Water Recycling in the Australian Food & Beverage Industry
A Case Study – Reduced Environmental Footprint

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ABSTRACT
Food and beverage manufacturing is a major industrial sector in Australia, and an intensive water user. To date, water reuse in this industry has been limited by hygienic concerns and legislation. However, recent changes in legislation now allow other water sources than town mains supply, provided that product safety risks are appropriately mitigated. This paper highlights a recent success story, where Lion Nathan National Foods (LNNF) reduced water consumption at the Castlemaine Perkins Ltd, XXXX Brewery, Brisbane, from 3.8-L/L beer to 2.2-L/L beer through implementing a water recycling plant. The brewery wastewater passes through a treatment scheme of physical, biological and chemical steps and > 70 % is re-used for non-product applications onsite. Recycle of the high quality water has also led to a reduction in chemicals required for cleaning, cooling towers and boiler water treatment. A significant amount of soluble organics in the wastewater are converted into biogas using a high rate anaerobic treatment process. The produced biogas contains ~75% methane and is co-fired in the gas fired boilers as an alternative to natural gas. This approach provides a reduction in costs and in the environmental footprint associated with managing the water and waste from the brewery. The plant was delivered as an EPCM approach with GHD acting as the owners engineer. The main process contract was with Aquatec Maxcon with core biological treatment technology (IC and CIRCOX) from Paques in Netherlands and membrane systems were supplied by Pall.

Keywords
Industrial water; high rate anaerobic treatment; water reuse; energy recovery; environmental footprint; brewery

INTRODUCTION
Due to recent drought conditions (2000-2008), water management has become a pressing issue in Australia, particularly for South East Queensland (SEQ). Over $7 billion (Australian) has been spent in SEQ for bulk water supply system upgrades. This has included an extensive water grid to provide flexibility in distribution of water, a 130ML/d sea water reverse osmosis desalination plant, Wyaralong Dam and the Western Corridor Recycled Water Scheme (230 ML/d).

During this period the cost of water has increased from around $1 to over $3 / kL. These conditions have provided the impetus for many water recycling projects. The implementation of water recycling techniques and discovering best practice standards has been a highly successful venture for many industrial businesses with benefits on an economic and environmental level. Up until recent years, efforts in developing industrial water recycling processes within the food and beverage industry have been limited due to legislation as well as uncertainty regarding hygienic integrity of reuse water. However with changes to
legislation permitting reuse, recycle strategies to reduce water consumption by supplementing sole dependence on town supply with decentralized treatment systems have been a point of interest.

The Castlemaine Perkins, XXXX brewery in Brisbane, owned by Lion Nathan National Foods (LNNF), is one recent success story where consumption of water through reuse was reduced from 3.8L/L beer to 2.1L/L beer following implementation of an on-site water recycling facility. Other benefits of the new WRP include

- The reduction in wastewater to sewer,
- Reduction of natural gas consumption through use of the biogas produced by the WRP,
- Reduced chemical consumption for cleaning, cooling towers and boiler feed water.

In the development of this recycling strategy, a number of Life Cycle Assessments (LCA) were undertaken. These compared the environmental footprint associated with current practice, where waste water is discharged to sewer and treated at a conventional activated sludge municipal wastewater treatment plant to different options for on-site Water Recycling Plant (WRP).

WATER MANAGEMENT IN THE FOOD AND BEVERAGE INDUSTRY

Water usage

Overall water consumption in Australia is about 14,100 GL/annum (ABS 2008-9). This has come down from 21,700 GL/annum in 2000-1. Water consumption by industry type in Australia is summarized in Figure 1. As noted below 6% of total water consumption is used in the manufacturing industry and of this over 60% is used in the food and beverage industries. This equates to a consumption of about 500 GL/annum. The industry generated some $80 billion in 2008, which equates to $160 million per GL of water used.

The food and beverage processing industry is the largest manufacturing sector in Australia with operations in all States and Territories. The industry does require large amounts of water, but until now very limited reuse has taken place due to hygienic concerns and legislations gaps. Over the last 20 years the industry has done a lot to reduce water consumption and waste production through the implementation of cleaner production practices with the processing facilities. Recycle of water into the processing area has been avoided in the past due to perceived risks to product quality. Confidence in new technologies such as micro and ultrafiltration and alternative disinfection methods has now opened the door to recycle water into the production area.

New legislation allows the use of water other than town supply drinking water. This requires the use of HACCP (hazard and critical control point risk assessment) to avoid endangering the food product safety. Water recycling and reuse practices in food industry involve supply of cooling water, wash water or even process water (Palumbo et al., 1996). According to Hiddink et al., (1999) the recycling of water in food industry can reduce the water demand by 20-50%.
Water consumption in the food and beverage industry is highly variable from industry to industry and also within industry sector. Water use will vary depending on the following:
- Age of the facility
- Operational hours (per day and week)
- Frequency of product changes
- Cost per kL of water
- Employee incentives to reduce water usage and raw material and product loss.

Water consumption is usually compared to production, so similar facilities can be benchmarked against each other (eg litres of water per litre or kg of product).

**Wastewater production**
As with water, wastewater production in the food and beverage industry is highly variable for different industries and also within industry sector. Wastewater production will be influenced by:
- Age of the facility
- Operational hours (per day and week)
- Frequency of product changes
- Batch or continuous production
- Cost per kL of water
- Cost for disposal of wastewater and solid wastes
- Employee incentives to reduce water usage and raw material and product loss.

Wastewater production is sometimes compared to production, so similar facilities can be benchmarked against each other (eg litres of wastewater per litre or kg of product). Wastewater contaminants are also compared to production for benchmarking purposes (eg kg solids per kg product). Generally food and beverage processing, results in wastewaters with high organic carbon content, usually measured as COD (chemical oxygen demand). Often the wastewater is highly biodegradable. Some industries also produce wastes high in suspended
solids, Oil and Grease (O&G), nitrogen, phosphorus and salts. A summary of major constituents from some food and beverage industries is shown below in Table 1.

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>COD</th>
<th>TSS</th>
<th>O&amp;G</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>TDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat Processing</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Dairy</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit &amp; vegetable processing</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Snackfoods</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beverage (beer, wine)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beverage (soft drinks)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beverage (distillery)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil seed</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seafood processing</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

The remainder of this paper will focus on the novel water management system put in place at LNNF’s XXXX brewery in Brisbane, and the environmental footprint of the plant.

**BREWERY WATER MANAGEMENT THE XXXX BREWERY**

**Conventional water management approach**

LNNF Castlemaine Perkins Ltd (CPL) XXXX brewery produces approximately 3 Million hL of beer per annum in kegs, bottles, and cans at the Milton brewery. The facility does not recycle or wash bottles. Potable water (3 ML/d) is used to produce the beer. As part of the Queensland Water Commission water restrictions CPL developed a Water Efficiency Management Plan (WEMP) that requires from businesses either to achieve a minimum reduction in water usage of 25% or demonstrate world’s best practice. CPL had already cut onsite water consumption significantly and demonstrated they were at best practice water consumption of ~3.8 L/ L beer by implementation of best water management practices. The wastewater system as it stood in 2006 is shown below in Figure 2. CPL implemented incentives such as:

- Low flow hoses
- Recycle of rinse water to boiler
- Reuse of pasteurizer overflow and vacuum pump seal water in cooling towers
- Spray balls in vessels for cleaning

The wastewater management strategy consisted of mixing, pH adjustment and discharge to the municipal sewer system for treatment at the sewage treatment plant. Water is consumed by a number of process operations within the brewing process including:

- In the beer
- Brew house operations;
- Filtration;
- Packaging (e.g. filling bottles, cans and kegs);
- Utilities – cooling towers and boiler feedwater and
- Clean in place (CIP) operations.
Figure 2. XXXX Brewery Water recycling (prior to upgrade)

Figure 3 illustrates the effect of water conservation projects carried out in the brewery since 1990. Good water reductions were made from 1990 to 2001 through the implementation of cleaner production techniques and modernisation of the brewery. The water use reduced from 10 to 4 L/L beer. This is considered world’s best practice for brewing. Since 2001 there has been little opportunity for further water use reductions. Installation of new brewing equipment in 2006 saw a further drop in water use. In 2007 another reduction was seen due to staff being more focused on water use reductions. However, persisting drought conditions in the region and CPLs own development plans have forced it to put a plan in place to ensure sustainable water supply into the future. The water reductions shown for 2008 were predicted at the time. The plant currently utilizes about 2.2L/L.

Figure 3: XXXX Brewery Water Consumption 1990-2008
**Water recycling approach**

Given these drivers, CPL engaged GHD in an Owners engineering role to study different options to upgrade the wastewater treatment plant and to integrate an advanced water treatment train to produce high quality water to be reused in the factory for non-product applications (eg cooling tower and boiler make up, cleaning, vacuum pump seals etc). GHD prepared conceptual designs and a feasibility study and provided tender and construction phase services to assist in implementation of the project. The water reuse plant was designed and built by Aquatec Maxcon Pty Ltd with core biological treatment technology from Paques in Netherlands and membrane systems were supplied by Pall. Figure 4 shows some pictures of the main plant. The biggest single challenge with this plant was the small amount of space available on site to construct the plant.

The plant involves the use of sustainable solutions that minimise the environmental footprint of the reuse facility. After screening and equalization, a high rate anaerobic tower reactor (BIOPAQ® IC) removes the majority (~85%) of the dissolved COD in the wastewater (Figure 3). An airlift reactor, making use of biofilm on a carrier material (Circox®) aerobic polishing system provides additional COD and nutrient removal. Removal of residual suspended solids as well as solids from the chemical phosphorus removal is via a dissolved air flotation (DAF), dissolved air flotation over filter (DAFF) and membrane microfiltration (Figure 3). Reverse osmosis is used to reduce salt content and further disinfection is achieved with ultraviolet light. Chlorine dioxide provides an additional level of disinfection to allow the water to be used throughout the brewery.

A unique feature of the water reuse plant is the use of tower style tanks for all main treatment vessels. This has enabled the plant to fit on the very small footprint that was available. The sensitive location of the brewery close in an urban area of Brisbane, required the plant to have a multi stage off-gas treatment system and a very high quality flare. The WRP produces a high water quality that exceeds town mains water.

The plant has been operating since 2009 and water consumption is now about 2.2 L/L of beer packaged. Another brewery in SEQ has been operating at about 2.3 L/L for 5 years through implementation of the recycling plant and using reusing water for non-product applications.

The biogas produced in the anaerobic process is high in methane content (75- 85%) and is utilised in the plant boilers to reduce consumption of non-renewable natural gas fuel. Thus the Water Conservation Scheme, has not only resulted in saving water but it has also allowed industry to become sustainable and environmentally friendly.

**Figure 4:** High rate anaerobic treatment and microfiltration and reverse osmosis skids
Costs associated with the new plant
The capital costs associated with implementation of the water recycling plant were about $15 million. This includes all the approvals, planning, design and construction of the plant and integration of recycled water and biogas back into the brewery. The Queensland State government provided a $5 million grant to CPL through the business water efficiency program (BWEP). The annual operating and maintenance costs of the WRP are about $1.2 million. Savings associated with lower water and natural gas purchase and reduced trade waste charges for sewer discharge are approximately $4.2 Million per annum. This provides a payback of around 5 years (including tax impacts).

LIFE CYCLE ASSESSMENT
The environmental assessment of industrial water reuse systems is becoming increasingly important due to modern environmental regulations. These regulations require the reduction or prevention of emissions to air, water, and soil in order to achieve a high level of protection for the environment as a whole. Life-cycle assessment is an excellent methodological tool for such an integrated assessment, as it takes into account the entire system of industrial wastewater treatment including upstream and downstream processes (Kohler et al., 2007). By adapting a holistic approach to waste water management and recovery, the overall environmental footprint can be reduced.

Life Cycle Assessment (LCA) is an internationally standardised process (ISO 14040, 2006) to assess the environmental impacts of a product or service from “cradle to grave” (Narayanasvamy et al., 2004). The benefits of conducting a LCA include identifying the most environmental friendly and cost effective option of a product or service, and identifying opportunities to improve the efficiency of a company, such as reducing greenhouse gas emissions (ISO 14040: 2006).

A LCA was conducted on this project to compare two treatment schemes typically used for treatment of industrial wastewaters, coupled with a water reuse plant. These were a high rate anaerobic pretreatment followed by an airlift aerobic treatment; and a suspended growth activated sludge system. The case study is based on a water recycling plant with treatment capacity of 2.2 ML per day. The two plants compared are:

<table>
<thead>
<tr>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen;</td>
<td>Screen;</td>
</tr>
<tr>
<td>Balance tank;</td>
<td>Larger Balance tank;</td>
</tr>
<tr>
<td>Pre-acidification tank;</td>
<td><strong>Sequencing Batch Reactor (SBR)</strong>;</td>
</tr>
<tr>
<td>Mixing tank;</td>
<td>Dissolved Air Flotation (DAF);</td>
</tr>
<tr>
<td>Anaerobic treatment;</td>
<td>Microfiltration and Reverse osmosis;</td>
</tr>
<tr>
<td><strong>High Rate airlift Aerobic treatment</strong>;</td>
<td>Disinfection;</td>
</tr>
<tr>
<td>Dissolved Air Flotation (DAF);</td>
<td>Sludge treatment.</td>
</tr>
<tr>
<td>Microfiltration and Reverse osmosis;</td>
<td></td>
</tr>
<tr>
<td>Disinfection; and</td>
<td></td>
</tr>
<tr>
<td>Sludge treatment.</td>
<td></td>
</tr>
</tbody>
</table>
In this study Life Cycle of the following is considered:
- Construction material used in each process;
- Chemicals used for process or cleaning purposes and their transportation to the plant;
- Solid waste generation and transportation to waste recycling plants or landfills;
- Energy consumption;
- Land requirement (Plant’s footprint); and
- Air emissions (such as greenhouse gas emissions).

The Life Cycle Inventory (LCI) of the plant was developed using vendor data and SimaPro LCA software (v.7.1.0) databases. Where possible, upstream inventory data has been constructed using the Australian LCA Data Library, developed from 1998 to 2004 by RMIT’s Centre for Design. IMPACT 2002+ LCAI method is adopted for the impact assessment. The result of the LCA study is provided in Figure 5 which is represented in terms of global warming, ozone layer depletion, respiratory inorganics, land occupation, carcinogens and etc. The analysis of the two options indicated that option 1 (which includes anaerobic treatment) is by far the preferred approach from an LCA perspective because:

- Anaerobic pretreatment removes > 80% of the COD with a low energy requirement;
- There is a benefit from the biogas produced which can offset energy consumption on site (replaces fossil fuel usage);
- There is less chemical addition is required; and
- There is less sludge to manage and dispose.

The results support the decision to pretreat the wastewater using anaerobic systems prior to discharge or reuse. Additional environmental benefits of the project outside the plant itself include:

- Reduced need for mains water (less impact of energy associated with treatment and reticulating water to site)
- Reduced emissions from the wastewater as it is conveyed to the sewage treatment plant (STP)
- Reduced need for aeration at the STP as the soluble brewery wastewater is now treated anaerobically rather than aerobically at the STP.
Figure 2 LCA of SBR vs Anaerobic/Aerobic Treatment

CONCLUSIONS

Implementation of a water recycling facility at the XXXX Brewery has

- Reduced water consumption by ~70% at the Milton Brewery, Brisbane, from 3.8 to 2.2 L/L beer
- Significantly reduced trade waste discharge costs.
- Reduced chemicals required for cleaning, cooling towers and boiler water treatment, via providing high quality water for recycling.
- Converted a significant amount of soluble organics in the wastewater into biogas that is co-fired in the gas fired boilers as an alternative to natural gas.
- Provided a reduction costs and in the environmental footprint associated with managing the water and waste from the brewery.
REFERENCES


