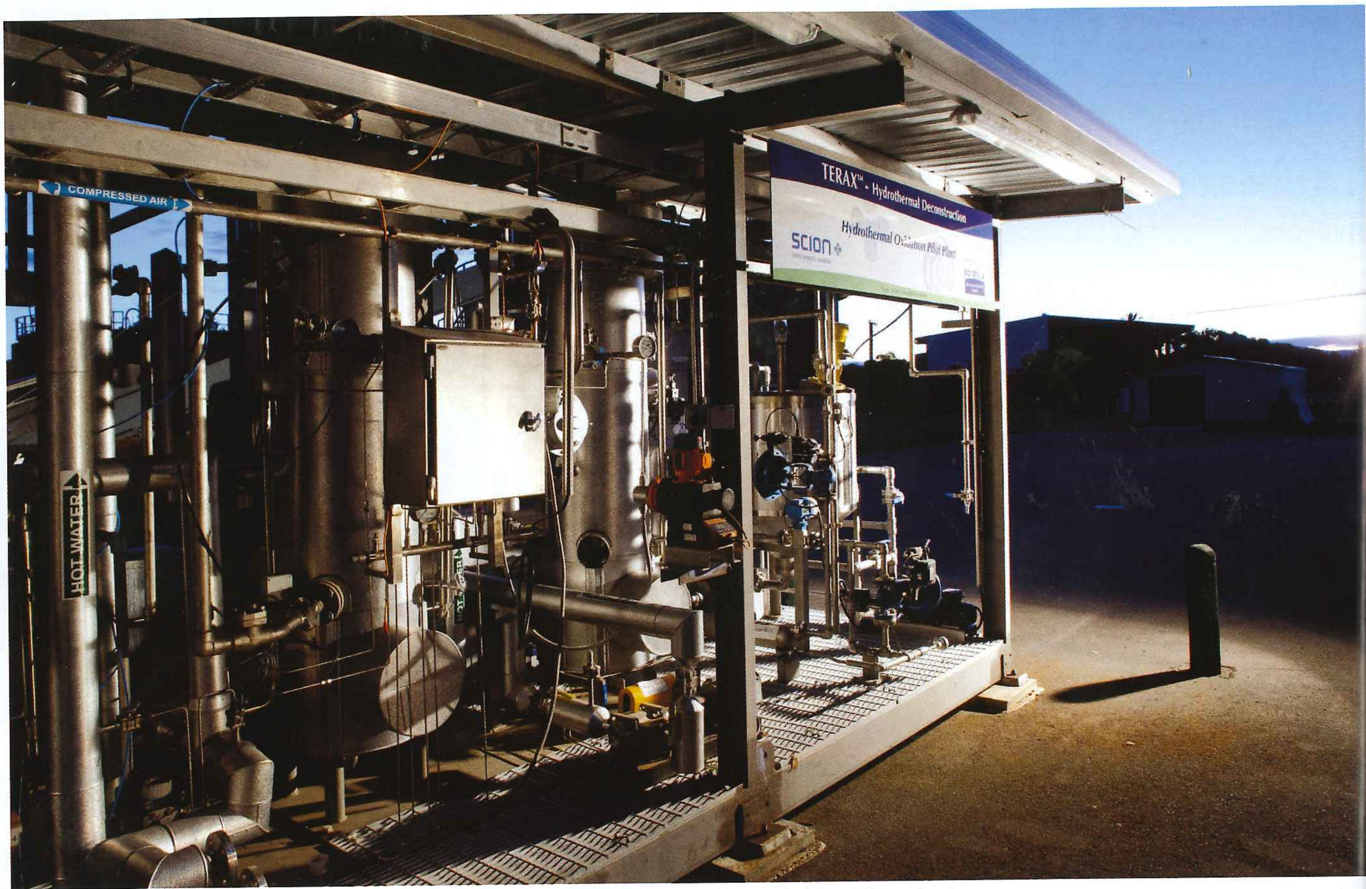

Figure 6. The pilot plant.

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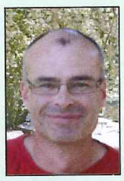
THE AUTHORS



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