THE HIDDEN VALUE OF DAIRY WASTEWATER

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ABSTRACT

Wastewater treatment and disposal is usually seen as an imposed cost, yet handled in the right way wastewater can be a source of energy, nutrients and reusable water. Here we present full scale industrial wastewater treatment plant case studies in Australia where process heat and high quality water are produced.

The dairy sector is the largest manufacturing sector in New Zealand, and consumes considerable amounts of energy and fresh water. Anaerobic treatment of the dairy wastewater generated results in the production of biogas, which provides a renewable source of energy. Secondary aerobic treatment generates effluent that is clean enough to be discharged into the environment or can be reused in the factory process. The combination of anaerobic and aerobic offers the best effluent quality for the lowest energy consumption.

The case studies include dairy and starch production wastewater in Australia. All production facilities use the ADI Systems ADI-BVF® reactor to anaerobically treat the wastewater, producing an energy-rich biogas. The biogas is used in plant boilers to generate process heat for the site. The anaerobic effluent is aerobically polished by a sequencing batch reactor or membrane bioreactor to further reduce the pollutants in the water prior to final discharge or reuse.

KEYWORDS

Dairy factory wastewater, anaerobic digestion, biogas production, bioenergy, water reuse.

1 INTRODUCTION

The food industry is the largest manufacturing sector in Australia, and consumes considerable amounts of energy and fresh water. A commitment to environmentally sustainable practices calls for closer examination of energy conservation and water recycling opportunities. Food and beverage production facilities typically produce wastewater which contains pollutants, such as organics measured as chemical oxygen demand (COD) and biological oxygen demand (BOD), and nutrients such as nitrogen and phosphorus. Treatment of this wastewater anaerobically results in the production of biogas, which provides a renewable source of energy. Secondary aerobic treatment generates effluent that is suitable for recycling. The combination of anaerobic and aerobic offers the best effluent quality for the lowest energy consumption.

The case studies presented include dairy and starch production wastewater. All production facilities use the ADI Systems patented ADI-BVF® reactor to anaerobically treat the wastewater, producing an energy-rich biogas. The biogas is used in the plant's boilers to generate process heat for the site. The anaerobic effluent is aerobically polished by sequencing batch reactor or membrane bioreactor to further reduce the organics, solids (measured as Total Suspended Solids, TSS) and nitrogen concentrations prior to final discharge or final treatment step by Reverse Osmosis (RO) to generate reusable water.

2 AUSTRALIAN CASE STUDIES

2.1 BIOGAS PRODUCTION FROM INDUSTRIAL WASTES

The COD concentration of industrial wastewater fluctuates based on the current processes operating in the factory (such as milk or starch production, equipment washing, etc.) and therefore the organic load, as well as the flow, is variable during the day and across the week. It is important for the treatment system to be able to handle the variations in flow and load. Aerobic plants generally do not handle variable flows and loads well thus an anaerobic treatment step can be the best solution to balance these variations.

The ADI-BVF® reactor is a low-rate anaerobic digestion technology that is a simple, efficient and low-maintenance method of treating food manufacturing wastewater. The system provides flow and load buffering, improving ease of operation for downstream processes and offering reasonably consistent production of biogas under these variable conditions. The biogas is typically used in boilers to generate steam or hot water for the sites. Table 1 shows the treatment, biogas use and water reuse of the case study facilities.

Table 1: Industrial Wastewater Case Study Plants

Wastewater	Treatment	Biogas Use	Water Reuse
Dairy 1	ADI-BVF® SBR	Factory Boiler	No
Dairy 2	ADI-BVF® SBR	Boiler and Engines	No
Dairy 3	ADI-BVF®	Treatment Plant Boiler	Under Consideration
Starch	ADI-BVF® MBR RO	Factory Boiler	Process Water

Secondary aerobic treatment of the anaerobically treated effluent results in more than 90% COD and BOD removal efficiency overall. The final effluent generated is of suitable quality to be discharged to the municipal sewer, and can be recycled for use in the factory. High-grade reuse of treated water can be undertaken with appropriate RO and post chlorination facilities, with the product able to exceed the Australian drinking water guidelines. Reuse for non-potable options frequently only requires lesser treatment.

2.2 PERFORMANCE OF ANAEROBIC PRETREATMENT

Anaerobic pretreatment systems can remove a significant amount of the COD, BOD and TSS from wastewaters, and can also remove some of the nitrogen and phosphorus. ADI has designed and built more than 250 industrial wastewater treatment facilities. The typical performance of anaerobic pretreatment is around 75-90% COD and 70-90% TSS removal. Table 2 below shows the average COD and TSS removal from the above four case study facilities in Australia.

Table 2: Industrial Case Study plant COD and TSS removal performance

Wastewater	**Average COD Removal %**	**Average Anaerobic Effluent Soluble COD mg/l**	**Average TSS Removal %**
Dairy 1	>80	210	>55
Dairy 2	>75	188	>70
Dairy 3	>90	180	>50
Starch	>90	90	>80

The above results are for the last year of operation. Generally the performance of an ADI-BVF® improves over the first year of operation.

For Dairy 1, the factory has a significant use of Clean-In-Place (CIP) chemicals including substances that are toxic to bacteria. This affects the performance, particularly the removal of suspended solids.

Dairy 2 has been in operation for approximately 10 years. This plant's processing methods and product range have changed significantly since the installation of the ADI-BVF®. This has affected the loading rates and the Hydraulic Residence Time (HRT), and despite these changes the facility continues to achieve high levels of COD and TSS removal and does so with little nutrient addition and little operational management.

In an anaerobic digestion system, the removal of COD creates biogas which can be used as a fuel source for heat production or electricity production. Each of the four Case Study plants create biogas, and Table 3 shows the approximate COD load to the different plants, the typical biogas production from the systems and the thermal energy produced (based on 55% methane in the biogas and a 85% boiler efficiency).

Table 3: Industrial Case Study plant flows and loads

Wastewater	**Flow (m^3/d)**	**Load (kg COD)**	**Biogas Production (m^3/d)**	**Produced Thermal Energy (kWh/d)**
Dairy 1	380	3,000	1,200	6200
Dairy 2	2,800	10,250	4,000	20,500
Dairy 3	3,900	28,000	12,000	61,500
Starch	9,000	60,000	25,000	128,000

The biogas produced is offsetting the use of natural gas or other fuel source to produce heat or steam for the food production process. For the starch manufacturer, the biogas is producing 190 tons of steam equivalents per day. As example estimation, the biogas produced in anaerobic treatment for this Australian starch plant is saving costs of around 2.44 million NZD per annum for natural gas (based on 15 NZD/GJ and 300 days production). These avoided costs in the production process need to be considered in the planning of capital expenditure and operational costs for anaerobic pretreatment of food industry wastewater.

3 NEW ZEALAND DAIRY FACILITIES ENERGY POTENTIAL

In New Zealand we have many comparable dairy production facilities, but only one to the author's knowledge that uses an anaerobic digestion system and the gas produced for a positive benefit.

The following is indicative data for three different NZ dairy facilities, and the gas production that could be achieved from them. The biogas could be used in boilers to produce heat for the dairy production process (as in the Australian case study facilities), or can be used for electrical generation. The flow, COD load and theoretical biogas production is shown in Table 4 as well as the indicative electrical generation capacity for each of the dairy facilities (based on 55% methane in the biogas).

Table 4: Indicative biogas and electrical power generation ability for three dairy factories in NZ

Wastewater	Flow (m^3/d)	Load (kg COD)	Biogas Production (m^3/d)	Electrical production (kWh/d)
Dairy A	4,000	14,000	5,000	10,150
Dairy B	7,500	60,000	32,000	65,000
Dairy C	4,500	22,500	10,500	21,300

At present these facilities discharge their wastewater to land, and do not recovery the energy from the wastewater.

3.1 IS ANAEROBIC PRETREATMENT OF DAIRY WASTE WORTH IT?

ADI has designed and installed more than 25 dairy wastewater treatment systems using the patented ADI-BVF® reactor, and has undertaken a number of economic feasibility assessments at dairy facilities in New Zealand and Australia. We have found that the trend internationally is different than in New Zealand.

Internationally many of our dairy clients choose to install anaerobic pretreatment to give cost savings, reliable operation and a lower cost base for their facilities in the future. The cost savings are not only from the beneficial use of the biogas (offsetting natural gas purchase), but also from reduced discharge fees from treated effluent, and lower treatment plant operating costs in comparison to aerobic treatment systems. In New Zealand our dairy producers have chosen not to use anaerobic pretreatment systems.

At this time there are almost no anaerobic pretreatment systems installed for the dairy industry in New Zealand. The only large scale anaerobic pretreatment system operating in New Zealand in the dairy industry to the author's knowledge is the Fonterra Tirau site which does deliver an operations cost benefit to that site.

In addition to the economic benefits of pretreatment, ADI has observed that anaerobic pretreatment significantly improves the operational ease of the post treatment facilities. The prevalence of filamentous organisms is greatly reduced when anaerobic pretreatment is undertaken, and this results in a significantly simpler and more reliable wastewater treatment facility.

Another benefit is that sludge production is significantly reduced for a dairy plant with an anaerobic pretreatment facility (when compared to aerobic treatment alone), and the sludge has a chemical composition that makes it a good fertilizer with more bioavailable nutrients.

There is a concern that anaerobic treatment will remove the readily biodegradable COD (rbCOD) needed for biological nutrient removal in the aerobic polishing step. This can simply be solved through a small bypass of raw wastewater directly to the aerobic step. In a cheese factory in Australia the bypass required for biological nitrogen removal is only 4% of the total wastewater flow. If high amounts of rbCOD are required where biological phosphorus removal is desired, the relatively poor rbCOD content of typical dairy wastewaters can be enhanced in a small fermentation step for the bypass. In one of the case study plant in Australia, another waste stream from the dairy process that is high in lactose is directly used to be dosed into the SBR as a carbon source for denitrification when it is needed.

ADI has undertaken a number of wastewater treatment reviews and feasibility assessments on anaerobic pretreatment followed by aerobic post treatment for dairy processing facilities in NZ (assessments undertaken in 2013 and 2014) based on data from NZ dairy companies. The feasibility assessments showed that the Net Present Value of the anaerobic pretreatment system can be significantly better than the equivalent land application system.

The feasibility studies showed that for a typical dairy facility, anaerobic digestion alone (no further post treatment) with the use of the biogas for electricity to displace power purchases, could result in an internal rate of return of around 20%. The study included data for a number of years production, and was based on ADI's low cost engineered in-ground digestion systems (ADI-BVF® and ADI-CGR®).

The capital cost for these systems were a little higher than the equivalent aerobic treatment systems, but these additional costs were more than compensated for by the energy production, reduced aeration costs and reduced sludge disposal costs. As a result the anaerobic/aerobic systems had a positive return, compared with significant net costs associated with all other systems reviewed.

The feasibility studies indicated that the energy savings associated with the pretreatment of the waste could offset the costs associated with post treatment facilities, including nitrogen removal, for a typical dairy facility.

4 CONCLUSIONS

ADI has significant experience with the design and construction of industrial wastewater systems internationally. ADI has designed and built more than 25 anaerobic pretreatment systems for the dairy industry, some of which have been operating for over 25 years and have shown that anaerobic pretreatment using the ADI-BVF® reactor is very reliable for dairy wastewater.

ADI has observed that the international trends for treatment of waste are different to the practices being undertaken in New Zealand, and our technical and economic feasibility assessment for dairy facilities in NZ suggests that treatment of dairy waste using an anaerobic digestion system can create a significant amount of energy for production facilities, and can also have a positive internal rate of return. One assessment indicated an Internal Rate of Return (IRR) of around 20%.

The feasibility assessments suggest that the anaerobic pretreatment can even offset the cost of operating the post treatment facility (IRR of ~5%), which can allow the water to be either used more effectively, or discharged with less adverse effect.

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REFERENCES

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