Dairy factory wastewater challenges and innovations

A précis of a paper by Jess Daly (Beca) and Bram Beuger (Fonterra), which also won a Bronze Award in the Paper of the Year Awards sponsored by Hynds at the 2017 Water New Zealand conference.

In recent years, Fonterra has expanded a number of its dairy manufacturing sites to increase the overall milk processing capacity of its operations. A new dryer was installed at Fonterra's Pahiatua site in 2015 and a new milk powder dryer is being built at the Co-operative's Lichfield site.

In order to accommodate the increased wastewater flows from the sites, new wastewater treatment plants (WWTPs) were required as part of the overall expansions.

Dairy factory wastewater has a number of characteristics that require careful management, including influent pH swings of 2-13, high fat loads and variable incoming organic and nutrient loads. Variations occur both on a seasonal and daily basis.

A number of innovations and features were incorporated into the Pahiatua and Lichfield treatment plant designs to overcome these challenges including: Use of a mixed liquor recycle to buffer pH swings; use of mechanical surface aerators with floating acoustic covers; in-pond anoxic cycling to promote denitrification; use of dynamic process modelling to assess the sensitivity of the design to peak loads and aid in the development of risk management strategies; and beneficial irrigation of waste activated sludge on to surrounding farms.

Elements of this approach to wastewater treatment in the dairy industry could be adopted in a wider setting. For example in municipal plants treating an industrial wastewater component or municipal oxidation ponds that require upgrading to meet more stringent consent conditions.

Fonterra has traditionally used pond based activated sludge systems when implementing biological wastewater treatment.

These systems combine the engineering economy of a pond with the performance of an activated sludge plant. However, increasingly stringent discharge consent conditions, particularly in regards to nutrient loads, noise and odour and Fonterra's commitment to limiting its environmental impact, has led to improvements in the traditional treatment approach.

Challenges in dairy wastewater treatment are very much linked to the seasonality of the dairy industry. During winter there is little or no wastewater being produced by the factories for that 2-3 month period. Wastewater volumes and loads increase very rapidly at the start of the dairy season and biological treatment systems have to be robust enough to be able to maintain enough biological activity during the winter to start treating the wastewater when the new season starts.

The wastewater contains mainly dilute milk or milk products (milk fat, protein and lactose), with significant quantities of cleaning compounds and sanitizers, including a high sodium content from the use of sodium hydroxide for cleaning. Wastewater characteristics can change through the season due to product mix, but also daily due to Clean-In-Place (CIP) and production cycles. Unplanned events in the factory can lead to very concentrated product being discharged to the wastewater stream with a very high COD load, or high nitrogen or phosphorous concentration. Conversely, during the season nutrient imbalances may occur in the biological plants, which can impact on the treatment plant performance.

The pH of the wastewater can vary greatly. Milk powder and butter plants tend to have strongly alkaline wastewater while the production of lactic acid in the wastewater from cheese, casein and whey plants makes the wastewater from these plants acidic. The wastewater pH can vary anywhere between 2 and 13 within short timeframes.

Providing a treatment system that can manage these varying conditions and provide reliable treatment to comply with consent conditions is a significant challenge. The approach to these challenges has been to include a number of treatment processes in the WWTP, the selection depending on the characteristics of the wastewater, the required effluent quality, cost and availability of land and predicted future quality standards.

COMPLEX IRRIGATION

Irrigation is the most commonly used method to treat dairy processing wastewater in this country and involving complex treatment systems with elements of physical and biological treatment. Considerations in the irrigation design and operation are 'volume' requiring irrigation, the nutrient content (organics, fats, nitrogen and phosphorous), pH, and metal ion and salt content.

The first step in any irrigation system is flow equalization and pH balancing. The primary purpose is to aid neutralization (where both acid and alkaline waste streams are present) and to equalize concentration fluctuations before chemical or biological treatment. Flow equalization is essential to optimize the DAF plant or an irrigation system.

Irrigation is currently used to treat wastewater directly from a site or after primary treatment (DAF). The irrigation system is operated at daily application rates between 15 and 25mm with a rotation period (start of an irrigation event to the start of the next event) of 16 to 20 days to allow conversion of the organic matter.

Soils must have good infiltration capacities. If the infiltration rate is too low then wastewater will pond on the surface of the land. If this happens wastewater can undergo anaerobic decomposition resulting in odours, acidification and damage to the plant cover. If infiltration rates are too high, then the wastewater will spend insufficient time in the top soil to receive adequate treatment and groundwater contamination may occur.

Soil moisture plays an important role in irrigation management and is one of the challenges of any wastewater irrigation system. The soil moisture on an irrigation property is related to the soil moisture characteristics (saturation capacity, field capacity and drainage), weather conditions (rainfall, wind, evapotranspiration, temperatures) and irrigation. Irrigating soils that are too wet can lead to compliance issues (ponding and run-off) and damage to the farming system. Traditionally, wastewater irrigation systems only have about four hours of storage, which means that all volume generated by the factory had to be irrigated almost immediately, resulting in a challenge to maintain a balance between irrigation and the farming operation.

The overall wastewater application is often driven by the

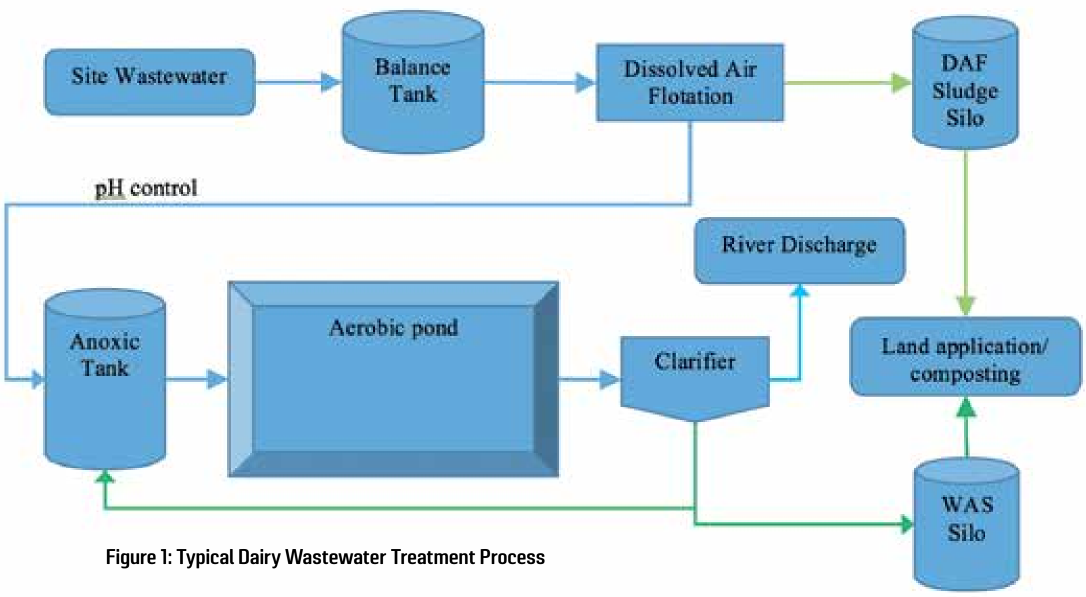

Figure 1: Typical Dairy Wastewater Treatment Process

annual nitrogen application rate. This rate is an integral part of irrigation consenting. In past years the focus has been shifting from a nitrogen loading rate (kgN/ha/y) to a nitrogen leaching rate. As leaching is difficult to measure, Overseer modelling is used to determine nutrient balances for the farms. The modelling looks at the whole farm and can make recommendations on the operation of the farming and irrigation system. Apart from nitrogen, phosphorous is becoming a major focus of any irrigation system. Achieving wastewater treatment using irrigation with a minimal impact on the environment is another significant challenge within a wastewater irrigation system.

BIOLOGICAL TREATMENT

A schematic of a typical biological wastewater treatment process implemented by Fonterra is presented in Figure 1.

DAF – Dissolved Air Flotation plants have been installed at a number of dairy sites to remove fat and protein and these plants are used as a primary treatment step for WWTPs as well as for irrigation systems. The advantages of DAF are that it has a small footprint and reduces the loads to a WWTP significantly. Removal of fat before irrigation is important to prevent "sealing" of the soil surface, which can reduce infiltration. Disadvantages are high operating cost and difficulty of further treatment of the DAF sludge.

Anoxic Tank – The dairy industry tends to have nitrate rich wastewaters primarily from the cleaning chemicals used in the factory (e.g. nitric acid). For this reason, initial anoxic conditions in the form of an anoxic tank are favoured for denitrification. This often requires pH adjustment to achieve adequate denitrification rates.

Pond Based Aerobic System – A pond based aerobic activated sludge system has often been the preferred treatment process if space allows. The key advantage is that it provides a robust system that balances variable flows and loads. Typical hydraulic residence times are four to eight days, with a sludge retention time between 20 and 30 days. Clarifiers have typically been used for secondary solids separation.

Aeration System – Most aeration systems used are based on floating mechanical surface aerators. Over the years they have proven to be reliable, with low maintenance requirements and an constant oxygen transfer efficiency over time. Downsides are that they are a significant contributor to the noise budget and on windy days spray drift can cause a nuisance.

Figure 2: Floating Surface Aerator with Acoustic Cover and Motor Silencer

Either land-based treatment or biological treatment have traditionally been used exclusively. If sufficient land was available land based treatment has been the preferred treatment method. If no suitable land was available, biological treatment was implemented prior to discharge to a nearby surface water source. In more recent times, both systems have been used in combination, with biological treatment used as a contingency during wet weather when the soils are too wet to irrigate. During this time, the treated wastewater is discharged to surface water.

TREATMENT INNOVATIONS

Variations of the traditional treatment approach including a number of innovations were adopted at the Pahiatua and Lichfield Fonterra sites.

Typically, Fonterra uses floating mechanical aerators for all pond-based activated sludge plants and this was the approach taken at the Lichfield WWTP.

However, the Pahiatua WWTP was required to comply with very stringent boundary noise and odour conditions and, hence, an alternative approach was adopted. The WWTP consent application was based on using submerged aeration to meet nighttime boundary noise limits of 45 dBA, which would not be possible with conventional surface aerators.

During preliminary design, the following submerged aeration systems were reviewed, including blowers and floating aeration laterals with suspended submerged diffusers, and submerged bottom mounted self-aspirating mechanical aerators.

While such systems were likely to comply with the noise limits, concerns were raised about access and maintenance, odour risk from dead zones in the pond, risk of pond liner damage and the limited track record of such systems in New Zealand.

To minimise risk, an alternative solution using mechanical surface aerators with acoustic covers, motor hoods and silencers was developed and a variation to the consent conditions granted. The addition of the acoustic cover, motor hood and silencer resulted in an 8 dBA reduction when compared with the supplier stated noise level from a standard 75 kW aerator.

The use of acoustic covers on mechanical surface aerators (Figure 2) was a first in this country and has aided in the site successfully meeting the overall noise performance requirements set out in the resource consent.

ANOXIC CYCLING

Pond anoxic cycling is a technique implemented by Fonterra to promote nitrogen removal at a number of its sites with two pond systems.

During an anoxic cycle, all aerators in the primary pond are turned off to reduce dissolved oxygen (D.O.) concentrations to a level that is suitable for denitrification to occur. After a set time period, the aerators restart and operate to maintain a D.O. set-point until the next anoxic cycle is initiated. The number of anoxic cycles that take place each day is typically operator determined and may vary throughout the season.

The second pond is continuously aerated to maintain an overall positive D.O. concentration in the system.

Anoxic cycling was considered for nitrogen removal at both the Pahiatua and Lichfield WWTPs. The specific site conditions at each WWTP determined which process was selected.

The Pahiatua site had limited space available and was in close proximity to sensitive neighbours. In addition, the resource consent for the site stipulated that the treatment pond was to maintain a positive D.O. at all times. This site was therefore better suited to an anoxic tank, which has a compact footprint and is able to be retrofitted with a cover and odour treatment system in the event that odours from the site become an issue.

The Lichfield site had space available for a two pond system and was in a relatively remote location. This site was therefore better suited to an in pond anoxic cycling process, eliminating the need for a separate anoxic tank.

Careful control of the cycling is required to achieve optimal nitrogen removal and to prevent performance issues such as odour and poor settling sludge.

During the design of the Lichfield WWTP, dynamic modelling was used to predict the optimal anoxic cycle duration and overall aeration requirements for the system in order to more consistently meet the nitrate targets in the discharge. The anoxic cycle time was 'tuned' during commissioning of the plant.

Wastewater from a milk powder plant can vary between pH 2-13 with an overall bias towards more alkaline conditions. For denitrification to occur successfully, a pH range of 6-9 is typically required. To achieve ideal pH conditions in the anoxic tank for denitrification, pH balancing or neutralisation may be required. Sulfuric acid dosing to control pH was considered upstream of the Pahiatua anoxic tank. However, Fonterra was seeking to eliminate the chemical handling and associated health and safety risks as well as the capital and ongoing operational costs of an acid dosing system.

As an alternative, the anoxic tank was enlarged and the mixed liquor recycle rates increased above that required for denitrification in order to provide additional pH balancing. The increased capital and operating costs from the upsizing was offset by the savings from eliminating a sulfuric acid dosing system.

PONDS AT LICHFIELD AND PAHIATUA

Both sites use a storage pond to store treated wastewater before irrigation to assist in the management of the irrigation systems.

During normal operation treated wastewater from the pond is irrigated onto the farms on a daily basis, subject to weather and soil conditions. During the spring and autumn the volumes of wastewater produced may exceed the volume that can be reliably irrigated on the farms. The excess treated wastewater during wet weather is stored in the pond until it can be irrigated in a drier period.

The Lichfield irrigation system consists of Fonterra owned irrigation farms as well as pod irrigation on third party farms. The development included an expansion of the irrigation on Fonterra owned land previously used as forestry, but now converted to pasture. The irrigation system is based on a fixed sprinkler irrigation system and is split into four blocks that can be irrigated simultaneously. Each of the blocks has 34-37 zones, with four zones (up to 2.5 hectares each) are sequentially irrigated every day at a peak flow of 165 m3/hr.

The storage pond at Pahiatua is required to maintain a DO concentration of 0.5mg/L at all times. During design, the requirement for supplementary aeration and mixing within the storage pond to prevent odours and algal growth was assessed. Given the large surface area of the pond, turnover in the pond, low BOD loadings (30- 50kg BOD/ha.day) and prevalent windy conditions, the requirement for aeration and mixing in the pond was considered unnecessary. Retrofit solutions were considered as part of the design and can be implemented in the future should algae growth become a problem. To date DO concentrations in the storage pond have been at or near saturation with typical concentrations being 6-8mg/L. Nor has there been any odour problems reported.

The biological treatment of wastewater removes a large portion of nutrients before irrigation on the nearby Fonterra owned dairy farms. Therefore, fertilizer applications would be required to maintain pasture growth rates and quality on the farms. The waste biomass from the biological treatment process contains nitrogen and phosphorus that can be beneficially applied to land as a slow release fertiliser, thereby eliminating fertilizer costs and reducing costs for the transportation and composting of biomass.

WIDER INDUSTRY APPLICATION

While dairy factory wastewater presents a number of unique challenges, parts of the approach taken to treatment could be applied to a wider industry such as municipal systems treating a trade waste component or oxidation ponds that require upgrading to meet more stringent consent conditions.

Acoustic Covers Surface aerators with acoustic covers could be adopted in municipal or industrial pond activated sludge systems that are required to meet strict noise boundary conditions.

Peak Load Management Dynamic modelling can be used to assess the sensitivity of a system to peak loading and aid in the development of management strategies. This approach is more applicable for treatment plants discharging to land where short-term excursions in effluent quality are better able to be managed than a system discharging to surface water.

In-pond Anoxic Cycling Anoxic cycling could be adopted in existing treatment processes in order to remove nitrate from the system. Careful control of the cycling would be required to achieve optimal nitrogen removal and to prevent performance issues such as odour and poor settling sludge.

Lastly, a large-scale storage pond could be implemented for systems that have limited irrigation capacity during wet weather. Treatment would be required prior to long-term storage to prevent the development of odours. **WNZ**

• View the full paper at: www. waternz.org.nz