Australian Water Recycling Centre of Excellence

Water recycling in food production and manufacturing

Project leader

This project was funded by the Australian Water Recycling Centre of Excellence and administered by CSIRO Food and Nutrition Flagship between 2012 and 2014.

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CSIRO team

Dr David Cox, Dr Darla Hatton MacDonald, Haidee Lease *(Consumer studies)*

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Dr Chris Smith, Dr Enli Wang, Zhigan Zhao *(Salt and nutrient uptake modelling)*

Murray Hall *(Value proposition)*

Neil McPhail, Dr Raymond Mawson *(Meat sector studies)*

Lloyd Simons, Jay Sellahewa *(Knowledge adoption)*

Project Partners

- Australian Meat Processor Corporation
- Meat and Livestock Australia
- Dairy Innovation Australia Ltd
- Australian Food and Grocery Council
- Kellogg's
- Bega Cheese
- Warrnambool Cheese & Butter
- ADI Systems
- Department of Agriculture Fisheries and Forestry, Queensland

Project management

Advice and guidance to the project team was provided by the Project Advisory Committee (PAC), which was appointed by the Centre. Progress of the project against the plan and quality of the work were assessed by PAC. An Industry Reference Group provided technical support, reviewed milestones, assisted case studies, and gave advice on industry practices.

Membership of PAC consisted of:

- Dr John Radcliffe (Chair)
- Dr Roger Bektash (Mars Australia)
- Dr Jimmy Yu (PepsiCo Advanced Research)
- Mike Johns (Johns Environmental Pty Ltd).

Membership of the Industry Reference Group consisted of:

- Dr David Poulsen (DAFF, Qld Chair)
- Michelle Edge (AMPC)
- David Barr (DIAL)
- Tony Mahar, Kartik Madhira (AFGC)
- Rob Morris (Southern Rural Water)
- Dr Alan Gregory (CSIRO)
- Jay Sellahewa (Project team).

Project summary

In recent years, Australia's agri-food industry has made significant progress in reducing its reliance on fresh water by adopting water-saving initiatives, improving efficiencies, and increasing water recycling. A number of technologies are now available for treating wastewater to obtain the required quality of water that is 'fit for the purpose' while being economically viable and conforming to the appropriate regulatory guidelines.

Tools and frameworks developed by this project, successfully demonstrated through case studies, are available for industry to assist with decision-making on wastewater treatment and water recycling options.

The rise in the price of water during the last decade is one of the main drivers for water reuse and recycling. Figure 1 provides data on the costs of residential water supplies.

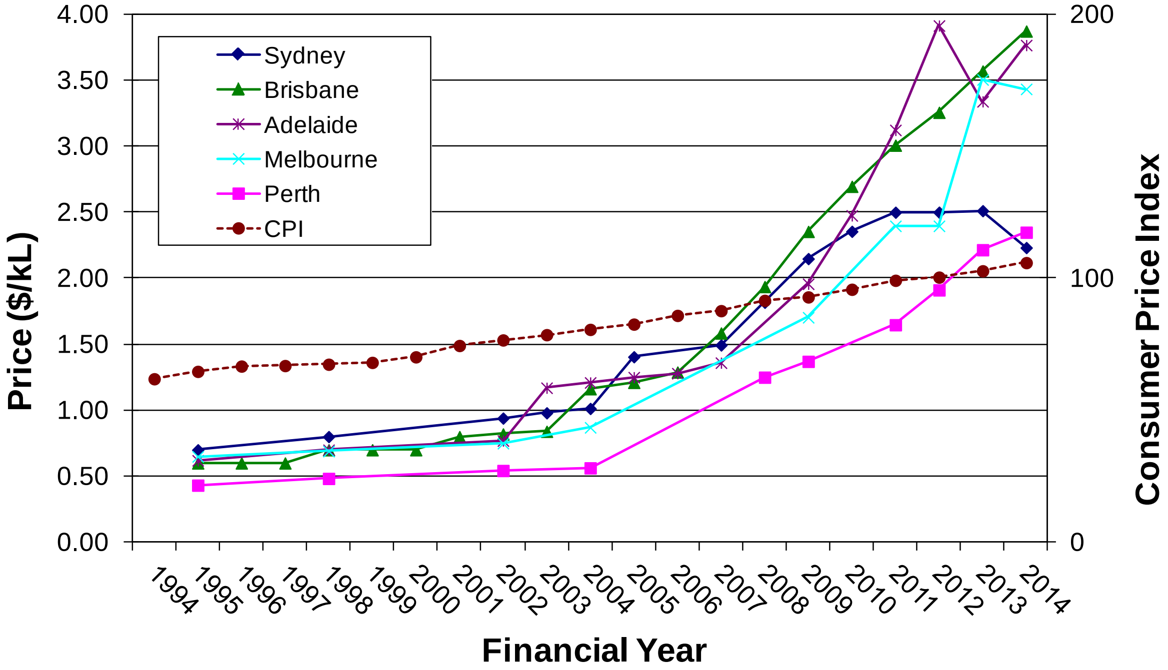

Figure 1. Rise in water prices in capital cities relative to the consumer price index (CPI)

While many individual food processing companies have invested in water recycling systems, generally however, Australia's meat, dairy and food processing industries have been slow to adopt water recycling initiatives. This is partly due to barriers such as:

- **Cost** - Investing in wastewater treatment systems is sometimes not attractive because the cost of fresh water is relatively cheap compared to the capital and operating costs of a wastewater treatment plant.
- **Technology** – Design, implementation and operation of water treatment and recycling systems can be a specialised field.
- **Consumer perception** - Negative consumer perceptions and emotions when food processing is associated with recycled water.
- **Regulations** - Challenges in complying with local, state and federal regulatory requirements related to recycling water.

Objective

The project investigated how water recycling opportunities in Australia's food processing industry can be enhanced through integrated systems analysis, technology assessment, economic analysis and targeted research. Specific objectives were to:

- Evaluate 'whole-of-system' opportunities to recover nutrient resources from wastewater streams in the meat and dairy sectors.
- Develop strategies to overcome perceived consumer barriers to water recycling by identifying product attributes that align with consumers' values and attitudes.
- Deliver decision-making tools for industry to assess water recycling and irrigation options based on the value proposition and available technologies.
- Identify opportunities to positively influence policies, regulations and incentives for water recycling by taking a systems approach to the supply chain.
- Inform stakeholders in the food, dairy and meat industries on the benefits and risks of water recycling based on scientific evidence.

Outcomes

Main outcomes from the project:

- A framework for selecting technologies for wastewater treatment for recycling and irrigation.
- A tool to evaluate the value proposition for different water treatment, recycling and irrigation options.
- A framework for operating within appropriate regulatory guidelines.
- Validation of tools and frameworks through case studies in the dairy, food and meat sectors.
- Successful use of Agricultural Production Systems sIMulator (APSIM) to predict the uptake of nutrients by crops and the sodicity of soil for treated dairy wastewater in irrigation.
- Understanding consumer attitudes and emotions when consuming foods associated with recycled water.
- Analysis of meat industry issues related to:
    - fats, oils and grease and nutrient recovery from meat processing effluents;
    - recovery of salts from reverse osmosis retentate; and
    - water usage in meat processing plants in Australia and overseas.
- Disseminating results to partners and stakeholders through workshops, conference presentations, publications, fact sheets and websites.

Project activities

The project addressed a range of technological, economic, regulatory and consumer-based issues. Team members had multidisciplinary skills and included engineers, chemists, economists, soil scientists, social scientists and psychologists. The project included five sub-projects:

Sub-projects

1. Developing a framework for selecting appropriate technologies for treating wastewater that is fit for purpose
2. Carrying out a study to understand the attitudes and emotions of consumers when consuming food associated with recycled water
3. Modelling nutrient accumulation and salt cycling in soil and nutrient uptake by crops when wastewater from dairy processing plants is used in irrigation. Agricultural Production Systems sIMulator (APSIM) software was used to carry out this modelling
4. Developing a tool to evaluate the value proposition for different water recycling and irrigation scenarios
5. Evaluating regulatory requirements and providing guidelines related to water recycling and irrigation in the agri-food sector

The project used a 'systems thinking' approach so that the various sub-projects and associated activities were not conducted in isolation.

The 'systems' approach led to a better understanding of the interdependencies of the sub-projects and enabled a more integrated reporting of the overall project outcomes (Figure 2).

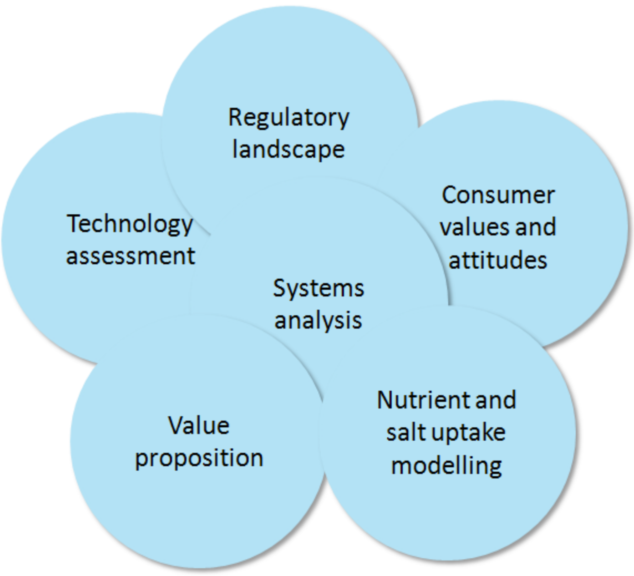

Figure 2. Integration of sub-projects

Interaction with external stakeholders

There was strong interaction between the project team, industry partners and external stakeholders. Industry workshops were held at the beginning of the project to plan and scope activities, and at the end to disseminate the project outcomes. A workshop at the halfway mark was used to discuss project progress and seek feedback from external stakeholders.

Collection of data and information

Segments of the agri-food sector have a made good progress in reducing their reliance on fresh water by increasing the reuse and recycling of wastewater after appropriate treatment. The project team collected existing information and data on recycling water in the agri-food industry. This included a literature review, consulting with the industry representative bodies - Dairy Innovation Australia Ltd (DIAL), Australian Meat Processor Corporation (AMPC), Meat and Livestock Australia (MLA) and the Australian Food and Grocery Council (AFGC).

Case studies

Case studies carried out with Bega Cheese, a large dairy manufacturing site, Kellogg's and the meat sector enabled the tools and frameworks to be tested and validated with real data. Further, the case studies provided valuable insights into the usefulness and limitations of the tools and frameworks.

Bega Cheese

The objective of the Bega Cheese project was to study the impact of irrigation from wastewater from Bega Cheese on the sodicity in the soil and the nutrient uptake by crops in irrigated farmlands. In addition, a discussion paper was prepared on the regulatory framework, three technology options were identified for consideration for treating the wastewater and the value proposition tool was tested.

Dairy manufacturing site

A comprehensive study was carried out at large dairy manufacturing site to evaluate the technical feasibility of treating its wastewater to potable quality for recycling using a pilot-scale processing system. This system consisted of chemical removal of phosphorus (P), biological removal of nitrogen (N) using a membrane bioreactor, further purification by reverse osmosis and disinfection by ultraviolet light and chlorination. An Excel-based value proposition tool was used to evaluate the value proposition for the proposed system. A regulatory framework for recycling water was also developed.

Kellogg's

The objective of the study at Kellogg's was to evaluate the feasibility of recycling water to non-food manufacturing areas and for irrigating surrounding parklands. In this study, the technology selection framework was used to identify a number of technology options to treat the wastewater to the required quality. The value proposition tool was used to estimate the net present value for different options. In addition, the regulatory requirements were addressed and guidelines for operations developed.

Meat sector

Activities for the meat sector were carried out under the guidance of AMPC and MLA, including a desktop study and survey of water consumption and recycling in Australian meat plants.

The study resulted in:

- A report on the removal of fats, oil and grease from meat processing effluents;
- A position paper on the removal of salt and nutrients from meat processing effluents; and
- A series of water recycling fact sheets for the meat industry.

Summary results from case studies

Bega Cheese

Results of the modelling of nutrient uptake by crops and soil sodicity illustrate the importance of the geographic location of a pasture being irrigated with screened wastewater from dairy processing. The site-specific climate and soil conditions determine the types of crops, the intensity of cropping in a year, as well as the maximum yield and demand for various nutrients. This in turn determines the frequency and amount of wastewater that can be irrigated and over how large an area.

The results of the modelling of nutrient uptake by crops and soil sodicity illustrate the importance of the geographic location of an irrigated dairy farm.

Crop or pasture harvesting and removal strategies also impact on nutrient cycling. The irrigated pasture management system can be optimised for the sustainable use of nutrients and salts in the wastewater. However, any salt applied must be managed by leaching it out of the soil. APSIM modelling showed that as a result of the wastewater application, P accumulates in the soil profile.

Recommendations:

- The nutrient balance in the current effluent irrigation be improved and Bega Cheese should consider different options to reduce the nutrient load in the soil when wastewater is used in irrigation. Options to consider are:
    a) treating or diluting the effluent to match the loading to crop nutrient demand (200 kg N/ha, 50 kg P/ha);
    b) increasing the area of irrigation (by 40–225% depending on the volume of wastewater used in irrigation); and
    c) adopting suitable pasture/cropping systems.
- As these options will have cost implications, a value proposition should be developed to choose the best one. The tool created by the CSIRO team may help Bega Cheese to develop value propositions for different wastewater treatment and irrigation options to assist in investment decision-making.
- The Australian Water Recycling Guidelines and NSW Environmental Protection Agency (EPA) Guidelines should be referred to when developing strategies for using wastewater for irrigation at Bega Cheese.
- The model predictions for nutrient uptake by crops, nutrient accumulation in the soil and the sodicity in the soil should be validated with actual soil data.

Further details refer to the Bega Cheese case study.

Dairy manufacturing site

Trials at a large dairy manufacturing site demonstrated that dairy processing wastewater can be recycled through a treatment comprising a P removal system followed by a membrane bioreactor, followed by a reverse osmosis system and an ultraviolet light/chlorination disinfection system. This will successfully produce water of the required chemical and microbiological quality for the dairy factory to meet potable standards and therefore find reuse within its production facilities. Installing such a system will enable the dairy factory to satisfy their future demand for water and expand their operations. As the quality of the water produced with the proposed system will be of potable quality, the current regulatory requirements will be fulfilled. An estimation of the value proposition showed that although there was no significant difference of the value compared to the cost of the proposed system for a 10-year period, the value was significantly higher for a 20-year period.

A more strict economic analysis should be carried out to ensure that the value proposition of the treatment system is viable.

Recommendations:

- Undertake a longer trial on the P recovery and membrane bioreactor systems to increase the confidence of the robustness of these systems and to ascertain how these systems will cope with seasonal and other variations in the plant and raw feed.
- Carry out an economic analysis to ensure that the value proposition of the proposed system is viable.

Further details refer to the dairy factory case study.

Kellogg's

Further treatment of the wastewater derived from the processing of food at the Botany plant with microfiltration followed by ultraviolet/ chlorination disinfection system should be considered as a viable option. The reuse of this water in non-food manufacturing areas (e.g. scrubbers) and for irrigating surrounding parklands by the local council would help Kellogg's to reduce its fresh water from the mains water supply, currently used by scrubbers, and also reduce its level of trade waste.

A value proposition analysis demonstrated that the sensitivity of the results can be explored for different data and assumptions. Initial results suggested a significant benefit compared to the cost, and the results appear to be sensitive to future water prices and to a lesser degree water use by council for irrigation. However, if there is no real change in water prices and no use of wastewater for irrigation by council over the next 20 years, then there appears to be no significant difference between costs and benefits.

> ***The value proposition tool demonstration shows that the sensitivity of the results can be explored for different data and assumptions.***

Several benefits were not included in the value analysis. The actual value of municipal irrigation is likely to be higher than considered in the analysis because of the social value associated with Kellogg's contribution to the local community. This social value is difficult to quantify but should not be under-estimated. The cost for pumping and storage of treated wastewater to local parklands was not included in the estimated cost.

For the proposed option of further treating the wastewater (microfiltration followed by disinfection with ultraviolet light and chlorination), it is expected that the health and environmental regulatory requirements will be met and the risk of non-compliance of water quality after treatment to the required standards will be very small.

Recommendations:

- Further evaluate the microfiltration option. Microfiltration followed by an in-line ultraviolet light/chlorination disinfection system is considered a viable option to enable treated wastewater to be recycled to the scrubbers and used to irrigate parkland at Botany.
- Review and refine the data and assumptions as appropriate and revise the value proposition.
- Before investment decisions are made, work closely with equipment suppliers and carry out plant trials to ensure that the required water quality could be obtained from the technology option chosen. The physical constraints at the Botany site are an important factor in making investment decisions.
- Engage with the relevant state health and environmental regulators at the earliest stage possible for any planned external uses of the recycled water.
- Determine sodium concentrations in the final wastewater. This will be important for third-party users to determine if there are any sodium absorption ratio issues at planned external irrigation sites.
- Validate that the additional treatment does remove or reduce microorganisms.
- Undertake further microbiological testing of the wastewater to determine the presence of any specific pathogens such as *Salmonella*.
- Develop a water-recycling risk management plan that meets regulatory requirements for any planned external uses.

Further details refer to the Kellogg's case study

Meat sector

Main results from the desktop study for the meat sector are:

- Red meat processing is significant to the Australian economy and large quantities of potable-quality water is used in meat processing, mainly for washing yards, unloading areas, stock floors, equipment and product.

- Average water use in Australian meat processing plants has reduced from 16.6 kL per tonne of hot standard carcass weight (tHSCW) in 1978 to 9.4 kL/tHSCW for 2008/09.

- Results from a survey in 2011/12 show that the average water use in Australian meat processing plants has dropped further to 7.2 kL/tHSCW, with a range from 2.8 kL/tHSCW for small plants to 8.6 kL/tHSCW for large plants. Large plants use more water per head because they have additional processing operations such as rendering.

- Benchmarking the water use of Australian meat processing plants with other countries shows that small plants in Australia without on-site rendering are comparable to world standards. It is difficult to make a direct comparison with large plants in other countries because of the wide variation of on-site operations in each country.

- Generally, regulations allow recycled water of potable quality to be used in meat processing areas where the water comes into contact with the product. However, for meat product that is exported, some countries do not allow any recycled water to be used if the water comes into contact with the product.

- Reverse osmosis (RO) is often used to de-ionise bore water for boiler feed and hot-water systems and large quantities of the retentate (brine) are generated. Managing and disposing of this brine is a problem because of the high concentration of dissolved solids and ions.

- A number of advanced technologies are available (and are being developed) that could be used to remove most of the dissolved solids and ions from the brine. However, these technologies (e.g. forward osmosis, vacuum membrane distillation, RO-nanofiltration integration, electrodialysis bipolar membranes, electrodialysis and electrodialysis reversal) may be costly.

- Effluents from processing red meat are high in N and contain moderate amounts of P. Therefore, these effluents should be treated prior to disposal. Physical and biological systems are available to recover nutrients and energy from these effluents. Improved efficiencies could be gained through appropriate separation of waste streams at their source.

- There are existing processes to remove fat, oil and grease from effluents in meat processing. However, there is a gap in knowledge and research is needed to determine the effects of different fat levels in effluents on anaerobic digestion. Furthermore, new processes should be considered such as:
    a) two-stage anaerobic treatment with a separate vessel or pond for initial hydrolysis and acidogenesis; and
    b) high-rate anaerobic system-inverted sludge blanket reactor for high fat effluents.

- Overall, the Australian meat processing industry is making good progress in using appropriate technologies to treat wastewater for reuse and recycling. However, further opportunities could be captured by adopting some of the emerging technologies and using the tools developed from this project.

For further details refer to Meat Sector case study

Consumer studies

Community opposition to drinking purified recycled water may extend to the use of recycled water in food production. Past research on recycled water for drinking indicates that the closer the risk of personal contact with or ingestion of recycled water, the lower the level of acceptance. Despite purification and expert assurances, emotional responses, including disgust - the 'yuk factor' - could be psychological barriers to the use of recycled water in food production.

Two studies were carried out in Adelaide, South Australia, which tested consumer acceptance of foods purported to be made from or contain recycled water (recycled within a food plant). The studies measured 'acceptance' in three ways:

- willingness to pay (relative to an alternative);
- hedonics (liking–disliking); and
- emotional responses.

Studies measured acceptance in three ways: willingness to pay (relative to an alternative), hedonics (liking–disliking) and emotional responses.

The studies suggest that anticipation of a meat product purported to be processed using or containing recycled water leads to negative reactions. However, the experience of eating the product overrides much of the negativity. Eating a meat product resulted in positive emotions and 'liking'. Experience (exposure) is well established as necessary to encourage liking. Liking is known to be one the best predictors of food consumption. All studies were conducted within the context of trust (CSIRO as a trusted and credible source of information) and how trust is conveyed generally within the domain of recycled water requires further work.

Further details refer to Consumer Studies.

Information and knowledge

Project results have been discussed in many workshops, conference presentations and publications. AFGC, AMPC, MLA and DIAL have played a key role in disseminating information to their members. An important industry forum was held at CSIRO, Werribee, Victoria in September 2014 with 45 participants.

A webinar and a summary report of the forum is available on the Centre's website.

Workshops/forums

- CSIRO workshops (March 2013 and September 2014)
- DIAL Resource Cluster Meeting (September, 2013)
- AFGC Sustainability Commitment Forums (November 2013, Sydney and Melbourne)
- AFGC Breakfast Forums (March 2014, Melbourne and Adelaide)
- Food Processing Industry Round Table Meeting (July 2014, Melbourne)

Conferences

- OzWater Conference (April 2014, Brisbane)
- Australian Institute of Food Science and Technology Annual Convention (June 2014, Melbourne)

Publications

Two papers published in *Food Quality & Preference* (2014). Both papers are in the area of consumer attitudes and emotions related to recycled water and food.

Knowledge adoption

Pathways for knowledge adoption were recognised at an early stage and were facilitated through interaction between the project team, industry representatives, and project partners. The industry forum held at Werribee in September 2014 discussed how the tools were used in the industry case studies. Cross-sector learnings and barriers for water recycling were discussed. Four key messages from this forum are summarised below.

- Industry found the value proposition tool, the technology selection framework and the regulatory framework useful when making investment decisions for wastewater treatment options for recycling or irrigation.

- APSIM is a useful tool for predicting the nutrient uptake by crops and the sodicity in soil when wastewater is used in irrigation.

- Consumer perceptions may be a barrier for adopting water recycling practices in food manufacturing areas. Appropriate terminology should be used when communicating water recycling activities in food manufacturing.

- Economic, technical, environmental, water supply and business drivers should be clearly assessed in a value proposition on water treatment systems to enable water recycling practices to be adopted.

As a direct result of this project, Fonterra engaged CSIRO to carry out a study in one of its wastewater treatment plants located in China. Some of the knowledge and tools developed by the project were successfully used. Several other Australian food processing companies are now using resources developed by the project.

Further work

Recommendations for further work are:

- Further develop the value proposition tool to enhance its function in decision-support by considering risk management with specific meat, dairy, and beverage industries. Additional funding by partners is required to customise the tool.

- Conduct additional consumer attitude trials in other states (Queensland and South Australia) to confirm the results of the trials in Adelaide. Additional funding by partners is required to proceed.

- Regulatory issues:
  a) Food industries considering the potential for recycling water in their processing and production plants should engage with relevant state health and environmental regulators at an early stage to outline what is intended.

  b) Microbiological testing of the wastewater should occur prior to any proposed treatment to determine the presence or absence of various microbial pathogens and to verify that no faecal pathogens are present. In addition, validation studies may be required.

  c) Food industries considering the potential for recycling water in their processing and production facilities need to be more proactive in calling for greater clarity within the regulatory framework because the current regulations for water recycling are somewhat ambiguous. Greater clarity and understanding of the regulations will assist industry reduce the apparent reluctance to initiate investigations into implementing water recycling and reuse processes, and in adopting different technology options.

- Develop the Technology Decision Tree into a stand-alone spreadsheet tool with a user-friendly interface. Such a tool is likely to be more readily adopted by industry.

- Continue communication activities by industry (industry forums, publishing newsletters, and trade articles) to disseminate project results so industry can benefit from the tools and knowledge for making informed decisions on water recycling options.