# Effluent Reduction and CIP Efficiency in Dairy Processing

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**Abstract**

*The major environmental problems associated with the dairy industry are high water consumption and discharge of wastewater with a high organic loading. This is due to the frequent cleaning of process equipment required to maintain strict hygiene standards. This paper presents a waste assessment conducted at Challenge Australian Dairy, and provides recommendations for reducing the effluent loading and the volume of wastewater produced at their Capel factory.*

## 1.0 Introduction

Challenge Australian Dairy (CAD) is a medium sized dairy processing company, with processing plants in Capel and Boyanup. CAD processes milk into various dairy products, including cheese, butter, milk powder, whey powder, and milk for export. During the course of production, process equipment must be cleaned regularly to maintain operational efficiency as well as maintain hygiene standards. Consequently, dairy processing plants usually have high water consumption and produce a large amount of wastewater of high organic strength.

This project aims to assess the generation within CAD's processing plant in Capel, and provide recommendations for reducing the organic loading and volume of effluent produced. The waste assessment involves two components:

1. site inspection to provide a comprehensive analysis of the plant operations
2. undertaking a mass balance to to characterise wastewater streams and identify major contributors to the overall wastewater generation

## 2.0 Background

### 2.1 Dairy Processing

Challenge Dairy's Capel plant produces cheese and whey powder for the food industry, and also processes milk for bulk export. Each production line involves several processes. Milk processing requires separation of cream and heat treatment. Product which has been treated cannot be mixed with untreated product, hence, each batch of milk must be kept separate and silos must always be cleaned between emptying and refilling.

Cheese processing involves the addition of a starter culture to the treated milk, which triggers coagulation and produces curd and whey. The curd is then cooked, salted, and ripened to produce cheese. Whey is the liquid fraction which is expelled and forms about 80-90% of the original volume of milk and contains about half the nutrients in the original milk (UNEP 2000). Processing of whey powder involves demineralisation, evaporation, crystallisation and spray drying.

## 2.2 Cleaning-in-place (CIP)

A significant part of the daily operations includes cleaning of process equipment and work areas. Process equipment must be cleaned regularly and to a high standard for the following reasons:

- to prevent the build up of product on internal surfaces
- to prevent contamination of product
- many processes occur in batches

The time used to clean a piece of equipment ranges between 30 minutes, for milk silos, and 2 hours, for the lactomatic.

Most process equipment at Capel is washed by cleaning-in-place (CIP). CIP enables water and detergents to be circulated through and clean the internal surfaces of process equipment without the need to dismantle parts. The advantages of CIP as opposed to removing parts for cleaning include minimised potential for contamination of equipment and reduced clean-up labour costs (DEH 2001).

The Capel dairy processing plant largely utilises a single-use CIP system, although a multi-use CIP system is used to wash the cheese vats and cheese-pressing towers. The single-use CIP system uses chemicals and water to wash a piece of equipment once; this water is then discharged as wastewater. The general CIP process is illustrated in Figure 1. An additional CIP stage using an acidic cleaning agent is required for equipment which processes heated product.

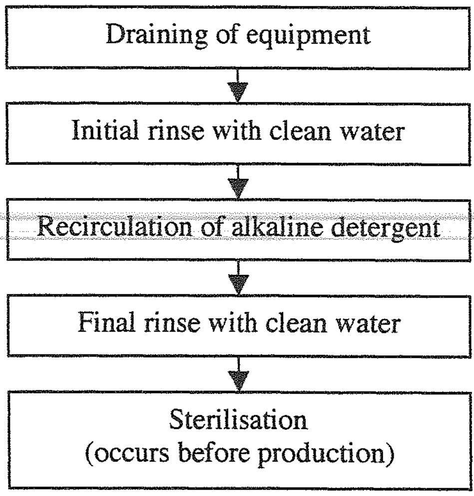


**Figure 1 – Typical CIP process**

## 2.3 Dairy processing effluent

The majority of dairy processing wastewater is produced by cleaning activities, which is why this waste assessment focuses on the CIP processes. Other sources of organic loading include spilt product, pipework that cannot be fully drained, and leakages in process equipment. Process wastewater contains milk solids, acidic and alkaline cleaning chemicals, sanitisers, and other substances used for processing, such as starter culture and salt. The main contaminant in the wastewater is milk solids.

The quantity of organic substances in effluent can be measured by the biochemical oxygen demand (BOD). The $BOD_5$ indicates the quantity of organic matter that can be biologically oxidised or degraded over a period of five days (Tetrapak 1995). The $BOD_5$ levels for dairy wastewater and other common dairy products are shown in Table 1. Factors which can affect the wastewater characteristics include the milk load dilution with wash water, pre-treatment, the type of cleaning compounds used, and the age of the plant. The best practice management options for waste in order of preference are: avoidance and reduction, reuse and recycling, treatment and, if there are no other feasible options, disposal (EPA 1997).

**Table 1 – Typical $BOD_5$ levels (Tetrapak 1995)**

| Product | $BOD_5$ |
|---|---|
| Dairy processing wastewater | 2 000 |
| Whole milk, 4% fat | 120 000 |
| Skim milk, 0.05% fat | 70 000 |
| Cream, 40% fat | 400 000 |
| Whey, 0.05% fat | 40 000 |
| Whey concentrate, 60% DM | 400 000 |

## 2.4 Environmental Issues at Capel

Wastewater produced at the Capel processing plant is treated by aeration digestion, Dissolved Air Flotation (DAF) and Conventional Activated Sludge (CAS). This produces two treated waste streams: sludge and treated wastewater. The sludge is currently being used as a soil improver, while the treated wastewater is being used to irrigate a nearby paddock. The effluent treatment plant is known to be sensitive to large variations in the effluent volume or loading, and is less effective when overloaded during heavy production.

To ensure that the application of treated effluent to the soil results in minimal environmental impacts, the water quality must be sound. Long term irrigation of poorly treated effluent can cause environmental impacts including salinity, eutrophication of surface and groundwater bodies and damage to the soil structure (EPA 1997).

## 2.5 Waste minimisation

Waste minimisation or cleaner production is an approach which aims to prevent or minimise the environmental and social impacts of production (UNEP 2000).

There are many programmes in place to promote cleaner production and assist businesses wishing to implement cleaner production technology and practices. Some of these include Zero Waste WA, Closing the Loop and the UNEP Cleaner Production Programme. General options for minimising waste are outlined in Table 2.

**Table 2 Waste management options**

- Changing plant operation or procedures
- Substituting materials in the production process
- Reclaiming and recycling materials
- Modify equipment to improve efficiency
- Altering the final product

## 3.0 Site Inspection

Cleaning and operating activities were observed to gain an overview of where, how and why waste is produced. One of the major aims of the site inspection was to distinguish between which losses were avoidable and identifying some practical options to reduce waste.

## 3.2 Housekeeping

Waste generation is significantly influenced by housekeeping practices. Good housekeeping refers to improvements to work practices and proper maintenance of equipment. It is estimated that 70% of all waste and emissions from industrial processes can be prevented by improved housekeeping and cleaner production practices (UNEP 2001). Some issues which have been identified at Capel include hoses left running during cleaning, adding CIP water to tanks that have not been emptied properly and overflowing equipment.

Overflowing milk is a concern relating to the pasteuriser balance tank. This is due to the product inflow and outflow being controlled separately. The former is computer controlled, while the latter is manually controlled. This problem could be eliminated by installing a level sensor in the balance tank or linking the outflow to the same computer console. Another less obvious source of lost product occurs when operators begin flushing CIP water into the balance tank before it is properly emptied. This is problem relates to the pasteuriser and concentrator CIP. At Capel, it is not best to drain the balance tanks entirely because this would cause cavitation in the pipes and cause damage to the pumps. However, this waste could be reduced by letting the level of product drop before filling the tank. Installing automated CIP systems would assist in preventing this wastage.

At the Capel processing plant, a major source of organic loading is the whey crystallisation tanks. Crystallisation is required to prepare whey concentrate for drying. During crystallisation, a thick slurry of whey is produced. When these tanks are drained, a large amount of whey remains in the bottom of the tanks after draining. Previous analysis carried out by CAD has estimated the wastage at 3.55%. This wastage is largely due to the viscosity of the whey, the tanks having flat bases, and the agitator paddles being too short and too far above the base.

### 4.3 Waste management at Capel

Some waste minimisation practices which are in place at Capel include:

- Recovering cheese fines from drains and reusing this as stock feed
- Collecting cheese fines from raw whey and irregular cheese blocks and putting this back into the cheese making process
- Collecting very milky wastewater from the concentrators and whey crystallisation tanks for stock feed
- Collecting waste whey powder for stock feed
- Processing whey, a by-product from cheese making, into demineralised whey powder
- All hoses in the factory are fitted with trigger nozzles

The dairy operators follow the established waste reduction practices fairly well and some are quite aware of waste management issues. However, most operators are not overly concerned with waste minimisation and largely accept the loss of product as a part of production.

## 5.0 Mass Balance

### 5.1 Method

The aim of calculating a mass balance is to characterise the various waste streams within the plant and identify those which are significant. This involved measuring the volumes of the wastewater streams and determining waste loading of each stream.

### 5.2 Results and discussion

The BOD levels for raw effluent at Capel are around 3500 mg/L. This is significantly higher than the typical BOD level for dairy wastewater, which is 2000 mg/L (EPA 1997). Figure 2 shows the relative BOD levels and wastewater volumes for the different waste streams in the plant. These values are based on the CIP activities during a typical day of production.

The results indicate that the equipment with automated CIP systems tend to produce a lower amount of waste than manually operated CIP systems. Equipment with automated CIP systems includes whey processing equipment, the pasteuriser and the UO. This suggests that there are likely benefits involved in implementing automated CIP systems throughout the dairy factory.

The lactomatic wastewater was found to contain high levels of BOD. However, there are some issues involved in developing methods to minimise the effluent loading from the lactomatic; these are related to its size, the fact the system is enclosed, and the nature of the product. As the curd moves through the lactomatic, cheese fines will be produced and some cheese will adhere to the internal surfaces. This cannot be removed until washing, at which it will become contaminated with cleaning detergent. Feasible waste reduction options will need to address the processes occurring within the system to prevent wastage.

Other CIP processes which contribute significantly to the total effluent volume are the pasteuriser, concentrators and eurotainer CIP. These equipment are washed several times a day, hence a review of the CIP procedures should be conducted to rationalise the amount of wastage and water used for cleaning. The effluent loading and amount of wastewater produced can vary considerably depending on the amount of water used, the individual operator, and the level of production. However, these results give a fair indication of the relative waste volumes and highlight some problem areas which can be addressed.

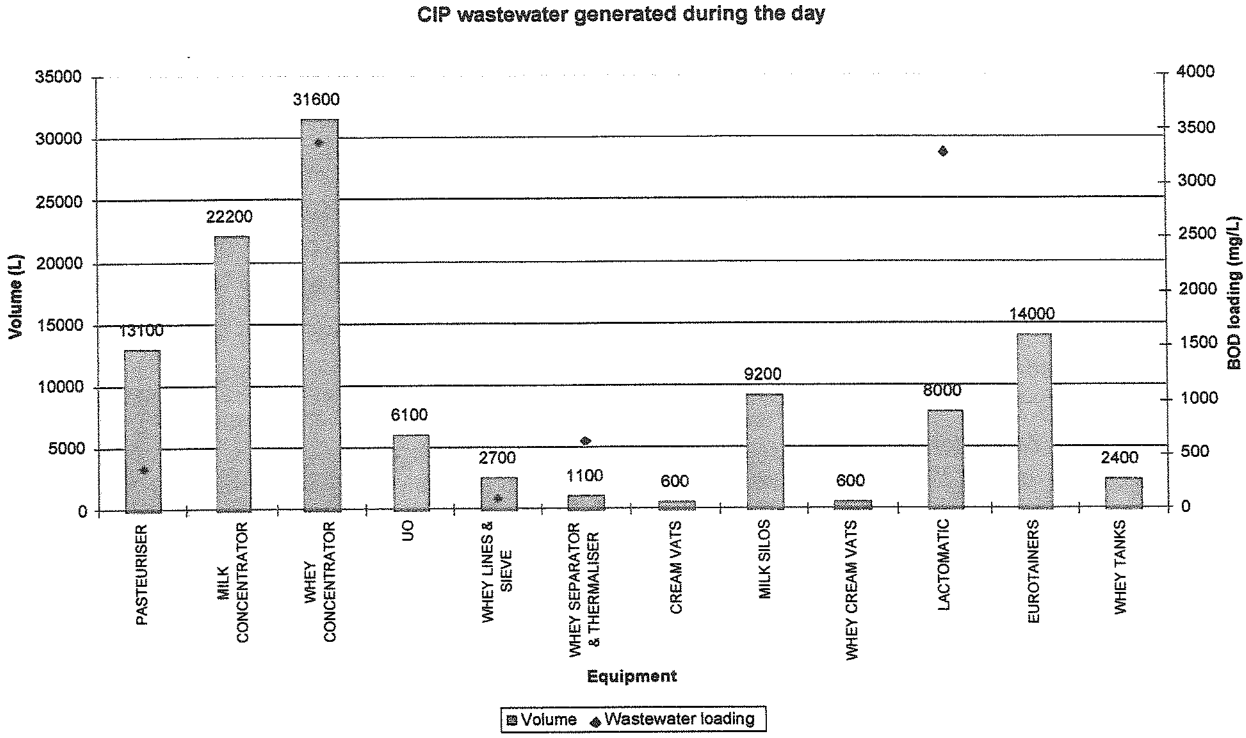


**Figure 2 – Volume and loading characteristics of wastewater streams for a medium-production day. These values indicate the total estimated volume of wastewater, based on typical CIP activities. Data for the whey silos, cheese vats and cheese towers have not been included.**

## 6.0 Recommendations

Waste streams of high priority are the lactomatic, whey tanks and whey concentrator CIP. Some practical waste minimisation options are given in Table 3. These options represent best practice, which aims to reduce waste production.

Other options include reusing waste from milk and lactomatic CIP for stock feed, and installing multi-use CIP systems in other parts of the factory. A very important measure would be developing and implementing a comprehensive corporate environmental policy. This should incorporate staff training and a waste management programme. When reviewing operational procedures and processes or planning new projects, the policy should serve as a guide to minimise the environmental impacts of the processing activities.

**Table 3 – Best practice options for waste minimisation**

| | |
|---|---|
| General | • Do not leave hoses running when not in use<br>• Install high pressure hoses<br>• Install/repair monitoring instrumentation (solids monitor, alarms, interlocks)<br>• Automate CIP systems<br>• Optimise start-up and shutdown procedures and changeovers, calibrate timers and install automatic systems to detect product interfaces |
| Lactomatic | • Maintain equipment |
| Whey tanks | • Extend the agitator paddles<br>• Use pitched tanks<br>• Use larger tanks to reduce the number of batches |
| Whey concentrator | • Reuse rinse water<br>• Ensure the balance tank is emptied before adding water (install level sensors, or modify cleaning procedure) |
| Pasteuriser | • Prevent spillages by electronically controlling product flow |
| Milk | • Purge lines<br>• Collect milk lost during transfers, start-up and shutdown |

## 7.0 Further work

A review should be carried out of the lactomatic processes and internal functioning to pinpoint the significant sources of waste and identify options to prevent the loss of product.

To gain a more complete view of the waste production, more waste loading data will need to be collected to complete the mass balance. A review of the manufacturing processes will also be vital in recognising waste reduction opportunities and determining which are of higher priority. These options should then be analysed for economic and technical feasibility. A waste management plan can then be prepared, containing recommendations which can be implemented and reviewed periodically.

## 8.0 References

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