

Australian Water Recycling
Centre of Excellence

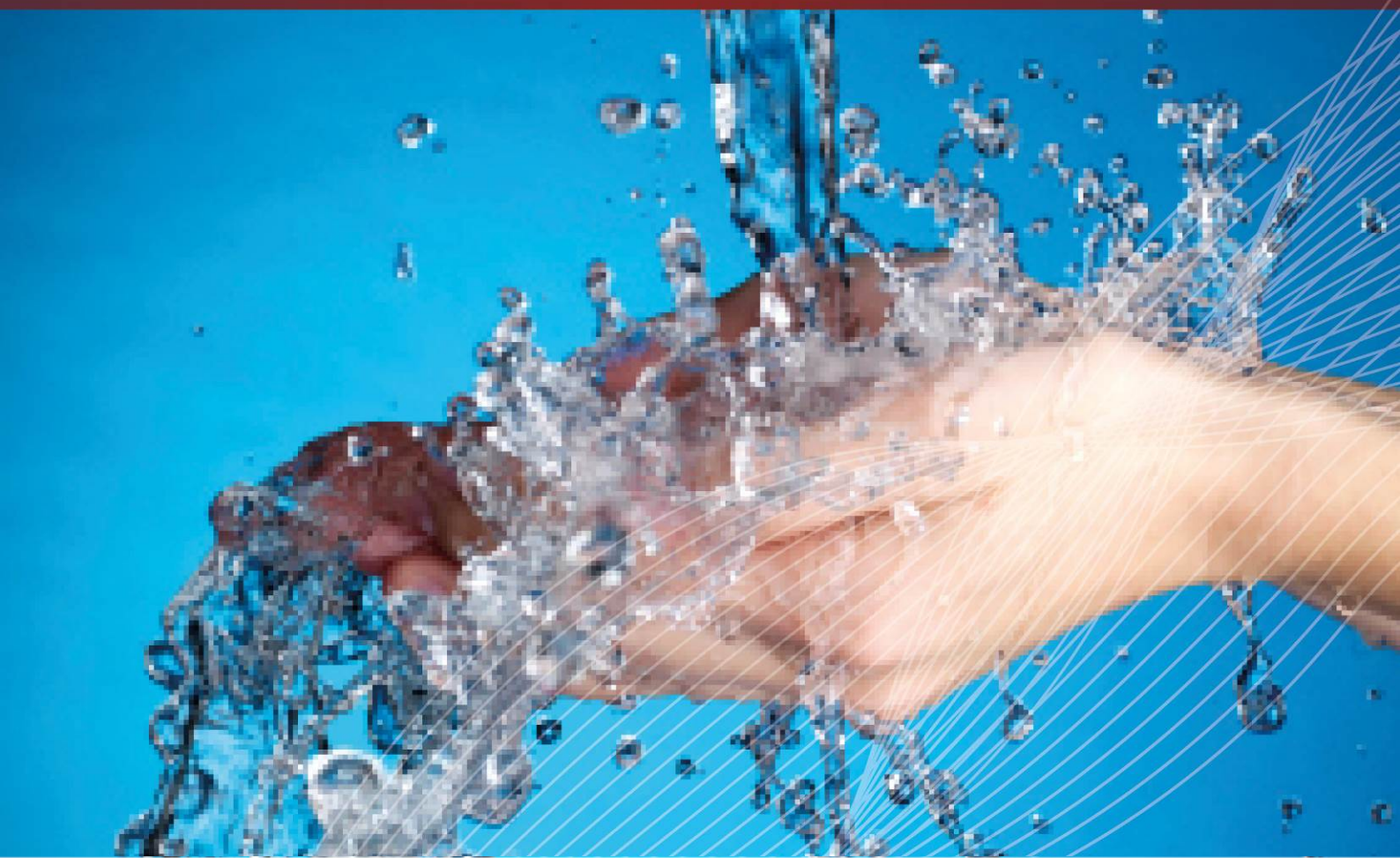


Project Report

Feasibility Study for increasing Water Recycling at the Kellogg Plant, Botany, NSW

A report of a study funded by the
Australian Water Recycling Centre of Excellence

CSIRO, June 2014



Feasibility Study for increasing Water Recycling at the Kellogg Plant, Botany, NSW

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CSIRO has been commissioned by the Australian Water Recycling Centre of Excellence, Dairy Innovation Australia Ltd. and Bega Cheese, to undertake this project. For further information about CSIRO, please visit www.csiro.au



About the Australian Water Recycling Centre of Excellence

The mission of the Australian Water Recycling Centre of Excellence is to enhance management and use of water recycling through industry partnerships, build capacity and capability within the recycled water industry, and promote water recycling as a socially, environmentally and economically sustainable option for future water security.

The Australian Government has provided \$20 million to the Centre through its National Urban Water and Desalination Plan to support applied research and development projects which meet water recycling challenges for Australia's irrigation, urban development, food processing, heavy industry and water utility sectors. This funding has levered an additional \$40 million investment from more than 80 private and public organisations, in Australia and overseas.

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TABLE OF CONTENTS

Acknowledgments	5
Executive summary	6
Background	9
Project Objectives and Scope	10
Methodology and Project Team	11
Technology assessment	11
Regulatory issues assessment	12
Value proposition	12
Key Results	13
Technology assessment	13
Regulatory issues assessment	13
Value proposition	14
Conclusions and Recommendations.....	15
Conclusions.....	15
Recommendations	15
Appendix A:- Proposed technology options for waste water reuse at Kellogg Botany Plant	16
Appendix B:- Assessment of Recycling Guidelines and Regulations as it Pertains to the Recycling of Wastewater at Kellogg Plant in Botany	26
Appendix C:- Value Proposition Analysis.....	30
Abbreviations.....	36

TABLE OF FIGURES

Figure 1 Micro Filtration Scenario 1 Components of Value.....	32
Figure 2 Micro filtration Scenario 1 comparison of costs and benefits	33
Figure 3 Scenario 2 - No water for irrigation.....	33
Figure 4 Scenario 3 No real increase in water prices.....	34
Figure 5 Scenario 4 no irrigation and not real price increase for water.....	34

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Executive summary

Background and project objectives

CSIRO is undertaking a project for the Australian Water Recycling Centre of Excellence (AWRCoE) to support the reduction of fresh water use in the Agri-food sector by increasing the amount of water that is being recycled. Kellogg has a water treatment plant at its manufacturing facility in Botany, NSW. Kellogg has identified an opportunity to further treat its waste water in Botany to the required quality standards so that this water could be used in their wet scrubbers and potentially in other applications in non-food manufacturing areas. Kellogg has been approached by local Council about the possibility of providing water for irrigation of local parks. There is interest in assessing what treatment would be required to do this. It is not certain what volume of water the Council may be interested in, and whether demands would be seasonal.

This project aimed to:

- Explore different water recycling options and to identify appropriate technologies to achieve target standards of water quality for non-food areas of the plant as well as for irrigation of local parklands
- Review existing regulations and compliance requirements for in-plant recycling of water and irrigation of local parklands
- Evaluate the commercial viability and value to Kellogg by implementing the selected technology options.

Methodology

A team from CSIRO and Kellogg was formed to undertake the project activities. The CSIRO team consisted of personnel with expertise in selecting technologies for waste water treatment, knowledge of regulatory requirements for water recycling and expertise in evaluating the value proposition for recycling options. Kellogg was responsible for providing key information on current water treatment processes, raw and treated waste water quality at various points in the plant, an understanding of water quality variability, proposed use of recycled water, history of water treatment system development and site constraints. This information was then used by the CSIRO team to provide guidance on 'fit for purpose' water quality requirements to conform to relevant regulatory requirements. Water treatment technology options to produce the required quality of water were also identified and a value proposition analysis was carried out for the selected technologies using a tool that the team has developed in its current project for AWRCoE.

Main results

Five technology options were identified to treat the waste water at the Botany plant in order to achieve the required quality of water for recycling in non-food manufacturing areas and for irrigating local parklands. These are:

- Microfiltration using a 0.2 micron filter
- Microfiltration and anaerobic digestion of sludge
- Aerobic membrane bioreactor
- Conversion of existing equalisation tank 1 into an aeration tank
- Anaerobic membrane bioreactor

All these options will require an in-line disinfection system (e.g. using ultraviolet light) prior to the final use.

These options were presented to Kellogg and after considering the advantages and disadvantages of all these options, Kellogg identified microfiltration as the most viable option. This selection was made after considering factors such as capital and operating costs, space requirements, energy recovery, odour issues and installation constraints.

Based on a budgetary quote for capital (including all associated equipment) and estimated installation and operating costs for a microfiltration system, a value proposition analysis was carried out for two scenarios when microfiltration is used to treat waste water. In the first scenario, it is assumed that 200 kL / day of treated waste water is made available to the local council for irrigation. In the second option it is assumed that the water available for irrigation is discharged as trade waste, although it is unlikely that Kellogg would build capacity to treat waste water and then discharge to sewer unless this could be justified on the basis of reduced BOD and volumetric charges. The value proposition analysis showed that based on a 20-year period, the microfiltration option will yield a present value of around \$5M with the irrigation option and \$4M

with no irrigation for a cost (capital and operating) of around \$2M. The main components of value were the savings of water for scrubbers (73,000 kilolitres/year [kL/yr]) as well as the reduced charges for trade waste volume (146,000 kL/yr) and BOD charges.

An analysis of the microbiological quality of the effluent showed acceptable levels of sodium, specific chemicals and microorganisms (including pathogens). However, due to the high sugar content and elevated temperature in the effluent sometimes, the regrowth of common organisms may occur from time to time. The microfiltration / UV sterilisation option will reduce the health and environmental risks for internal and external use of treated waste water. An assessment of the regulatory framework showed no major concerns when treated waste water is used for internal use (in non-food manufacturing areas) and in irrigation of surrounding parklands and it is believed that the health and environmental regulations will be met.

Conclusions

Further treating of the waste water at the Botany plant with microfiltration followed by UV / chlorination disinfection system could be considered as an option, but the return on investment is very low. The reuse of this water in non-food manufacturing areas (e.g. scrubbers) and in irrigating surrounding parklands by the local Council would enable Kellogg to:

- Reduce the use of fresh water from the mains water supply in the use of scrubbers by around **73,000 kL/yr**
- Reduce trade waste by around **146,000 kL/yr**.

These figures are calculated on the basis that 200 kilolitres per day (kL/day) of fresh water is currently used in the scrubbers and 200 kL/day of treated water could be used in parkland irrigation. This figure is based on the assumption that the waste water is pumped through a piping system from the Kellogg site. If however, a tanking system is used, the volume of water that could be used in irrigation would be much smaller.

The demonstration of the value proposition tool shows the sensitivity of the results can be explored for data and assumptions. For example, given data and other assumptions, **the initial results suggest a benefit of \$5million for a cost of \$2million over a 20-year period.** These results appear to be sensitive to future water prices and to a lesser degree the use of water by council for irrigation. However, if it is assumed that there is no real change in water prices and no use of waste water for irrigation by council over the next 20 years then there appears to be no significant difference between costs and benefits.

Further testing of the results by Kellogg could:

- Refine the data and other assumptions
- Define cost/benefit ratios for project viability.

It should also be noted that a number of benefits were not included in the analysis. The actual value of the irrigation option is likely to be higher than considered in the analysis because of the social value associated with Kellogg contribution to the local community. However, this social value is difficult to quantify. The cost for pumping and storage of treated waste water to local parklands is not included in the estimated cost.

With this option (microfiltration followed by UV/Chlorination disinfection), 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

- Consider microfiltration followed by an inline UV / chlorination disinfection system as a viable option to enable the recycling of treated wastewater to the scrubbers and parkland irrigation at Botany. This option should be further evaluated.
- 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 quality of water could be obtained from the chosen technology option. Such work will also enable suppliers to provide Kellogg with accurate quotations for capital equipment and will enable Kellogg to refine the cost/ benefit analysis. It is recognized that the physical constraints at the Botany site will be 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 confirm the absence of specific pathogens.
- Develop a water recycling risk management plan that meets regulatory requirements for any planned external uses.

The project scope explicitly excluded using treated wastewater in food manufacturing and packing areas.

Background

CSIRO is undertaking a project for the Australian Water Recycling Centre of Excellence to support the reduction of fresh water use in the Agri-food sector by increasing the amount of water that is being recycled.

The food manufacturing sector is the largest manufacturing sector in Australia and consumes large amounts of fresh water. As a major player in food manufacturing, Kellogg has an active team in sustainable processing and has reduced its usage of fresh water by half in the period from 2000 to 2007. These savings were achieved mainly by capturing opportunities that could be easily implemented, such as using water efficiency devices and reducing wastage. In 2007, a water efficiency study was carried out at the Botany site by the NSW Department of Commerce and further opportunities for saving water were identified and some of these opportunities have been implemented.

Kellogg has a system of treating effluent from their manufacturing plant prior to discharging to the sewer to conform to Sydney Water requirements. This system consists of primary screening, sedimentation, dissolved air flotation and pH adjustment. Kellogg has identified an opportunity to further treat the treated effluent to the required quality standards so that this water could be used in their scrubbers for odour and dust removal. Currently these scrubbers use around 200,000 litres per day (L/day) of fresh water. Water that is treated to the required quality could also be used in other support services in the plant such as in cooling towers. Kellogg does not have any intention of using recycled water (from within Kellogg premises) in the food manufacturing area at any proximity to food (cleaning floors, cleaning equipment or as an ingredient).

Following a request from the local Council, Kellogg is also considering the use of recycled water (treated to the required quality standards) to irrigate local parks and gardens. Although this initiative will promote Kellogg image with the local community, it will have cost implications. At this stage, it is not known what volume of water the Council requires.

In order to consider the feasibility of these new initiatives of recycling water, Kellogg would like to know the following:

- a) What quality standards of the treated water should be achieved for different applications (fit for purpose) in order to fulfil the regulatory requirements?
- b) What technologies should be used to treat the effluent to achieve the required quality for recycling?
- c) What is the value proposition (economic, environmental and social) in recycling water for the identified opportunities?

The CSIRO team has developed prototype tools / methodologies for selecting appropriate technologies for treating water to achieve the desired quality for specific purposes and for evaluating the value proposition of recycling water for different scenarios. In addition, the team has expertise in the regulatory framework for recycling water in food manufacturing.

The CSIRO team, as part of CSIRO's agreement with AWRCoE, expressed an interest to work collaboratively with Kellogg to address their interest in capturing opportunities for using recycled water in their scrubbers and in irrigating the local parklands and a proposal was developed to undertake this project.

Project Objectives and Scope

The project aims were:

1. To explore different water recycling options relevant to both Kellogg and the AWRCoE / CSIRO research project. Options considered were:
 - Replacing fresh water with recycled water in the scrubbers for odour and dust removal and potentially other utilities, as defined by Kellogg
 - Using treated recycled water for irrigating local parklands
2. To use the value proposition tool, technology selection framework and compliance with legislation to support their future development.

A potential benefit to the CSIRO team and AWRCoE in undertaking this project is for the CSIRO team to use and evaluate the tools developed in the current project for AWRCoE and to integrate three key activities (technology assessment, developing a value proposition and assessing the regulatory framework) in a real case study.

The scope of this study was restricted to the operations of the Kellogg manufacturing facility at Botany, NSW. The study focussed on the use of water recycled in-house, primarily on use in the odour removal scrubbers and green space irrigation. Only currently available technologies for the production of fit for purpose water recycling were considered and there was no attempt to investigate new or unproven technologies. The regulatory assessment focussed only on the identified appropriate recycled water quality that is fit for purpose as required by Kellogg. The value proposition assessment focussed on water recycling options following the assessment of appropriate technologies. The intention of this study is to provide only best estimates for treatment costs and savings based on reductions of water use or wastewater discharge. These estimates are based mainly on data supplied by Kellogg and no attempt is made to produce highly accurate values.

The project scope excludes using treated waste water in food manufacturing areas.

Methodology and Project Team

As this was a collaborative project between CSIRO and Kellogg, the project team consisted of personnel from CSIRO and Kellogg.

CSIRO team

Jay Sellahewa (Team Leader)
Nigel Goodman (Leader, technology assessment)
Simon Toze (Leader, development of regulatory framework)
Murray Hall (Leader, development of the value proposition)
Kirthi De Silva (membrane separations technologies)
Tim Muster (waste water treatment technologies)
Peerasak Sanguansri (food processing systems)

Kellogg Team

Helena Cooke-Yarborough (Team Leader)
Joe Caruana
Bruce Macklin
Nicole Woodbridge
Laura De Martin

There was close collaboration between the CSIRO team and the Kellogg team throughout the project from planning to implementation. The project commenced with a kick off meeting at the Botany site where the project objectives, timelines and the roles of the team members were discussed. In addition, the current status of water recycling at Kellogg and future plans for developing a fit for purpose water recycling strategy were discussed. A month later, the team met again on site and a comprehensive site tour was conducted so that the CSIRO team could understand the current water treatment operations at Kellogg and identify opportunities for improvement. In addition to site meetings, regular progress meetings were held via teleconferences to ensure that the project was on track.

The team focussed on the assessment and selection of appropriate technologies for waste water treatment options, developing a regulatory framework and developing a value proposition for selected technologies.

Technology assessment

The technology selection process for wastewater treatment relies on:

- The required end use of the treated water
- Determination of regulatory requirements and issues relating to specific end-uses
- Key water quality and quantity data
- Details of existing treatment processes
- Site constraints (e.g. space/odour/noise restrictions)
- An understanding of variability in water quality and flow - high / low case scenarios

The decision support tree developed by the CSIRO team was used to draw information from a database of common treatment technologies as a framework to help assess suitable technologies for Kellogg. This database does not consider technologies which are novel or high risk processes or processes which are difficult to implement in Australia (for example Anammox - due to biomass quarantine restrictions).

To complete the technology selection process, regulatory requirements, specific water quality and flow data were used as inputs to ascertain the necessary water quality improvements required and to determine which waste streams are likely to provide the greatest opportunity for treatment to levels determined by the end use.

Regulatory issues assessment

The regulatory assessment was carried out by comparing the available water quality with the Australian Guidelines for Water Recycling which identifies health and environmental implications of water recycling. It also took into consideration whether the recycling of wastewater was to be done within the plant in non-food manufacturing areas (internal: e.g. scrubbers) or sent out of the plant boundary (external: e.g. irrigation use). Issues from each of these impact categories and boundary conditions were then defined and recommendations made on how to proceed.

Value proposition

The development of the value proposition used the draft tool developed by CSIRO as part of the AWRCoE project. This tool provides a net present value calculation which considers capital and operating costs as well as resource recovery and pollution reduction costs. Although the tool does not consider social benefits, it can provide an estimate of the costs to enable Kellogg to consider whether possible social benefits will be greater than the costs.

The development of the value proposition for water recycling scenarios at the Botany site took into account the outcomes from technology and regulatory assessments and included existing desktop studies for costs in order to evaluate the feasibility of the selected water recycling options. Additional cost information was sought from Kellogg where data was not available. This information was used to estimate costs based on unit rates.

Key Results

Technology assessment

The technology assessment team visited Kellogg plant in Botany to look at the current water treatment set up and obtain information on water quality at different stages in the water treatment process. The collected information was then used to identify five water recycling technology options which would treat current waste water to the desired quality target for the required application. The options identified were:

- a. Microfiltration
- b. Microfiltration + anaerobic digestion of sludge
- c. Aerobic membrane bioreactor
- d. Aeration of equalisation tank 1 and
- e. Anaerobic membrane bioreactor

All these options will require an in-line sterilisation system (e.g. using ultraviolet light) prior to its final application.

A modified process flow diagram with tables showing advantages, disadvantages and operating costs (where available) are presented for each option (see Appendix A). Based on feedback from Kellogg and after considering advantages and disadvantages and available costs for all options, microfiltration was identified as the simplest technology to implement because it has a small footprint and can be added with minimal change to the existing plant. The introduction of an aeration system into the existing equalisation tank 1 was selected as another option to consider. This option potentially only requires the conversion of existing infrastructure which reduces the cost of wastewater treatment plant upgrade and any need for significant additional footprint. In a meeting with the Kellogg project team, it was agreed that budget costs for options a) and d) should be obtained by Kellogg with assistance from CSIRO. These costs were used as inputs in the value proposition analysis.

Regulatory issues assessment

The regulatory assessment study evaluated the implications of internal and external recycling of water on the protection of human health and the environment in the context of Kellogg operations at Botany. This study identified sources and types of contaminations, likely impact, paths of exposure, required treatment processes and the regulatory bodies responsible for internal and external water recycling at Kellogg (Appendix B).

An assessment of existing information from Kellogg Botany plant did not uncover any significant health or environmental issues for future water recycling. However, Kellogg would consider engaging with relevant state health and environmental regulators at a very early stage to highlight their intentions for water recycling and confirm this assessment. This is particularly important for any planned use by a third party. However, consultation with health and food regulators may be warranted if there are any uncertainties regarding planned internal uses. This involves being aware of how the current water quality compares to the required recycled water quality standards and providing scientific evidence to demonstrate that through validation studies that a process can be put in place to bring the waste water quality to the required standard which is fit for purpose. This involves (but not restricted to) checking levels of sodium, other chemicals and microorganisms (including pathogens) in the waste water and recycled water streams. The validation work must be documented as part of a risk management plan that can be presented to the regulators for discussion and endorsement as needed.

Value proposition

The value proposition tool was used for the microfiltration option based on information obtained from performance trials, a budgetary quote from an equipment supplier and estimated operating costs (Appendix C).

A value proposition analysis was carried out for two scenarios when microfiltration is used. In the first scenario, it is assumed that 200 kL/day of treated waste water is made available to the local council for irrigation. In the second option, it is assumed that the water available for irrigation is discharged as trade waste. However, it is unlikely that the waste water would be treated prior to discharge unless cost justified due to high BOD and volumetric charges. The value proposition analysis showed that based on a 20 year period, the microfiltration option will yield a present value of around \$5M with the irrigation option and \$4M with no irrigation for a cost (capital and operating) of around \$2M. The main components of value were the savings of water for scrubbers (73,000 kL/yr) as well as the reduced charges for trade waste volume (146,000 kL/yr) and BOD charges.

A sensitivity analysis showed that the costs and benefits appear to be sensitive to future water prices and to a lesser degree the use of water by council for irrigation. Details of this analysis are shown in Appendix C.

Conclusions and Recommendations

Conclusions

Further treating of the waste water at the Botany plant with microfiltration followed by UV / chlorination disinfection system could be considered as a viable option as the return on investment is low. The reuse of this water in non-food manufacturing areas (e.g. scrubbers) and in irrigating surrounding parklands by the local Council will enable Kellogg to:

- Reduce the use of fresh water from the mains water supply for use in the scrubbers by around **73,000 kL/yr**
- Reduce trade waste by around **146,000 kL/yr**

These figures are calculated on the basis that 200 kL/day of fresh water is currently used in the scrubbers and 200 kL/day of treated water could be used in parkland irrigation.

The demonstration of the value proposition tool shows the sensitivity of the results can be explored for data and assumptions. For example, given data and other assumptions, **the initial results suggest a benefit of \$5million for a cost of \$2million over a 20-year period.** These results appear to be sensitive to future water prices and to a lesser degree the use of water by council for irrigation. However, if it is assumed that there is no real change in water prices and no use of waste water for irrigation by council over the next 20 years then there appears to be no significant difference between costs and benefits.

Further testing of the results by Kellogg could:

- Refine the data and other assumptions
- Define cost/benefit ratios for project viability

It should also be noted that a number of benefits were not included in the analysis. The actual value of the irrigation option is likely to be higher than considered in the analysis because of the social value associated with Kellogg contribution to the local community. However, this social value is difficult to quantify. The cost for pumping and storage of treated waste water to local parklands is not included in the estimated cost.

With this option (microfiltration followed by UV/Chlorination disinfection), 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

- Consider microfiltration followed by an inline UV / chlorination disinfection system as a viable option to enable the recycling of treated waste water to the scrubbers and parkland irrigation at Botany. This option should be further evaluated.
- 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 quality of water could be obtained from the chosen technology option. Such work will also enable suppliers to provide Kellogg with accurate quotations for capital equipment and will enable Kellogg to refine the cost/ benefit analysis.
- If the water is intended to be used externally for irrigation purposes:
 - Engage with the relevant state health and environmental regulators at the earliest stage possible;
 - Determine sodium concentrations in the final wastewater and any Sodium Absorption Ratios issues that may exist;
 - Validate that the additional treatment does remove or reduce any microorganisms to acceptable levels;
 - Undertake further microbiological testing of the wastewater to confirm the absence of any specific pathogens; and
 - Develop a water recycling risk management plan that meets regulatory requirements.

Appendix A:- Proposed technology options for waste water reuse at Kellogg Botany Plant

Introduction

CSIRO is undertaking a project for the Australian Water Recycling Centre of Excellence (AWRCoE) to support the reduction of fresh water in the Agri-food sector by increasing the amount of water that is being recycled.

Kellogg has identified an opportunity to further treat the treated effluent to the required quality standards so that this water could be used in their seven scrubbers for product dust and odour removal. Currently these scrubbers use around 200kL / day of fresh water. Water that is treated to the required quality could also be used in other support services in the plant such as in cooling towers. Kellogg does not have any intention of using recycled water (from within Kellogg premises) in the food manufacturing area at any proximity to food (cleaning floors, cleaning equipment or as an ingredient). Kellogg would consider the use of recycled water (treated to the required quality standards) to irrigate local parks and gardens. Should the local Council be interested in such an initiative, agreement on the cost-sharing and ownership of infrastructure to pump and store the water would be required.

Objectives

CSIRO has proposed five different technology options for wastewater treatment and reuse at Kellogg, Botany, to provide 'fit for purpose' recycled water. Several of the approaches presented are potentially lower capital expenditure as they utilise existing infrastructure, others are potentially higher cost but add value and reduce electricity and heating bills as they incorporate energy production.

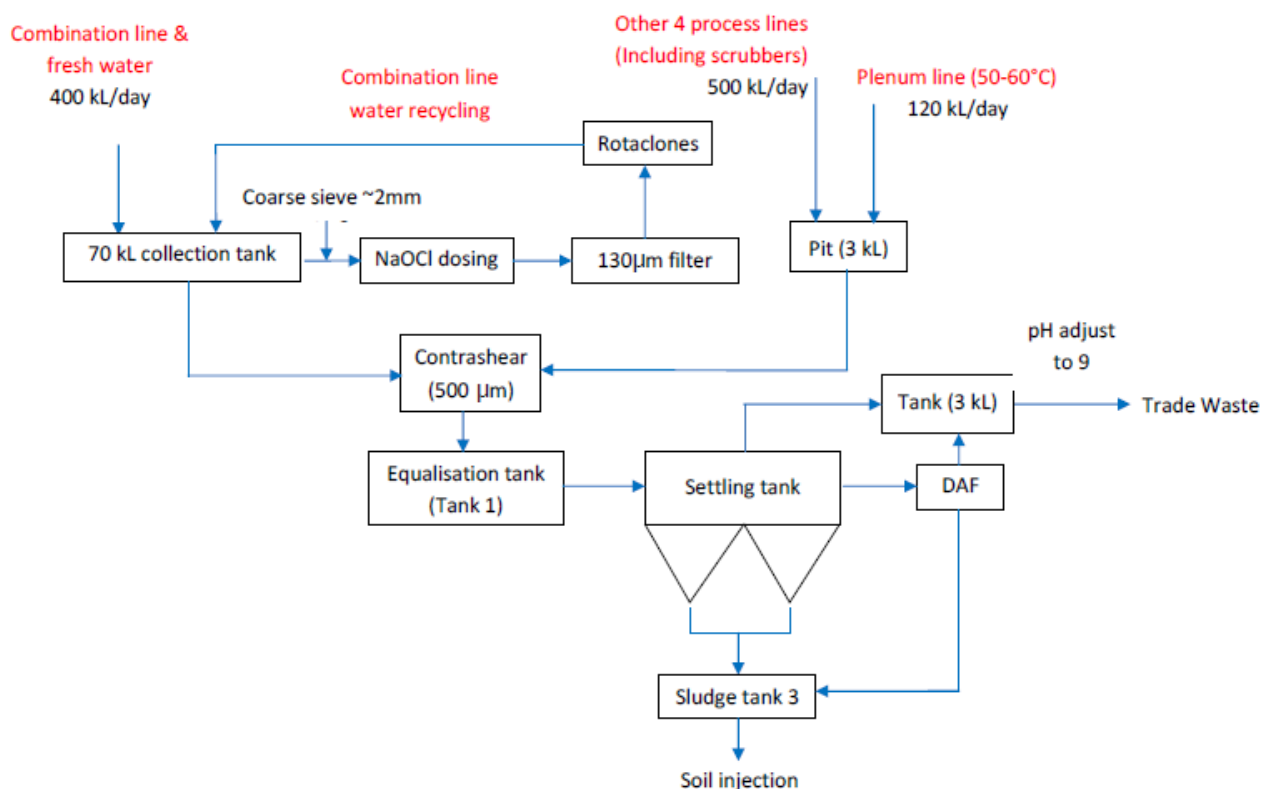
Current wastewater treatment process

Figure 1 describes the existing wastewater treatment process at Kellogg plant in Botany. The flow rate is currently 800 kL/day. The screened wastewater reporting to the pit contains approximately 3000 mg/L BOD, has a pH = 4.3, total N = 17.6 mg/L, total P = 5.8 mg/L (Table 1). This water has the potential to be treated to a level where it could be recycled, and has the ability to be treated anaerobically to generate methane. However, it is unlikely that the volume of methane generated will be sufficiently high to be utilised in the boiler house.

The current treatment process uses a sedimentation tank which has rough dimensions of 6 x 2 x 1.5 m (18 m³). The sedimentation tank has fins that slope backward against the wastewater flow, and the tank also has a scraper that is operated intermittently to remove oil-based emulsion. The solids from the sedimentation tank have the visual appearance of flowing wet sand and are pumped into the sludge tank. Wastewater from the sedimentation tank reports to a transfer tank and then an inline mixer doses cationic flocculent (Ecofloc F4612E). The wastewater then reports to an induced air flotation (IAF) vessel. The IAF vessel is a local design and specified to handle 1 ML/day. It is cylindrical in shape, and is an over-and-under design (total volume approx 12 m³). The floated fraction is placed under a mild vacuum and then delivered to the sludge tank.

The combined sludge contains 8-12 wt% solids and is taken away at the rate of approximately 40 t/month.

Figure 1. Summary of existing wastewater treatment process at Kellogg plant in Botany



The treated effluent is pumped back 50 m (towards pit/contrashear) and dosed with NaOH (50% NaOH, 96t/yr) to raise pH to 7-9 to meet trade waste requirements. Trade waste water is charged on the basis of volume and BOD; with Sydney water indicating that they will increase levies into the future. Treated effluent quality is described in Table 1.

Table 1. Water quality data is shown below.

Description	BOD (mg/L)	pH	TN (mg/L)	TP (mg/L)	Conductivity (µS/cm)	FOG (mg/L)
Wastewater	3000	4.3	17.6	5.8		
Treated Effluent	2100	7.7	3.1	5.5	<800	11

The cost/day for treating wastewater was not available from Kellogg. An estimate for the operation of various technologies and associated costs is detailed in Table 2.

Table 2. Summary of the current cost of wastewater treatment for various technologies

Process / step	Cost (\$/day)	References
Sedimentation	41	Based upon Young et al 2013 Vancouver paper
IAF	281	Based on Aquatec-Maxcon data (2002)
Caustic Dosing	131	Assuming \$500/t for 50% NaOH solution
Sludge Removal	95	400-500 t/a; at 8c/L (Kellogg)
Trade waste fees for BOD	600	2100 mg/L BOD (Sydney Water fees, 2013)
Total	1148	

Technology Options

Option A: Investment into Microfiltration (Ceramic)

Summary of technology: Based on the data supplied by Kellogg, the partially treated wastewater ex-DAF is of reasonable quality, hence microfiltration (MF) with a 0.2 micron filter could be employed to re-use the water in the scrubbers and in any other areas where there is no direct contact with food. Microfiltration together with inline disinfection, such as UV should result in microbial quality of water equivalent to potable water (Figure 2). The results of the preliminary trials conducted at Kellogg indicate that MF is capable of reducing the microbial load, total suspended solids and BOD. If the BOD levels need further reduction (<100mg/L), the addition of ultrafiltration or nanofiltration should be considered after evaluation of their performance. Based on the figures supplied by Kellogg, this strategy could potentially save up to 400 kL/day. Any excess water would be suitable for use for irrigation purposes. Some of the advantages and disadvantages of this approach are outlined in Table 3.

Figure 2. Proposed microfiltration / UV- Chlorination disinfection system

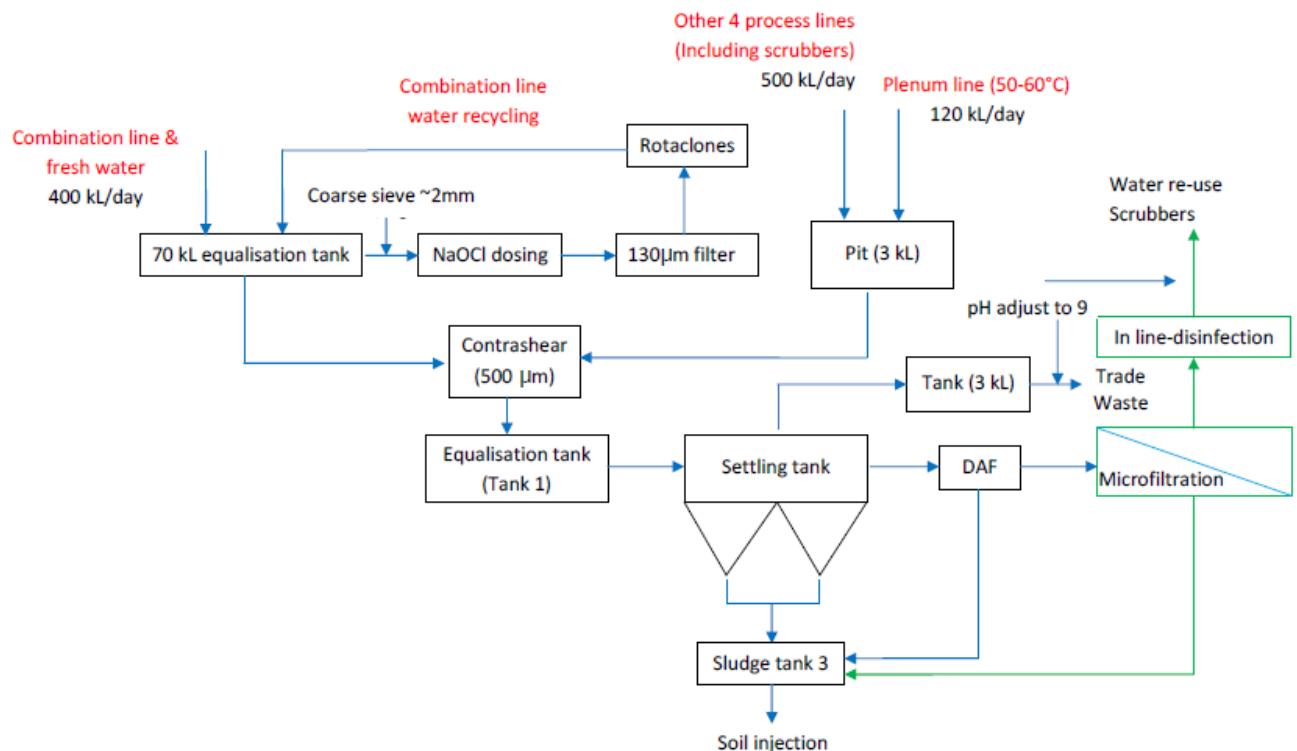


Table 3. Potential advantages and disadvantages of microfiltration

Advantages of technology	Disadvantages of technology
Low consumption of treatment chemicals when compared with other technologies	High pressure systems can be energy intensive
Can easily be automated, therefore reduced labour costs.	Ceramic membranes are more expensive than polymeric
Reduces microbes	Irreversible membrane fouling is a risk
Greater water savings; reduced billing	Potentially a long payback period (3-4 years)
Simple proven technology	No energy recovery
Removes BOD	Increased sludge volumes
OPEX includes electrical energy, membranes replacement, CIP chemicals (NaOH)	May need treatment chemicals to prevent fouling, leading to increasing space requirements
Small foot print and long lasting (3-10 years)	Flux rate gradually declines over time, recovery rates can be much less than 100%

Option B: Investment into Ceramic Microfiltration plus anaerobic digestion of sludge

Figure 3 describes a process of microfiltration / UV sterilization system with anaerobic digestion of sludge, this is the same as above with the addition of anaerobic digestion of sludge via UASB (upflow anaerobic sludge blanket) or EGSB (expanded granular sludge bed). Table 4 outlines some of the potential advantages and disadvantages of this approach.

Figure 3. Proposed microfiltration / UV-chlorination disinfection system with anaerobic digestion of sludge

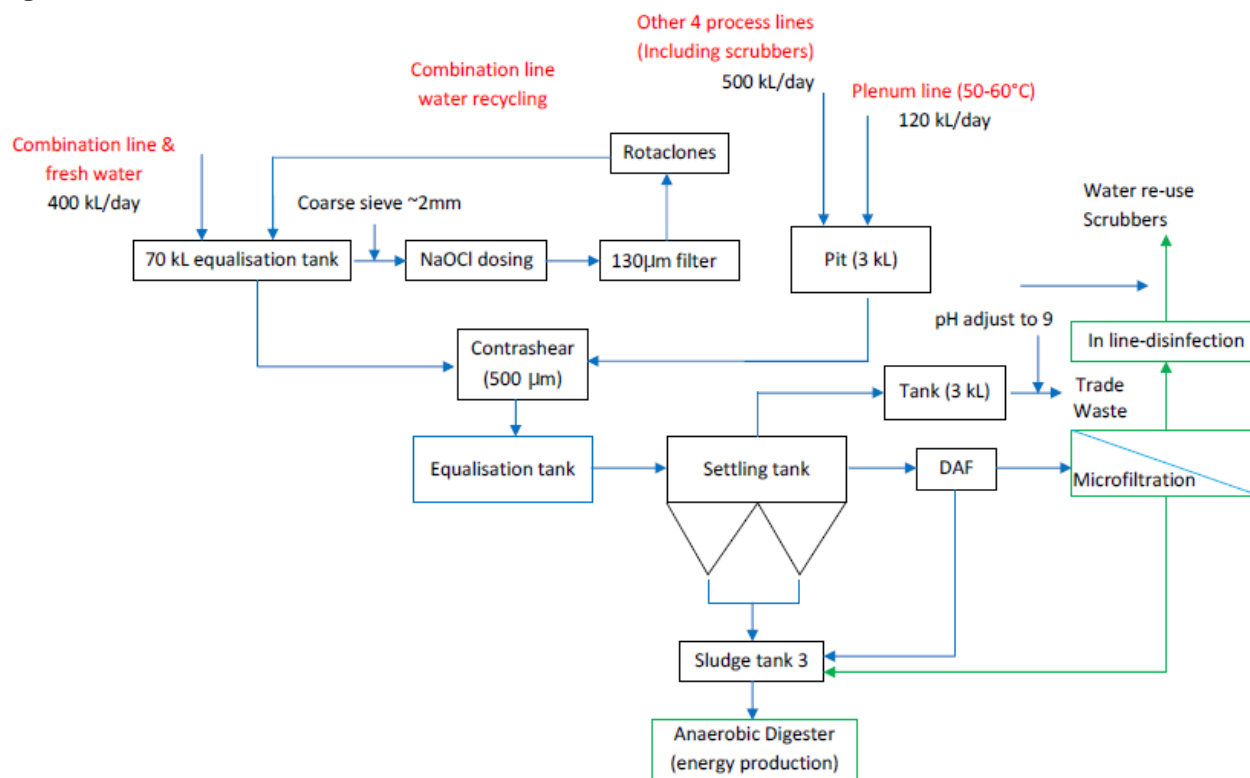


Table 4. Potential advantages and disadvantages of microfiltration with anaerobic digestion of sludge

Advantages of technology	Disadvantages of technology
Makes use of larger sludge volumes	Additional anaerobic technology needed, plus gas management
Gas production may offset some energy costs (MJ) It should however be noted that the volume of gas production is likely to be small and may be flared rather than utilised as a source of energy	Potentially longer payback
	Turbine, flaring, gas scrubbing may be needed
	Possibility of increased odour

Option C: Investment into aerobic membrane bioreactor (MBR)

Summary of technology: Aerobic MBR technology is similar to conventional activated sludge (CAS) wastewater treatment systems except that the biomass is retained within the system rather than via returned activated sludge (RAS). The membrane cassette is usually submerged within the same tank as the biomass (and wastewater), however configurations can also include external membranes. Submerged membranes generally require lower capital investment. Separation of treated effluent from solids occurs via microfiltration membranes with pore sizes ranging between 0.1 -0.4µm. Facilities generally require permeate pumps, chemical storage tanks, chemical feed pumps, air scouring system, back-pulse water flushing system. Some of the potential advantages and disadvantages of an aerobic MBR are outlined in Table 5.

Figure 4. Proposed membrane bioreactor (MBR) / UV-chlorination disinfection

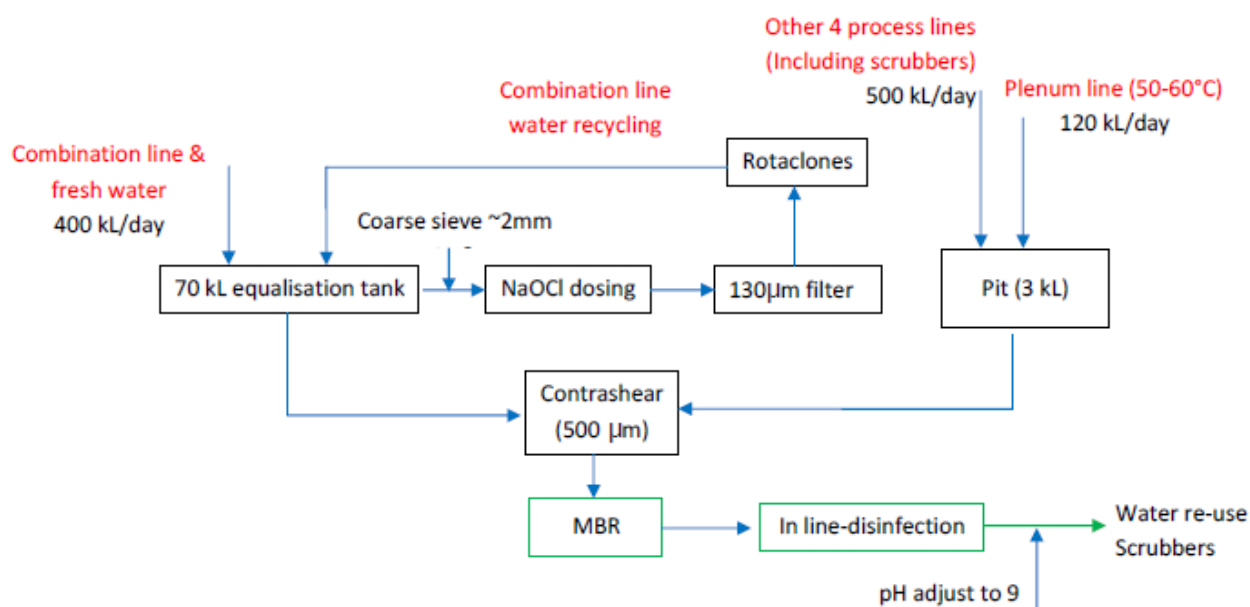


Table 5. Potential advantages and disadvantages of an aerobic membrane bioreactor (MBR)

Advantages of technology	Disadvantages of technology
Up to 95% reduction of BOD	No energy recovery from sludge
Eliminates the need for secondary clarification (IAF)	Larger footprint when compared to Options A and B
High volumetric loading rates and shorter hydraulic retention times	Potentially high capital costs
Longer sludge retention times (SRT) resulting in less sludge production	Membrane fouling may be an issue
High quality effluent (low TSS, low BOD)	Higher energy costs
Less space required than CAS	Membrane replacement (3-7 years)

Option D: Investment into aeration of Equalisation Tank 1

Summary of technology: High rate aeration has been demonstrated to significantly lower BOD levels with hydraulic retention times of as little as 30 minutes. High rate aeration of the equalisation tank 1 and subsequent settling in laminar settling tank will improve water quality by reducing BOD and TSS while utilising Kellogg existing infrastructure. This may be achieved by aerating the equalisation tank as is practiced in high-rate A stage treatment processes which were developed in Europe circa 1980 (Versprille, 1985). Adapting the existing equalization tank (Tank 1) to become an aeration chamber for BOD reduction (Figure 5) would involve the installation of blowers and aeration diffusers located at the bottom of the tank. As this utilises some existing infrastructure, this may present a low cost option to provide significant BOD reduction. Potential advantages and disadvantages are shown in Table 6.

Figure 5. Proposed conversion of Equalisation Tank 1 to an aeration tank, followed by disinfection

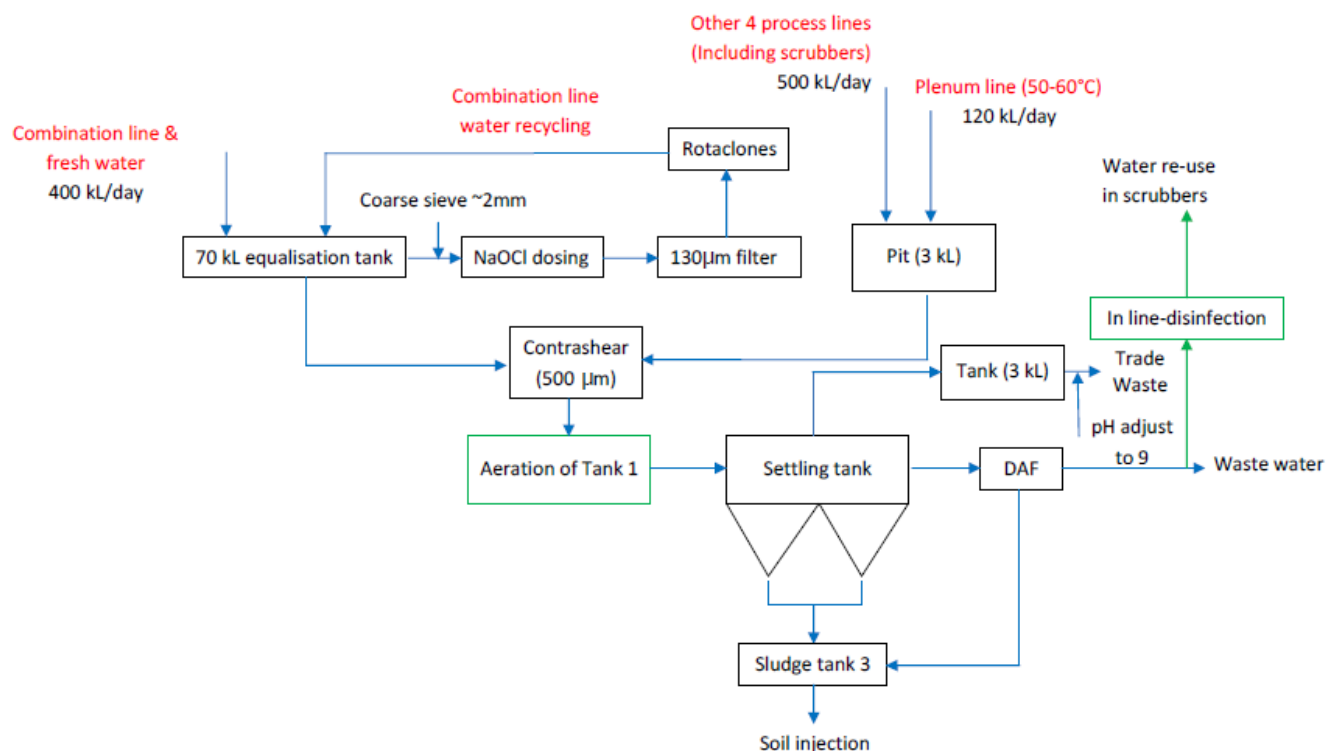


Table 6. Advantages and disadvantages of converting equalisation tank 1 to an aeration tank

Advantages of technology	Disadvantages of technology
It may be possible to utilise the existing tank although it is not clear whether this tank could operate effectively.	Aeration OPEX can be expensive
Low CAPEX investment	No energy recovery

Requirements:

- The approach looks to maximise the BOD reduction in as short space of time as possible
- Aeration process using fine bubbles, combined with a returned sludge to significantly reduce BOD and TSS
- Target reduction of greater than 50% depending on configuration.

Table 7 highlights the water quality parameters; BOD, pH, TSS, nutrient concentration from recent sampling of the equalisation tank 1 effluent.

Table 7. Water quality parameters

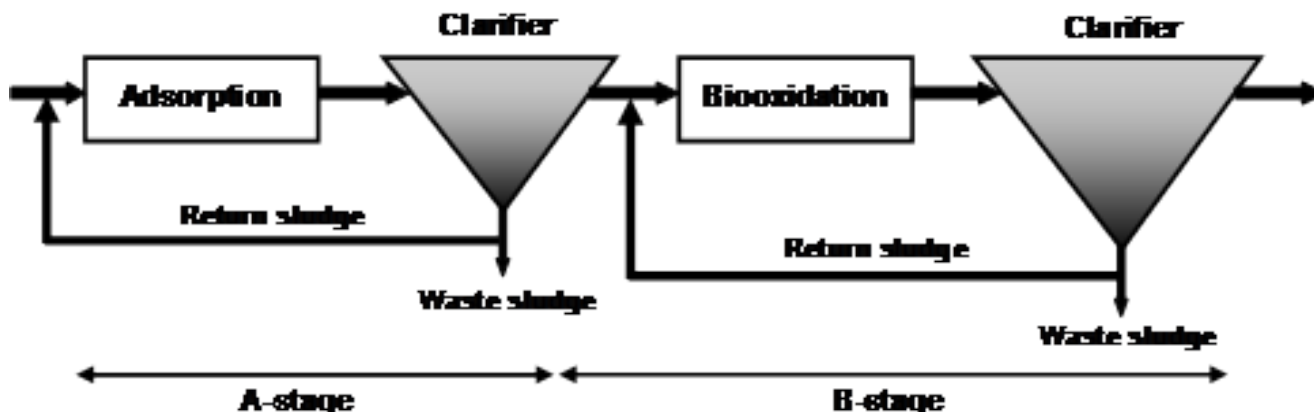
Location of sample	BOD (mg/L)	pH	TSS	TN (mg/L)	TP (mg/L)	Conductivity (µS/cm)	FOG (mg/L)
Wastewater in Tank 1 Eq. tank	Up to 14000, typically 6000-8000	4.4	1380	17.6	5.76	< 1000	8-48

Aeration technology

Approach using High Rate Aeration (A-B process)

High rate aeration technologies have been used since the 1970's and the adsorption – bio-oxidation (A-B) process has been shown to rapidly adsorb and immobilise organic carbon into microbial biomass (HRT 0.5 h and SRT 0.5 d) for further treatment in secondary process termed “the B stage”. A schematic representation of the A-B process is presented in Figure 6. Only the A stage would be required for Kellogg and would lower BOD through rapid microbial growth and the adsorption/coagulation of organic material. The higher energy of A-stage processes is predicted to improve the settling characteristics within the laminar settling tank. The food to microorganism ratio (F/M ratio) in the A-stage typically ranges from 3 to 6 kg BOD/kg.MLSS.d, which is much higher than the F/M ratio of 0.04 – 1.0 kg BOD/kg.MLSS.d for typical activated sludge (Gray, 1990). The hydraulic retention time (HRT) and sludge residence time (SRT) in the A-stage are typically 0.5 h and 0.5 d, respectively (Wett et al., 2007).

Figure 6. High rate aeration showing A-B process



The action of aeration is expected to increase the pH of the effluent towards the optimal range for microbial growth (6.5-7.5). Some alkalinity may be added prior to high rate treatment, however the cost of this is expected to be offset by the reduced usage of sodium hydroxide currently required to raise the pH of treated effluent (prior to discharge or use).

Volumetric organic loading rate: expressed in kg BOD/m³/day is calculated to be approximately 110 kg BOD/m³/day (assuming 5500 kg/day based on flow of 690 kL/day and BOD of 8000 ppm, HRT of 1.5 hrs and a volume of 50 m³). The BOD loading of the Kellogg equilibrium tank will be significantly greater than is used for municipal wastewater treatment applications which typically require BOD loadings of approximately 10 kg BOD/m³/day. For this reason, it is recommended that some preliminary trials be carried out on Kellogg effluent to fully evaluate the potential for BOD reduction at these loadings.

Design and process considerations

- As we are potentially utilising the existing tank, the design must be able to work within this boundary - i.e. work backwards from a specified tank volume. It is assumed that the actual capacity of the equalisation tank is 50 m³, allowing for head space and expansion of water due to the high air content.
- pH 6 to 9 is ok, but neutral is best.
- If aeration alone is insufficient to increase pH, chemical addition (i.e. NaOH) may be needed to increase the pH in the tank.
- Sufficient nutrients (N and P) are needed to maintain biomass, this will need to be verified as TN (17.6 mg/L) and TP (5.67 mg/L) are low in Kellogg effluent. Higher nutrient wastewater may need to be introduced into the system to enhance levels, (e.g. other waste sources such as that from the coating line).
- Total flow is up to 800 kL/day and useable tank volume approximately 50 kL. Retention time approx. 1.5 hrs (including return sludge) which should enable high rate aeration to remove in excess of 50% of the BOD.
- Typical O₂ supply is 0.1 kg O₂/ kg BOD for A stage processes.

Suggested hardware for aeration

Blowers:

Centrifugal blowers or positive displacement blowers (rotary –lobe) can be used depending on the amount of control required, with centrifugal blower being better suited to inlet throttling and rotary-lobe blowers controllable by a variable speed drive (VSD). Inlet and discharge silencing may also be required.

Diffusers:

Diffused air should be introduced through a fine bubble (fine pore) system- bubbles will be generated with ceramic, plastic or flexible membranes. Diffusers are rated according to their oxygen transfer efficiency as tested in clean water, for example 35%. An example is ABS Nopol HKL-215 Sintered HDPE Porous disc diffusers (<http://www.sulzer.com/en/Products-and-Services/Pumps-and-Systems/Aeration-Systems/ABS-Nopon-Disc-Diffuser-System>). Fine bubbles are necessary as efficient consumption of BOD is required due to short retention time.

Important:

This information does not represent the design requirements of a system and it is meant to be a guide as to what may be possible to improve Kellogg wastewater quality with a view to treating to a standard suitable for reuse. A detailed process design would need to be conducted by an engineering / equipment supply firm to fully validate this option.

Option E: Investment into Anaerobic Membrane Bioreactor

Summary of technology: Anaerobic MBR (AN-MBR) is a compact form of anaerobic digestion which enables the reactor to operate at high solids loadings and solids retention, but enables a shorter wastewater retention through its use in conjunction with a microfiltration membrane. The water reporting to the equalisation tank is still at 30-35°C and at low pH, the perfect conditions for hydrolysis of recalcitrant carbon (Figure 7). Table 8 shows some of the advantages and disadvantages of this technology. AN-MBR has been demonstrated to result in 90% destruction of COD whereas USAB/lagoons are typically limited to approximately 70% COD destruction. This is attributed to the longer solids residence times within the digester. The application of the microfiltration membrane enables the removal of effectively all suspended solids (99%) and greater than 90% BOD. The wastewater contains 3000 mg/L BOD, which has been assumed to equate to 4000 mg/L COD (thought to be a conservative estimate considering that bakery wastewater has a BOD:COD ratio of 0.45). The methane produced is estimated at 686 kg/day. Methane contains 55.6 MJ/kg, which equates to an energy of 38.1 GJ/day. The cost of gas for Kellogg is currently around \$10/GJ suggesting that the value of the methane is not significant, at approximately \$381/day. Table 9 below provides a summary of estimated operational costs for the AN-MBR option. The capital costs for implementation of AN-MBR are estimated at \$800,000/ML/day (Lin et al., 2011), suggesting that a 2-3 year payback may be possible. Further reduction in costs may be possible if existing infrastructure could be modified (i.e. equalization tank possible use as modified digester).

Figure 7. Proposed anaerobic MBR / UV- chlorination disinfection

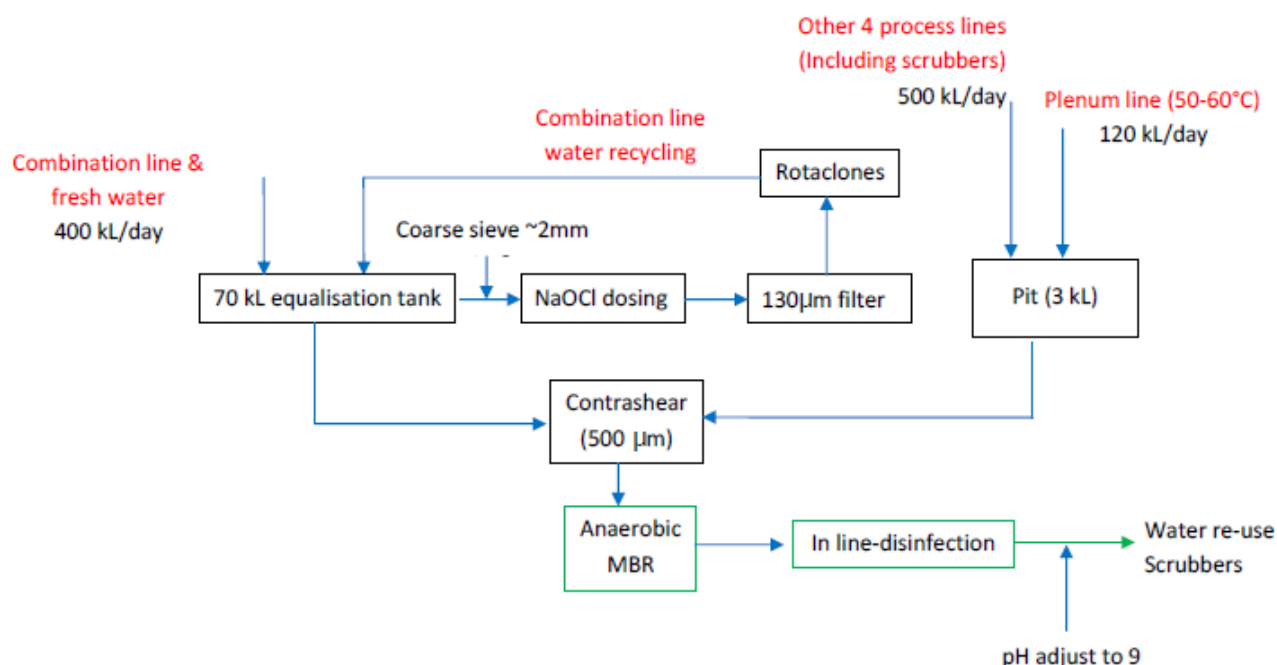


Table 8. Potential advantages and disadvantages of converting equalisation tank 1 to an anaerobic MBR

Advantages of technology	Disadvantages of technology
High energy recovery	Possibility of large capital investment
Reduced sludge volumes	Possibility of increased odour

Table 9. A comparative cost for the operation of an AD-MBR

Process / step	Cost (\$/day)	References
Sedimentation	0 (not required)	
IAF	0 (not required)	
Caustic Dosing	131	Required to ensure pH 6.8-7.5 for methanogenesis (Kichula et al.)
Sludge Removal	9.5	400-500 t/a; at 8c/L (Kellogg)
Trade waste fees for BOD	60	Assuming 300 mg/L BOD (Sydney Water fees, 2013)
Value of methane generated	381	Lin et al. (2011) and Dereli et al. (2012) Based on available data from the Botany site for the period 01/01/12 to 01/04/13, 18270 Kg of BOD was chargeable. This equates to around 7.3 ML of methane, which is equivalent to 283 GJ of energy, worth around \$1500, based on \$5.30 / GJ. This saving may not justify the capital cost of capturing, storing and piping the methane to the point of use.
Operating cost of AN-MBR	710	Lin et al. (2011) and Dereli et al. (2012).
Total	530	

Summary

Five technology options for wastewater treatment and reuse at Kellogg have been presented. Microfiltration may present the simplest technology to implement as it can be easily added and requires minimal changes to the existing plant. Disposal of high BOD retentate will still be required therefore anaerobic digestion of this stream is a good option to minimise trade waste fees.

The effluent quality following anaerobic-MBR is similar to that from aerobic MBR and however energy production is only possible from an AN-MBR. Blowers and aerators can have high OPEX therefore energy production is a sensible consideration.

Conversion of existing infrastructure may reduce the cost of upgrading the wastewater treatment process and eliminates the need for additional space.

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- Boykin, J.C Soerens, T.S Siebenmorgen T.J 2005. Treatment of rice cooker wastewater and recovery of by-product by membrane microfiltration. Applied engineering in Agriculture, American Society of Agricultural Engineers ISSN 0883-8542
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Appendix B:- Assessment of Recycling Guidelines and Regulations as it Pertains to the Recycling of Wastewater at Kellogg Plant in Botany

Introduction

The ability to recycle wastewater produced by the Kellogg factory, either within the factory or externally for green space irrigation, is reliant on meeting a number of requirements. One of the most important requirements is meeting regulatory requirements for the protection of human health and the environment. This assessment relates the regulatory requirements that need to be considered to enable the water to be effectively recycled.

As a prelude to any formal discussions with State regulators, an assessment was undertaken comparing the quality of the final wastewater, taking into consideration the impact of proposed further treatment, and comparing these final qualities with requirements listed in the national guidelines. As part of this assessment, the information in the ANZFA Food Safety Australia guidelines, the Phase 1 of the Australian Guidelines for Water Recycling, and the Australian Standards for Cooling Towers were consulted for information relevant to this assessment. The assessment was then divided into regulations pertaining to Health and Environment, as well as examining the implications of recycling the water within the factory or externally for green space irrigation.

The NSW State Food regulations, like in all other states, refer back to the ANZFA Food Safety Australia guidelines. The ANZFA Food Safety guidelines state that *"If a food business demonstrates that the use of non-potable water for a purpose will not adversely affect the safety of the food handled by the food business, the food business may use non-potable water for that purpose."* The Food Safety guidelines also state that *"Businesses are permitted under subclause 4(3) to use non-potable water provided they can demonstrate to the appropriate enforcement agency that the water will not affect the safety of food produced by the business. It is the responsibility of businesses to provide evidence to an enforcement officer that the quality of the water and the use to which it is put will not affect food safety."*

The Australian Standards are generally vague about water recycling and requirements for regulatory approval. Likewise, State Food Acts (for example in NSW) generally refer directly to Food Standards Australia relating to water usage. The Australian Water Recycling Guidelines are more emphatic about seeking approval from regulators, however, this is based on the assumption that the recycled water originated from an external source such as treated wastewater or stormwater, not the reuse of production wastewater. It is recommended that if there is any doubt as to the impact of using in-house water recycling that the appropriate State health and food regulators are consulted to ensure in the initial stages of the design and establishment of any recycling program to ensure that no local regulatory issues are overlooked.

It has been determined, however, that the ANZFA Food Safety Australia guidelines provide only limited information relating to the recycling of water in a food production plant, predominantly only indicating that water recycling in food production facilities was permissible but if the recycled water is to come in contact with food stuffs then it needs to be treated to a potable quality. As Kellogg has no intention of using recycled water where there could be contact with food, the Australian Guidelines for Water Recycling was deemed to be a more appropriate source of guidance and, thus, were used as the main source of information. The Australian Standards for Cooling Towers was also referred to where the use of the recycled water as cooling tower make up water, or in the scrubbers was being considered.

Health

Health issues relating to non-potable recycled water predominantly relate to the presence, type and number of microbial pathogens. The other major issue that needs to be considered is the potential for community members to be exposed to any pathogens present in the recycled water. The Australian

Water Recycling Guidelines, and therefore State regulations, provides considerable information on controlling pathogens in recycled water and reducing exposure.

The count number of common microorganisms was found to increase through the various stages of the wastewater treatment system. This is most likely due to the high BOD and other nutrients and the temperature of the wastewater stream. The microbial quality of the final Kellogg wastewater was determined to have a high total heterotrophic count (THC). As the wastewater comes from the production of breakfast cereals from grains, no pathogens are likely to be in the water and that the THC are minor transient contaminants that increase in number in the wastewater treatment system through regrowth. It is recommended, however, that further microbial assessment is undertaken to confirm the absence of specific bacterial pathogens.

If the intended recycling use is internal and only used for the scrubber systems (as is proposed), which are contained systems, then Kellogg employees (as well as visitors) will not be at risk. This is different from applications that could create a spray drift, such as in cooling towers or irrigation which could have the potential to pose risks through exposure to aerosols and any other physical contact with the treated wastewater. In these cases the risk of spray drift would need to be assessed more closely. As the closed systems such as scrubbers do not cause spray drift, this is not an issue for Kellogg. As the proposed increase in treatment of the final wastewater includes a disinfection stage (most likely UV treatment) this will reduce the bacterial numbers in the wastewater and significantly limit the potential for the presence of other more harmful microorganisms.

Despite this, as the normal requirement around maintenance and cleaning of scrubbers and other equipment will remain, it will need to be kept in mind that a higher BOD concentration in the recycled water (than potable water) could enable a build-up of biofilms and nuisance bacteria. There is a reasonable assumption that these biofilms could contain opportunistic pathogens such as *Pseudomonas* and *Legionella* which may pose a risk to susceptible individuals. Kellogg staff and contractors involved in maintenance of the scrubbers should therefore be made aware of this and exercise an acceptable level of good hygiene and care.

For the considered potential for off-site recycling options, the group exposed would depend on the application of the water. In this scheme, recycled water would be used for green space irrigation (parks and gardens). Like with the internal use, the major health risk for this recycled water would be opportunistic bacterial pathogens capable of regrowing in the water (for example *Pseudomonas*, *Legionella* and *Aeromonas*). The initial testing of the recycled water during this assessment could not detect *Legionella* indicating that there is a limited risk from this microorganism. No testing was done for other opportunistic pathogens such as *Pseudomonas* and *Aeromonas* but their recognised ubiquitous distribution through water and the environment means that there is a high possibility of them being present in the Kellogg wastewater.

Control of the regrowth issue for these opportunistic pathogens will be most effective through the treatment of the wastewater prior to the supply of the water to the council (or any other 3rd party). The proposed additional treatment which includes disinfection, (particularly if the disinfection is through UV) would remove most, if not all problem bacteria from the wastewater prior to supply for external recycling. Based on the details in the Australian Guidelines for Water Recycling, this extra treatment will cover any health regulation requirements pertaining to irrigation with this recycled water. The only other issue that would be required to be demonstrated to the health regulators would be the length of storage and the potential for the regrowth of problem microorganisms (opportunistic pathogens) during storage (note that it is very difficult to keep these microorganisms from being in the post-treated water due to their ubiquitous nature and the inability to control sterility of the post-Kellogg supply line). As this is outside of the Kellogg plant however, Kellogg should ensure that this remains the responsibility of the council or any other third party using the water.

Environment

Any environmental impact of the final Kellogg wastewater will depend upon the intended uses of the wastewater; where the water will be used; and what material, plants or soil conditions will be in contact with the water (for much greater details see Box 4.1 on Page 123 of the Australian Guidelines for Water Recycling: Phase 1). The section in the Australian Guidelines for Water Recycling that describes the requirement for environmental controls predominantly considers wastewater that is sourced from sewage, stormwater or grey water as these are considered to be the most risk with the greatest range and levels of microbial and chemical contaminants. There is limited mention of the use of industrial water sources in the guidelines. Based on the information in the guidelines and the water

quality data provided by Kellogg (Appendix D), it can be assumed that all of the water sources discussed in the guidelines can be considered to be much more likely to be contaminated with contaminants than the wastewater from the Kellogg plant. This means that, with appropriate interactions with state regulators, there should be no major impediments to the Kellogg wastewater being able to meet environmental regulatory requirements for reuse.

Based on the information available in the Australian Guidelines for Water Recycling, the major environmental issues that need to be considered for the Kellogg wastewater will be:

- Salinity (EC)
- Sodium
- Phosphate
- Nitrogen
- BOD

A qualitative measure of consequence or impact (using Table 4.4 page 133 of the Guidelines) suggests that the treated Kellogg current raw wastewater quality should have a minor environmental impact (in some cases maybe even insignificant). If the treatment options suggested by the CSIRO assessment are also taken into considerations, then any further removal of nutrients achieved through enhanced treatment will reduce any potential impacts even further.

While the treatment options considered will reduce the nutrient loads it is likely that salinity concentrations will remain virtually unchanged. To further reduce the salinity a higher level of treatment such as nanofiltration or Reverse Osmosis would need to be considered. As this is not considered a financially viable option for Kellogg, it will remain the consideration of any third party using the water to note the salinity levels and use the water accordingly.

Likewise, there also remains a need to assess if any more sodium issues exist outside of the general salinity issues (in particular soil sodicity issues). This strongly depends on where the water is used and the soil type at that location. Again, this should remain the responsibility of any third party to consider this issue for impacts at any location. An assumption has been made that there are no toxic chemicals (organics, boron or copper) as the wastewater has generally come from processing food components (unless cleaning agents added to the recycled water through cleaning activities in the plant contain any chemicals that may impact the growth or health of plants irrigated with the waste water).

Details of the Assessment of Specific Environmental issues for external (irrigation) uses (based on the current raw waste water quality)

Salinity: An EC value of 0.7 dS/m ($\cong 700 \mu\text{S/cm}$) has been provided for the average salinity of the final Kellogg wastewater. This level fits within the critical limits of 700 $\mu\text{S/cm}$ set by the Water Recycling Guidelines. When this level of 700 $\mu\text{S/cm}$ is compared to the maximum EC tolerances of grasses, native plants and ornamental shrubs (provided in Appendix 5 of the Guidelines), generally the limits for most plants range in the 1000-2000 $\mu\text{S/cm}$ (and often higher). This indicates that the current EC of the Kellogg wastewater should not pose a problem. Therefore, no further reduction in the EC should be necessary if the water is used for irrigation purposes.

Sodium: Sodium can have an impact on some soil types and cause sodicity issues. This is the one environmental issue that may need to be investigated further to cover requirements within environmental regulations approval. As no information was available on sodium concentrations in the final Kellogg wastewater, more information would be needed at this stage on sodium concentrations and Sodium Adsorption Ratios (SAR) for soils receiving the wastewater. This would need to be part of any discussions with potential 3rd party users of the wastewater and a potential consideration appropriate uses or site assessment of sodium impacts on the soil.

Nitrogen and Phosphate: Nitrogen and phosphate in wastewaters are considered to have the potential of being used as a source of fertiliser for plants. The guidelines do consider that these nutrients in the wastewater need to be used in place of, or in combination with the use of commercial fertilisers. The amount of substitution will depend on the type of plants receiving the recycled water.

Phosphate is often considered to be a limiting nutrient. The supplied figure of phosphate concentrations of 3.1 mg/L in the Kellogg wastewater is slightly less than what is considered to be the normal range for treated sewage and is within the limits set by the Guidelines.

The guidelines and the scientific literature states that when recycled water is used for irrigation, any nutrients present in the water can be advantageous as a fertiliser replacement or supplement. As the level of nutrients in the untreated wastewater are within the normal range listed in the Recycling Guidelines would only produce a limited amount of fertiliser, therefore should not be a concern in any regulatory assessment.

The presence of phosphate in the wastewater, however, could still be a concern for waterways if the wastewater is allowed to enter a water body. This is an issue for the end user but would still need to be kept as a consideration for potential further treatment requirements.

Details of the Assessment of Specific Environmental issues (for 'In-House' uses)

There are minimal environmental concerns for any in-house use of the recycled water in the Kellogg factory. The two major potential in-house uses for the recycled water that have been considered are as top up for the scrubbers. The major issue for these intended uses would be to ensure that the quality of the recycled water fits with the operating parameters of the scrubbers. As all plant have different operating parameters (even different brands of the same type of equipment), reference would need to be made to the manufacturers guide to the maximum allowable water quality. As such, this is not an environmental issue.

Recommendations

- That Kellogg engage with the relevant state health and environmental regulators at a very early stage to outline what is intended and so that any requirements or issues raised by the regulators is met in relation to greenspace irrigation.
- Obtain more information about sodium concentrations in the final wastewater and obtain an assessment of any SAR issues that may exist if the wastewater is used for greenspace irrigation.
- Demonstrate that the additional treatment installed does removal or reduce microorganisms. This may require a validation study, depending on any input from the regulators.
- Undertake further microbiological testing of the wastewater prior to the additional treatment to confirm the absence of any microbial pathogens.

Appendix C:- Value Proposition Analysis

The value proposition tool is a *research* tool to consider a range of costs and benefits.

The scope of the tool was defined through industry workshops.

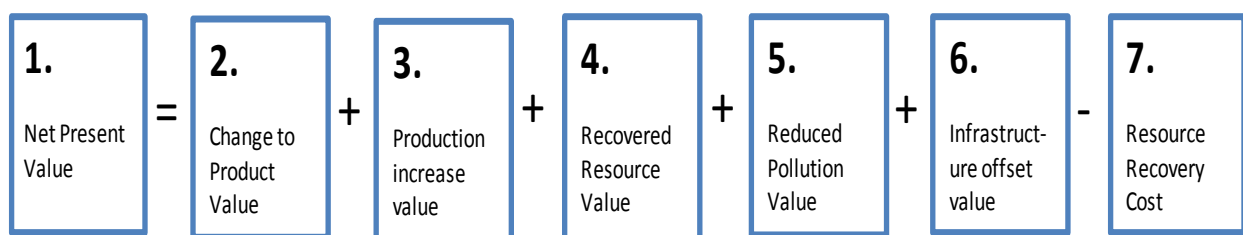
The Kellogg case study aims to:

1. Provide a trial of the tool and seek feedback on its applicability and areas for further development
2. Provide Kellogg the opportunity to use the tool and provide insight into the evaluation of water recycling options.

The results are for **demonstration** only.

The data used is a draft to be reviewed by Kellogg.

Summary of the Value Proposition Methodology



The value proposition includes capital and operating costs for equipment.

It also considers savings such as resources recovered, reduced pollution costs and infrastructure offsets.

The tool allows only the *relevant* components to be selected by each company.

Description of the tool outputs

The results are presented as a comparison of costs and benefits.

The values are expressed as Net Present Values to explore the sensitivity to discount rates and price paths.

- The tool currently does not provide a Simple Payback Period (capital cost/annual savings) or a Return on Investment (annual savings/capital cost)
- These measures do not consider discount rates and changes to operating costs over the period of analysis.

The following **demonstration** results are for the microfiltration option.

- To illustrate the demonstration a set of assumptions will be presented and then modified based on the results.
- The results are **NOT** intended to be definitive or be prescriptive for an investment decision.

Option A: Microfiltration (Ceramic) 400kL/day capacity microfiltration

A critical assumption for this process is that the microfiltration retentate is used within the process and does not add to the sludge disposal costs. If the microfiltration filtration retentate is disposed as an additional sludge stream then the process is unlikely to be financially viable due to the high unit rate of sludge disposal costs. The retentate may actually provide an additional benefit by replacing water that is currently used to dilute grit from the DAF process to enable pumping for disposal. Excess retentate will need to be fed back into waste treatment process. The retentate volume is approximately 10% of the total flow volume for microfiltration. Assuming 400kL/d total flow through the microfiltration unit will provide 40kL per day.

Other data assumptions for Scenario 1 for the microfiltration option are outlined in Table 1.

Table 1. Assumed data for the value proposition

Period of Analysis	20 years	Can be changed for sensitivity analysis
Discount rate	10%	Can be changed for sensitivity analysis
Capital investment	\$1591760	Based on quote from AMS for 0.2um membrane Option 2 with 3 treatment trains and 400kL/day flux. Low and high estimates of \$318 000 and \$578 000 for Option 1 and 3 which have 2 and 4 treatment trains respectively.
Maintenance (\$per year)	\$19897	Membrane replacement every 4 years with low and high estimates of 3 (warranty period) and 5 years (possible performance). Membrane replacement cost assumed to be 5% of capital cost. The cost of treatment chemicals such as sodium hydroxide for cleaning membranes is assumed to be part of this cost.
Reduced mains water (kL/year)	73000	200kL/day considered as cost saving for reduced mains water use in scrubbers. 200kL/day is also potentially available for other non-food contact uses but not included in this analysis.
Reduced trade waste volume (kL/year)	146000	200kL/day for scrubbers as well as a potential of 200kL/day for council park irrigation.
Reduction in suspended solids (kg/year)	4526	Assume reduction of 33mg/L to 2 mg/L which is a 31mg/L reduction based upon a trial conducted by Kellogg June 2012 using a 0.2um membrane.
BOD5 (kg/year)	5110	Assume reduction of 112mg/L to 77mg/L which is a reduction of 35mg/L based upon a trial conducted by Kellogg June 2012 using a 0.2um membrane.
Grease – primary treatment (kg/year)	95	Assume 95% removal for MF performance. Assume effluent concentration of 0.6838 mg/L based on Sydney Water Aug-Sep 2013 Bill. This is a reduction of 0.64961 mg/L.
Operating energy (kWh/year)	58400	Based upon an assumed operating energy of 0.4kWh/m3

Table 2. Assumed unit costs

Water supply (\$/kL)	2.168	
Wastewater discharge (\$/kL)	1.30	
Suspended solids – primary treatment (\$/kg)	0.458	
BOD5 – primary treatment (\$/kg)	0.448	Reduction of 2100mg/L Formula $\$0.203 + (0.07 * [\text{BODmg/L}] / 600) / \text{kg}$
Grease – primary treatment (\$/kg)	0.413	
Electricity (\$/kWh)	0.25	Based on household electricity price, but likely to be lower for Kellogg.
Gas (\$/GJ)	10.81	
Sludge disposal (\$/L)	0.083	
Sodium hydroxide 50% solution (\$/t)	500	

Note: Unit costs were based upon information provided by Kellogg (email 23 Oct 2013).

Demonstration Results

The aim of the results is to explore the sensitivity of the results to the assumptions. The results were developed as a series of scenarios.

Scenario 1

Figures 1 and 2 provide the results for Scenario 1 based upon the assumptions outlined in Table 1 and 2.

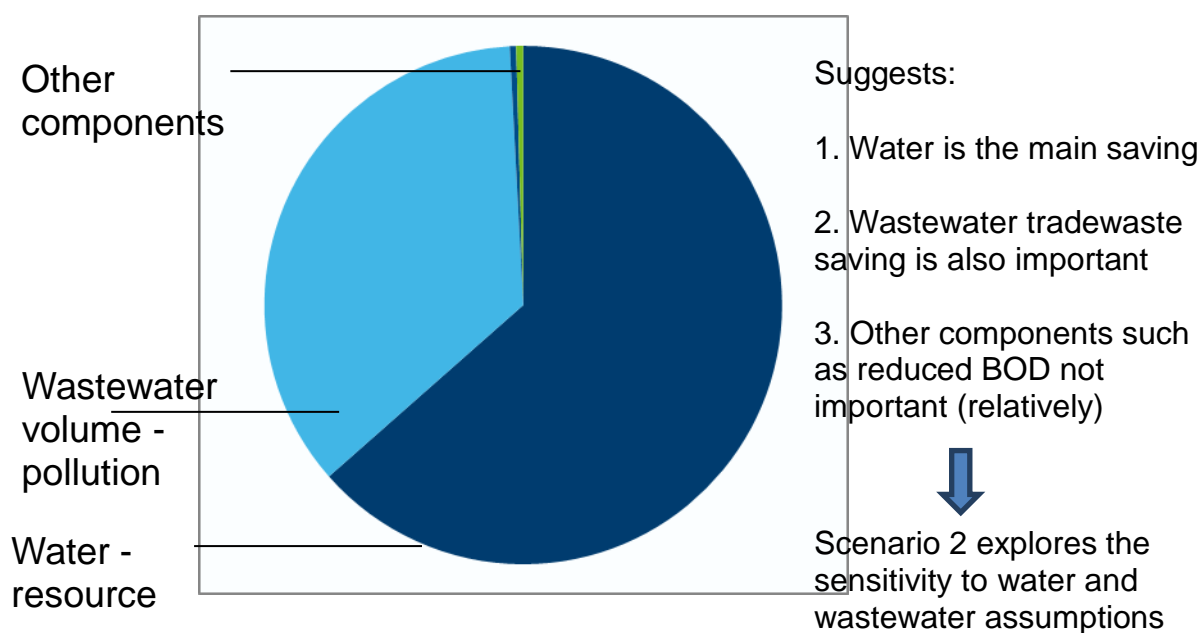


Figure 1. Micro Filtration Scenario 1 Components of Value

Comparison of Value and Cost

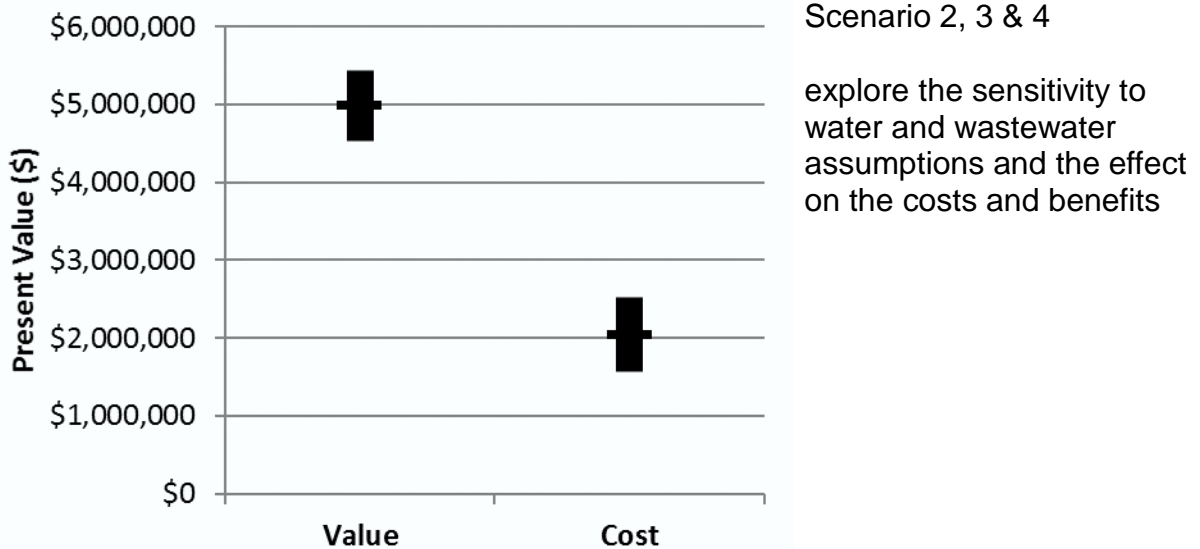


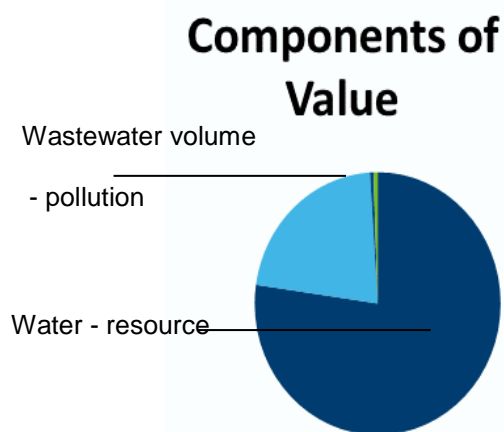
Figure 2. Micro filtration Scenario 1 comparison of costs and benefits

The following results explore the sensitivity to assumptions that appear to have a large effect on results. All assumptions are kept the same except for the assumption being tested for Scenarios 2 and 3. This shows the sensitivity to a change in a single variable. Scenario 4 provides a concurrent change in two variables.

Scenario 2

Assumptions for Scenario 1 remain the same except:

- No water for irrigation (trade waste volume changes from 400kL/day to 200kL/day)



Comparison of Value and Cost

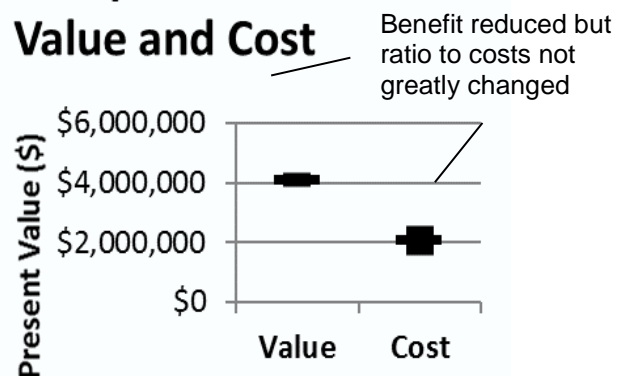


Figure 3. Scenario 2 - No water for irrigation

Scenario 3

Assumptions from Scenario 1 remain the same except:

- No real price increase for water

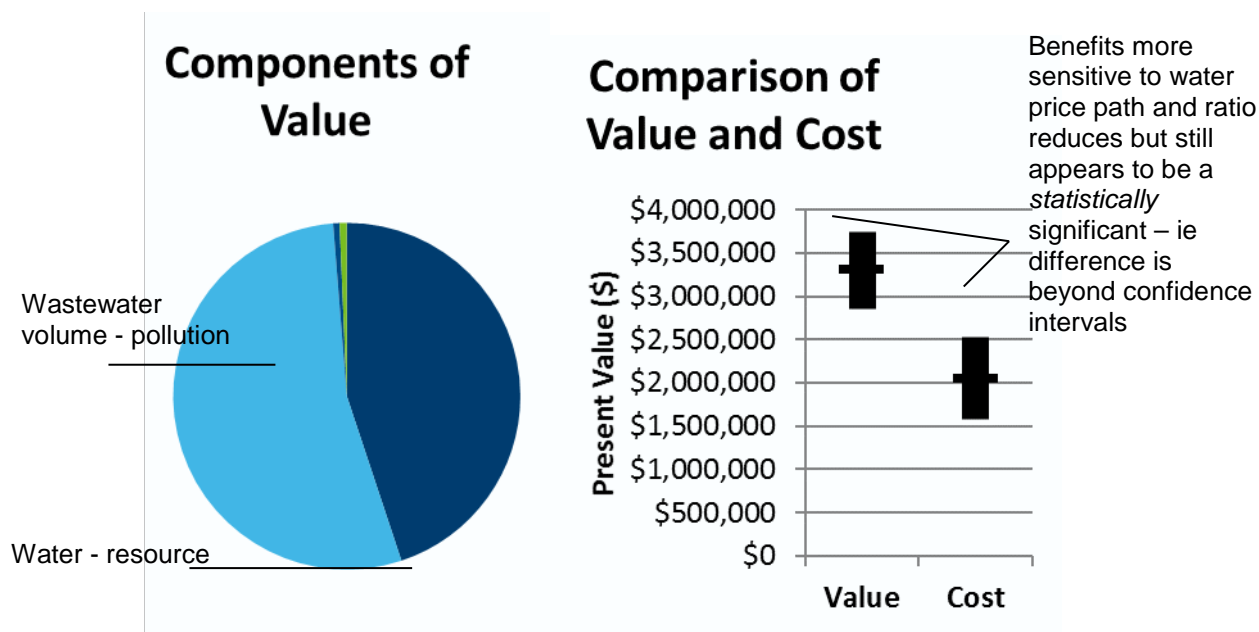


Figure 4. Scenario 3 - No real increase in water prices

Scenario 4

Assumptions from Scenario 1 remain the same except:

- No water for irrigation (trade waste volume changes from 400kL/day to 200kL/day)
- Not real price increase for water

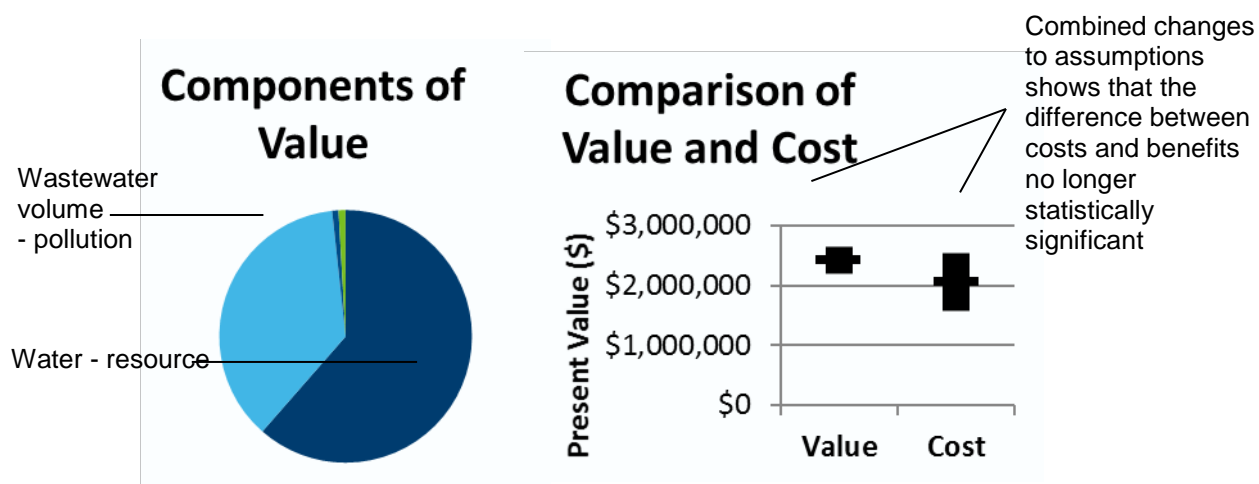


Figure 5. Scenario 4 - No irrigation and not real price increase for water

Conclusions

The demonstration shows how the results can be sensitive to assumptions.

It provides a way of testing and defining scenarios and the potential viability of a project.

- For example, given data and other assumptions, the results appear to be sensitive to future water prices and to a lesser degree the use of water by council for irrigation.
- If it is assumed that there is no real change in water prices and no use of waste water for irrigation by council over the next 20 years then there appears to be no significant difference between costs and benefits.

Further testing of the results by Kellogg could:

- Refine the data and other assumptions
- Define price paths for water and wastewater irrigation assumptions
- Define cost/benefit ratios for project viability.

Abbreviations

ABS	Acrylonitrile Butadiene Styrene
ANAMMOX	Anaerobic Ammonium Oxidation Process
AN-MBR	Anaerobic Membrane Bioreactor
ANZFA	Australia/New Zealand Food Authority
AQIS	Australian Quarantine and Inspection Service
AWRCoE	Australian Water Recycling Centre of Excellence
BOD	Biological Oxygen Demand
CAPEX	Capital Expenditure
CFU	Colony Forming Units
CIP	Cleaning in Place
COD	Chemical Oxygen Demand
DAF	Dissolved Air Floatation
EC	Electrical Conductivity
EPA	Environment Protection Authority
EPHC	Environment Protection Heritage Council
EGSB	Expanded Granular Sludge Bed
FDA	Food and Drug Administration
FOG	Fat, Oil and Grease
HDPE	High Density Polyethylene
HPC	Heterotrophic Plate Count
MBR	Membrane Bioreactor
MF	Microfiltration
NF	Nanofiltration
OPEX	Operating Expenditure
PFU	Plaque Forming Units
RAS	Returned Activated Sludge
RO	Reverse Osmosis
SAR	Sodium Adsorption Ratio
THA	Total Heterotrophic Count
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Soluble Solids
UASB	Upflow Anaerobic Sludge Blanket
UV	Ultraviolet
WHO	World Health Organisation
WWTP	Wastewater treatment plants