AUSTRALIAN MEAT PROCESSOR CORPORATION

Cost Benefit Analysis of Dewatering Abattoir Sludge Using Three-way Decanters

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GLOSSARY OF TERMS

BOD_5	Biological Oxygen Demand. Milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C.
CAL	Covered anaerobic lagoon
DAF	Dissolved air flotation
FOGs	Fats, oils and greases
TSS	Total Suspended Solids

1.0 Executive Summary

Lycopodium Process Industries (Lycopodium) was engaged by Australian Meat Processor Corporation (AMPC) to conduct a process and cost-benefit analysis review of the use of three-way decanters for managing waste water treatment sludge produced at Australian red meat processing facilities. As part of this work, Lycopodium visited three Australian sites that recently installed three-way decanters, interviewing plant personnel and developing case study reports summarizing the project and lessons learned. The process review, case studies and an illustrative cost benefit analysis based on inputs from one of the Australian sites studied are presented in this report. A summary of the project findings includes:

- Three-way decanters provide a means for separating the sludge into three nominal fractions; dewatered solids, tallow and clarified waste water;
- The immediate value of three-way decanters are their ability to divert the tallow component from being discharged to trade waste or sent to secondary treatment processes. Given that the tallow results in a large contribution to the BOD_5 load within the waste water sent to sewer (Approx. 1.5-1.7 kg (BOD_5)/kg (tallow)), its removal can result in a substantial saving for the processor in terms of costs associated with trade waste disposal;
- The decanters systems work most effectively when the sludge is pre-heated to approximately 90-95°C. The pre-heating can be achieved more economically by using waste heat in the clarified waste water to bring the sludge up to an intermediate temperature followed by steam heating of the sludge to achieve the final required feed temperature. This approach also facilitates cooling of the clarified waste water, allowing it be recycled through the DAF or combined with the bulk waste water flow;
- The high feed temperature required for decanter operation also results in a degree of pasteurisation of the sludge. This element of the process has the potential to:
    - Improve the categorisation of the solids produced with respect to the environmental regulators;
    - Increase the number of composting sites capable of receiving this waste;
    - Decrease the associated disposal costs;
    - Provide revenue from the dewatered solids produced as a nutrient-rich compost additive.
- The regulatory environment around handling/disposal of dewatered solids from meat processors remains relatively complex but there appear to be current opportunities, particularly within Victoria, to provide input to the regulatory framework being developed/clarified and to demonstrate the value of the three-way decanter process for improving the quality of the solids produced. Such engagement should hopefully lead to a better understanding between the two groups regarding their relative position with respect to disposal of meat processing solids;

- Correctly implemented, three-way decanter systems can result in very short payback periods and substantially improved environmental performance at Australian red meat processing sites. However, it was also noted that business case for such projects is highly site specific and that a) size of the facility can play an important factor in the economics – typically the larger the more favourable a similar project is likely to be; b) location can dictate waste disposal costs and regulatory requirements and; c) simple payback periods may not be the only factor to take into account when considering a similar project. Meat processors should therefore carefully evaluate the opportunity based on their own site conditions.

2.0 Introduction

'Sludge' is produced during waste water treatment at red meat processing facilities, typically in the form of floated material from save-alls or the top-skimmings from dissolved air flotation (DAF) units. The composition of sludge varies depending on the site and water treatment processes in place but, apart from being 80-95% w/w water, the sludge typically contains high levels of organic solids (approximately 5-15 wt%) as well as liquid organics in the form of fats, oils and greases (FOGs) (approximately 1-6 wt%). Traditional sludge processing methods typically involve a dewatering process in which a reasonable portion of the suspended solids are removed (i.e. via belt filter press or two-way decanter) but which result in much of the FOGs carrying on to be discharged to sewer with the rest of the treated waste water. Given that FOGs have the potential to contribute significantly to the biological oxygen demand (BOD_5) within the discharge waters (approximately. 1.5-1.7 kg (BOD_5)/kg (FOGs) [1, 2]) and that many Australian water authorities have substantially increased load-based trade waste charges in recent years, particularly with respect to BOD_5 loading, there is incentive to look at ways of removing as much of the FOGs in the wastewater as possible. The dewatered sludge material produced by these processes is also typically odorous to compost, has potential for high microbial activity and elevated pathogen loads, and has traditionally formed a problematic waste source which is often costly to dispose of. The solid component of the sludge, however, is generally high in useful nutrients such as nitrogen and phosphorous, while the FOG component can be readily used as low-grade tallow.

Recognizing the potential for 'resource recovery' and reduction in waste disposal charges, some red meat processors in Australia and overseas have employed three-way decanter technology (also referred to as tricanters) to separate meat processing sludge into three principle components: water, solids and FOGs. Decanters rely on the density difference between the three products (solids being heavier than water and FOGs being lighter than water) and the centrifugal acceleration within a rapidly rotating bowl to separate the streams within the sludge. Pre-heating the sludge to 85-95°C enables much greater separation efficiency while also reducing microbial levels. The outcomes of this approach are; a) the water component is typically recycled back to the DAF system, sent to sewer or for secondary treatment; b) the dewatered solids (depending on composition and aggregating chemicals used in the DAF process) are sold to a renderer or feed producer, blended with compostable material or disposed of to landfill, and; c) the FOGs are processed or sent offsite as low grade tallow. Three-way decanters therefore have the ability to improve waste water treatment, reduce waste disposal costs and produce potential revenue streams. The drivers for installing a three-way decanter system, however, are often specific to a given site.

3.0 Outline of Waste Water Treatment Systems at Red Meat Processors

As described in the introduction, the composition of the waste water stream exiting the primary treatment circuit within an abattoir or rendering facility can have a significant impact on trade waste disposal costs and/or the function of secondary treatment processes (generally anaerobic or aerobic ponds). Poorly treated primary waste water can lead to situations where either function of the secondary treatment is reduced (i.e. shock loading of an anaerobic pond) or the maintenance costs/plant longevity are adversely effected (i.e.

through excess suspended solids depositing in pond sludge). It is therefore important for the meat processor to have as much control over the outputs of the primary treatment circuit as possible in order to optimize the plant performance and profitability.

The composition of red meat processing wastes, however, often provides specific challenges for the primary treatment circuit. The waste water is typically high in total suspended solids (TSS) and fats, oils and greases (FOGs) as well as being produced at relatively high temperatures (up to 50°C to 60°C) [3]. Insufficiently treated, the TSS will build up at the bottom of the secondary treatment lagoons or carry over into the discharge, the FOGs will disturb biological processes, form crusts on the top of the ponds or carry over into the discharge, while the high temperature fluids will also adversely impact the biological processes, tend to emulsify the FOGs or carry excess heat over into the discharge [4]. A well-designed primary treatment process will therefore seek to reduce TSS and FOGs levels, provide a consistent flow and manage the temperature of the wastewater to meet discharge or secondary treatment process constraints.

Dissolved air flotation (DAF) technology is commonly used in red meat processing waste water primary treatment for the removal of FOGs and TSS from waste water. To reduce the load on the DAF and allow it to operate more effectively, DAF treatment is typically preceded by coarse solids removal techniques such as screw presses, contra-shear rotary drum filters, baleen filters and shaker screens (Figure 1). The wastewaters that are processed are typically generated from two different sections of the meat processing operations and contain quite different products. The "green" stream primarily results from wash down and transport of manure and paunch based materials, while the "red" stream is typically derived from the wash water and blood/organics that are generated during the slaughtering process. In some facilities the two streams are treated separately while in others they are combined and treated together (Figure 8).

DAF technology typically involves pressurization and aeration of the feed stream (usually combined with a recycle stream) followed by de-pressurization across a nozzle or orifice which results in micro-bubble formation. Suspended solids and FOGs within the wastewater attach to the micro-bubbles and are floated to the top of a receiving vessel and are then scraped off as sludge. Often pre-treatment of the feed through pH adjustment and/or inorganic metal salts addition (i.e. ferric chloride, ferric sulphate, polyaluminium chloride (PAC) etc.) and/or polymeric flocculant addition is carried out to enhance solids capture efficiencies [5, 6]. In order to optimize the effectiveness of a DAF the feed temperature typically needs to be below approximately 38 °C [7].

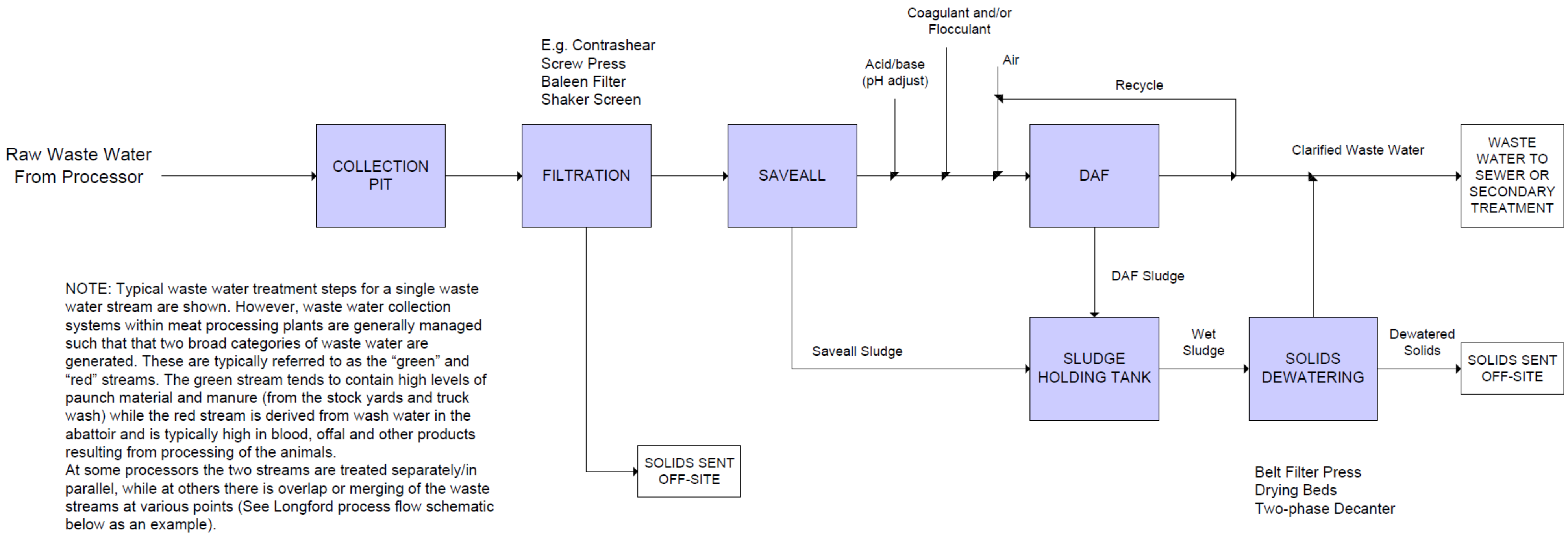


Figure 1. Overview of typical processes involved in primary treatment of red meat processing waste water

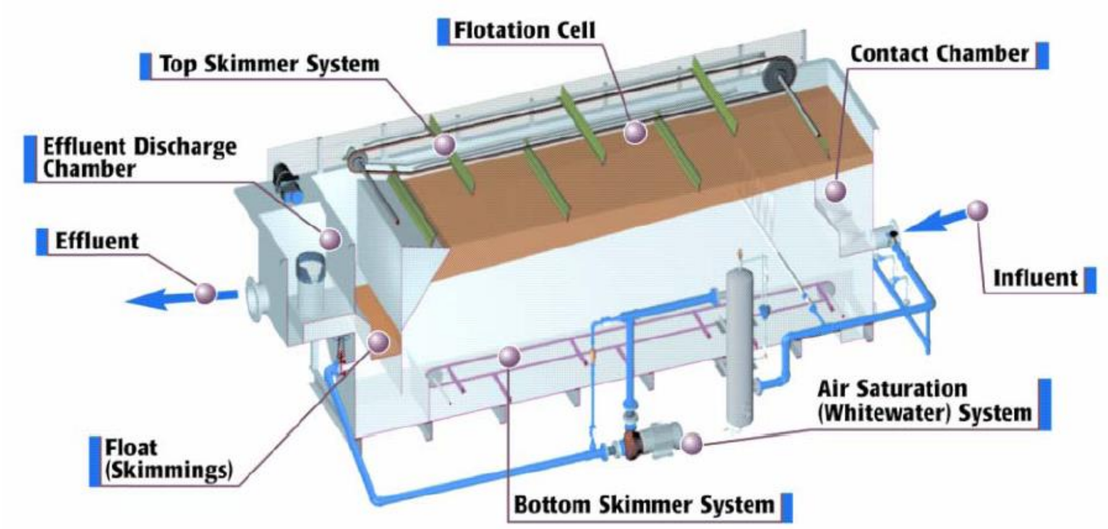


Figure 2. Typical rectangular DAF system (from [8])

While a DAF can substantially improve the disposal characteristics of the resulting waste water, the sludge that is produced often presents a significant waste disposal cost for the processor. DAF sludge is typically high in moisture (90-97%) [9, 10], high in volume (up to 3% of total wastewater flow) [9] and will often contain the chemical additives used to assist with the flotation efficiency such as polymeric flocculants and inorganic salts/coagulants. In the absence of further treatment, disposal options for DAF sludge have included rendering, land application, sub-soil injection or landfill [9, 11]. The DAF sludge is often partially dried via belt filter press or porous drying beds to reduce the sludge volume sent for disposal. Due to the presence of the FOGs and other animal based organics such as blood and viscera the sludge requires rapid processing to avoid biodegradation and odor generation [12].

Rendering is often the first option considered for processing of dewatered red stream DAF sludge but is often made difficult due to high water content (costly to process due to the evaporative load required), high free fatty acid content (particularly in situations where sludge is not processed immediately) and presence of impurities which may impact performance of processing equipment (i.e. foul heat exchangers) [9, 13]. Each of these factors reduces the value of the product. Disposal options which involve land application of the sludge pose short and long term environmental problems and are increasingly being discouraged through increased regulatory restrictions and licensing requirements.

There is potential value in recovery of the components present in the DAF sludge as the FOGs can be utilized as low-grade tallow or even a boiler fuel [14] while the solids have potential as a compostable organic matter for land application or on-sale provided they can be processed in a manner that avoids categorization as a prescribed industrial waste [15]. Due to the complex nature of DAF sludge (i.e. containing blood, viscera, paunch, manure, colloidal solids, aggregating chemicals and other organic/inorganic contaminants) separation of the various components is a challenging task.

4.0 Resource Recovery Using Decanters

In the 1980's one of the early proponents of an alternative approach to the traditional treatment and disposal of DAF sludge was the US-based company, Bird Environmental Systems and Services, Inc. The approach, which they referred to as 'resource recovery', combined heating DAF sludge to 85-95°C and then processing it through a 3-phase centrifuge. The approach is depicted in Figure 3.

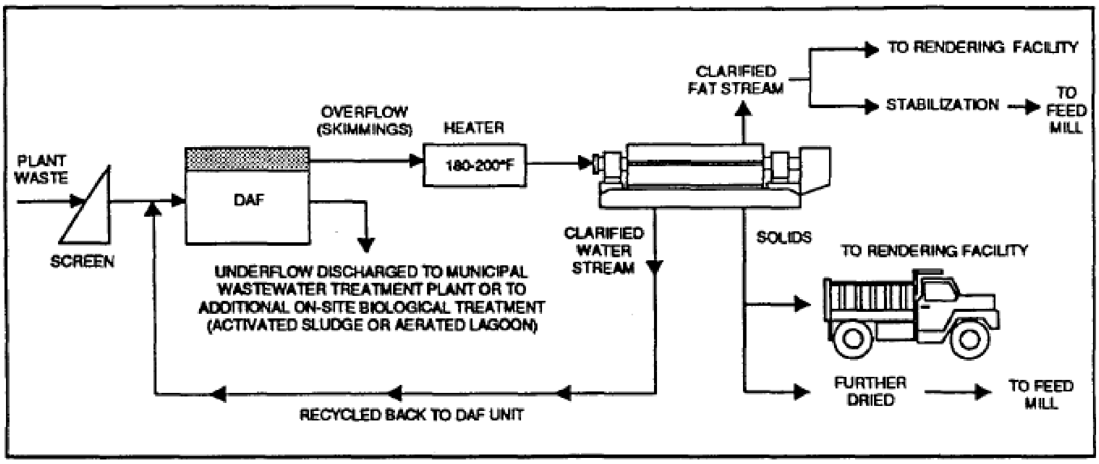


Figure 3. Bird Environmental pretreatment system utilizing DAF and 3-phase separation technologies (from [9])

The objective was to break down the DAF sludge into its three principle components: water, solids and oil. Using this approach, the water component is typically recycled back to the DAF system and ultimately sent to sewer or for secondary treatment, the solids are purported have potential value to a renderer, feed producer or for blending with compostable material (although this may not be possible if produced using metal salts coagulants) and the oil has potential commercial value as low grade tallow [9, 13].

Increasing the temperature of the feed to the centrifuge promotes oil/water separation and also acts to coagulate the blood present and assist with its recovery within the solid phase [10]. With respect to oil/water separation an increase in temperature has the following effects [16]:

- Reduces the viscosity of the oil;
- Increases the mobility of the water droplets;
- Increases the settling rate of water droplets;
- Increases droplet collisions and favours coalescence;
- Weakens or ruptures the film on water droplets because of water expansion and enhances film drainage and coalescence;
- Increases the difference in densities of the fluids that further enhances water-settling time and separation;
- Reduces the extent to which solids present are wetted by oil which further assists to destabilize emulsion behaviour and minimise oil entrainment within the solid phase.

Heating DAF sludge is an energy intensive process, however, and in order to increase the efficiency and reduce the processing costs it is usually achieved by first passing the sludge through an economizer heat exchanger (which recovers heat from the decanter water recycle and helps remove heat from this stream to avoid exceeding the temperature limits for effective DAF operation) and then bringing it up to the final feed temperature through direct steam injection or indirect steam heating within a second heat exchanger. Other adjustments to the feed stream which have been reported to be of benefit are pH adjustment up to at least 7.5 and preferably as high as 10.5 as this assists with coagulation [10].

With respect to the 3-phase centrifuge technology used for DAF sludge processing, horizontally-oriented decanting centrifuges (Figure 4) are generally recognized as the most appropriate. Vertically-oriented disc stack style centrifuges (Figure 5) are also capable of 3-phase separation but, due to the high potential for clogging of larger solids carried over from the DAF within the tightly stacked discs and sludge outlets, they would not be recommended for this application. Rather they would be reserved (where necessary) for polishing of the liquid phase component(s) exiting the decanter centrifuge. Due to the variability of the sludge properties requiring processing and the propensity for process upsets upstream which can result in larger material passing through with the sludge and potentially avoiding capture in the decanter, the use of vertically-oriented disc stack clarifiers for polishing is likely to result in occasional issues with clogging.

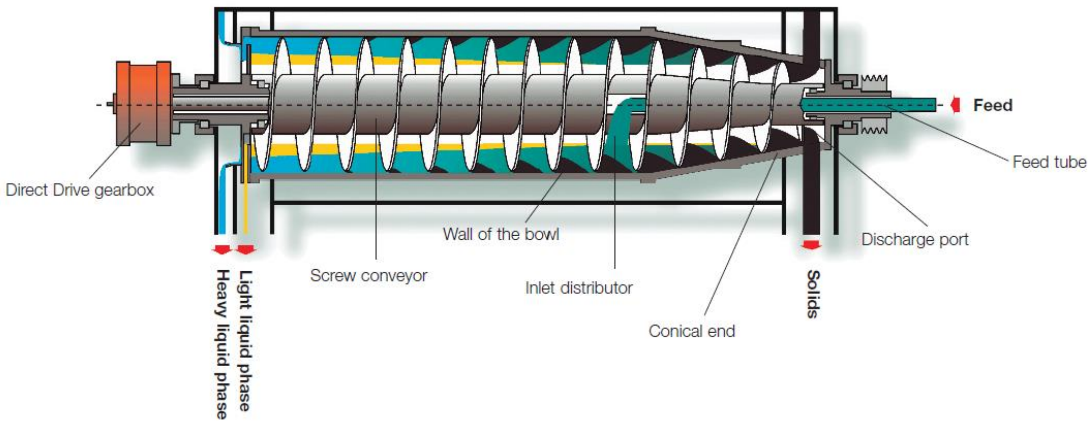


Figure 4. Three phase decanter centrifuge (from [17])

As described by Alfa Laval [17], in a 3-phase decanter centrifuge, "*separation takes place in a horizontal cylindrical bowl equipped with a screw conveyor. The feed is led into the bowl through a stationary inlet tube and smoothly accelerated by an inlet rotor. Centrifugal forces cause sedimentation of the solids on the wall of the bowl. The conveyor rotates in the same direction as the bowl but at a different speed, and conveys the solids to the conical end. These solids are lifted clear of the liquid, and the capillary liquid is then drained centrifugally before being discharged through the solids outlet port into the casing. Separation takes place over the entire length of the cylindrical part of the bowl, and the clarified heavy and light liquids leave the bowl by overflowing two sets of weir discs into two separate outlets in the casing.*"

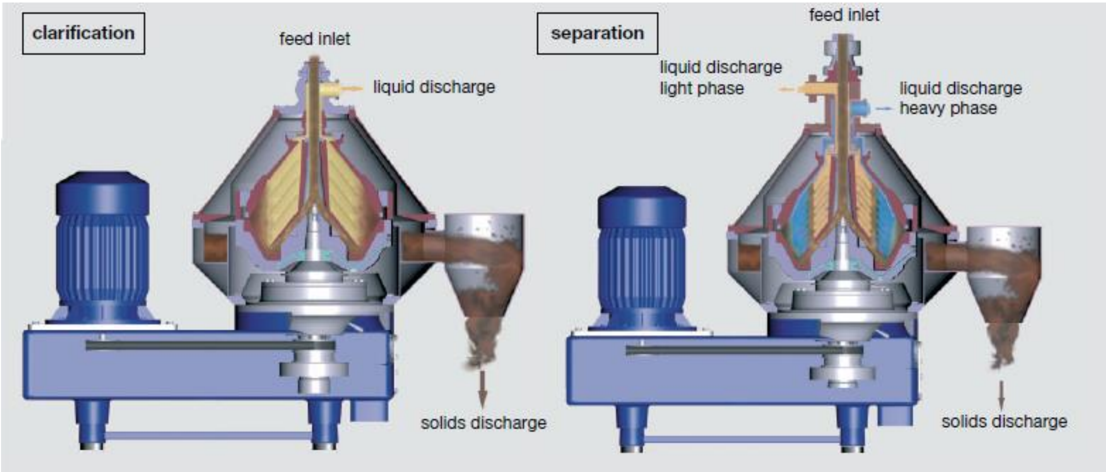


Figure 5. Disc stack centrifuge (from [18])

Optimization of the decanter performance can be achieved by varying the following[17]:

- Bowl speed, to ensure the exact G-force required for optimized separation;
- Conveying speed, for optimized balance between liquid clarity and solids discharge capacity;
- Pond depth in the bowl, for the ideal balance between liquid clarity and solids dryness, and inter-phase settings between the heavy and light liquid phases;
- Feed flow.

An additional requirement of the DAF sludge resource recovery system is typically a clean-in-place (CIP) system which will allow the centrifuge and associated fluid transfer systems to be regularly cleaned to avoid blockages and efficiency losses [19].

Bird Environmental estimated that with their prescribed mode of operation, the DAF sludge, on average, would be broken into the following constituent parts: 90% water, 7% solids and 3% oil. These resulting streams are not pure, however, and each is partially contaminated by components from the other two. For example, studies conducted by Bird Environmental found that, depending on specific facility drivers and process conditions, the solids stream contained approximately 5.5-12 wt% oil and 55-70% water, the oil stream contained 0.04-0.26 wt% water and 0.06-0.2 wt% solids, while the water stream contained 0.04-1.0 wt% solids and 0.0-0.4 wt% oil. Although Bird Environmental no longer appears to be in business, a number of other major equipment vendors such as Alfa Laval, GEA Westfalia, Flottweg, Hiller Separation & Process, and Huading Separator, provide 3-phase centrifuges to the food processing industry. The mode of operation recommended by centrifuge equipment manufacturers today is the same as proposed by Bird Environmental 20 years ago;—heat the DAF sludge to 85-95°C and then process the DAF sludge with the 3-phase centrifuge. Today, centrifuge equipment manufacturers will typically report that they can achieve 3-4% oil extraction by volume in DAF sludge produced using inorganic metal salts as coagulants and perhaps 5-6% in DAF sludge produced using polymer flocculants [13, 20].

Despite these oil recovery levels, there are very few examples of red meat processors in Australia with three-way decanter equipment installed to process DAF sludge. Drivers for the uptake of the technology are discussed in detail in the case studies presented in the following section but include a desire to decreased waste disposal costs, increase overall stability of wastewater treatment processes and the potential to generate revenue through the sale of the oil and solids components. The fact that the DAF sludge is treated at such high temperatures results in a degree of pasteurization of the resulting material and increases the ability of the solids to be on-sold as a compostable material. The degree of pasteurization, however, does not appear to be quantified at this stage or substantially recognized by the environmental authorities. The industry would therefore benefit from consultation with the relevant authorities concerning pasteurization targets as it may be possible to demonstrate that dewatered sludge processed in the manner described is capable of being composted via less stringent means than currently ascribed to paunch and meat processing sludge. For example, in Victoria authorities such as Sustainability Victoria and EPA Victoria are currently finalizing an organic waste strategy which is intended to provide a clearer path forward for industry and regulators regarding organic waste produced in the state. EPA Victoria's recently released Draft Guidelines-Composting provide a preliminary set of guidelines as to how organic wastes which are suitable for composting are likely to be treated by regulators as well as an indication as to how composters and meat processors can potentially treat wastes and apply for additional consideration regarding licensing and waste categorization [21].

Some of the general barriers to uptake of the 3-phase decanter technology include:

- Decanter performance dependent upon site specific waste quality (i.e. composition of wastes and any additives present). Optimisation generally entails a trade-off between desired solids concentration and water quality;
- Overall project economics are dependent upon the size and location of the red meat processing facility as well as the incumbent waste water treatment system. The size of the facility influences economies of scale while the location influences the existing waste disposal costs and other resource recovery drivers. The incumbent waste water treatment infrastructure will have an influence on the characteristics of the DAF sludge produced and elements such as longer processing times (>24 hrs) can result in free fatty acid generation that causes issues for tallow quality and shelf-life [9] while the use aggregating chemicals in DAF sludge can also impact on the end uses and subsequent value of the recovered products [9];
- Lack of technological understanding and/or existing reference projects;
- Upfront capital costs;
- Ongoing operational and maintenance costs.

Apart from seeking to understand the extent of the capital and operating cost barriers, the red meat processing industry is also looking to evaluate whether or not there are potential techno-economic advantages in using a two stage process to process DAF sludge to water, oil and solid rich streams. The two stage process typically involves a two phase (solid-liquid) decanter (Figure 6) followed by a polishing liquid-liquid separator. According to one of Alfa

Laval's publications [22], "*Single-stage separation, using a three-phase decanter, is preferable in cases where the composition and consistency of the DAF [sludge] are fairly consistent. Two-stage separation, with a decanter and a high-speed separator, is a more versatile and efficient method, which provides the best separation performance on products with more variations in composition, quality, and chemicals. The fat complies with more demanding specifications, and the remaining water has a lower BOD loading*." Initial correspondence with technology suppliers and meat processors employing 3-phase decanters, however, suggests that a single stage system is preferable for most projects looking to separate out the components from DAF sludge produced by Australian red meat processors [19, 20]. According to Alfa Laval, the 3-phase decanter system achieves a similar outcome with respect to the separation efficiency of the three principal sludge components but does so with approximately two thirds of the capital outlay relating to the separation equipment [20].

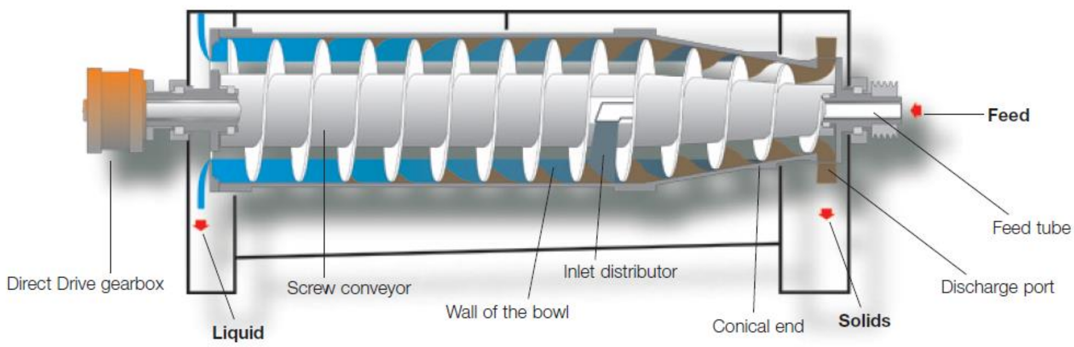


Figure 6. Two phase decanter centrifuge (from [23])

5.0 Decanter Case Studies

In order to illustrate the variety of drivers for implementing three-phase decanter processes to treat red meat processing sludge and the practical concerns associated with installing and operating them, three Australian red meat processing facilities which have installed the technology assisted with developing the following case studies.

5.1 Case Study 1 – Brooklyn, VIC

Abattoir Capacity: 1,500 head per day (cattle), 8,000 head per day (sheep).

Site Particulars: The Brooklyn site is located approximately 12 km west of Melbourne's CBD. Although it is an industrial area there is residential housing approximately 500 metres to the south and 1 km to the east of the plant. The site is bounded by a number of other businesses to the south and west while a railway line runs along the north-east border. The site is therefore somewhat constrained in terms of available space for new projects and is also bound by strict emissions limits and Metropolitan-based waste disposal pricing.

Key Project Drivers: Previously two smaller (4 tonnes per hour) two-way blood decanters were used to process the DAF sludge. These decanters were not fit for purpose and only removed approximately 40% of the solids present while leaving the FOG component in the waste water. The waste water leaving this system therefore added significantly to the organics load being discharged – both in terms of suspended solids (SS) and biological oxygen demand (BOD_5). Production rates at the processor also doubled from roughly 700 head per day of cattle to approximately 1,400 to 1,500 head per day. The corresponding increase in sludge produced meant that the existing system was undersized. Waste water quality leaving the site is closely monitored and regulated by local authorities and trade waste disposal prices have increased dramatically in recent years which provided a further financial incentive to complete the project.

Sludge Details: Sludge processed by the three-way decanter is produced from a DAF unit which is fed with a combination of screened red and green waste as well as recycled water (centrate) from the decanter. Prior to being combined, the green stream passes through a press screw separator while the red stream passes through an inclined rotary screen. Both streams are then passed through a baleen filter followed by a shaker screen. The screens are designed to remove solids above 500 microns but this is not always achieved in practice. The feed to the DAF is kept at or below approximately 38°C, the pH is adjusted and then a coagulant and polymeric flocculant are added to enhance the DAF performance. The sludge produced by the DAF is stored in an 80 m^3 insulated holding tank prior to being processed within the three-way decanter.

Decanter Installation: The decanter installation includes two three-way decanters each with a nominal 12 m^3/hr maximum throughput and which can be run on their own or in parallel depending on sludge production rates. To ensure optimum separation efficiency the decanters are normally run at approximately 8 m^3/hr for solids concentrations up to 20% w/w. Prior to processing within the decanter, the sludge is pre-heated to the production set point (95°C) by first passing it through a Hipex tube-in-tube heat exchanger (which is heated by the centrate recycle) and then through a direct steam injection heat exchanger.

The decanters are located side by side on a mezzanine floor in an enclosed building. Solids are discharged by gravity to a collection bin below and are then conveyed to an adjacent storage bunker via screw conveyor where they can then be loaded onto truck for transport offsite. FOGs from the process are discharged into a buffer tank before being pumped across to a larger tallow storage tank, ready for further processing. Centrate from each decanter is discharged into a buffer tank below the decanters and pumped back to a holding tank that feeds the DAF system. On the way to the DAF feed tank the centrate passes through the HIPEX heat exchangers - recovering some of this energy and simultaneously cooling the recycle stream to avoid exceeding the recommended maximum DAF operating temperature of 38°C. A clean-in-place system allows for regular flushing and chemical cleaning of process lines in order to avoid blockages and degradation of process equipment.

System Performance: The decanter system described was commissioned in October/November 2013 and operates 15-17 hrs/day for approximately 270-290 days per year. The solids produced by the system are low in moisture and have a high nutrient content. They are currently being sold as a compost additive. The tallow produced is generally good quality and is currently sold as is.

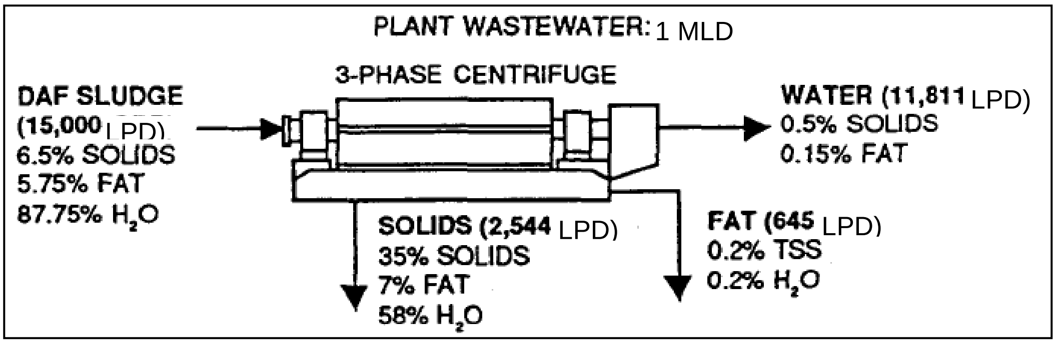


Figure 7. Indicative mass balance for a three-way decanter[1]

Lessons Learned:

1. For sludge storage a conical bottom sludge tank with a top mounted agitator would be preferred. The sludge stratifies while stored in the tank which can make the heavier and sometimes thicker layer harder to process.
2. Where possible use 45° bends in the sludge and centrate pipelines. Experience has shown

[1] Adapted from: Steele, C. P. and J. D. West (1988). *Elimination of DAF Sludge Disposal Through Resource Recovery*. Food Waste Processing Conference, Georgia Institute of Technology, Atlanta, GA, Bird Environmental Systems and Services, Inc.

that many blockages tend to occur on the 90° bend section of the pipe work, particularly, on the sludge feed lines. This is particularly the case on occasions of higher levels of solids and FOGs.

3. Use gate or full bore ball valves instead of butterfly valves. The butterfly valves cause solids (i.e. paunch, hair, plastics) to collect and build up, eventually leading to blockages in the line.
4. Allow sufficient fall and diameter of the tallow discharge pipe line from the decanter discharge point. Not providing sufficient sizing and fall will lead to tallow blockages.
5. Odours are generated from the steam emitted from the tricanter during processing and from the dewatered solids once they are discharged.
6. Heat exchangers with close clearances between elements (i.e. spiral or plate and frame systems) should not be used as they will become quickly blocked.

Installed Cost: Approximately $2 million.

Estimated Payback: Approximately 1 to 2 years based on avoided trade waste costs and revenue from tallow and dewatered solids.

5.2 Case Study 2 – Longford, TAS

Abattoir Capacity: 460 head per day (cattle), 1,430 head per day (sheep).

Site Particulars: The Longford meat processing site is located approximately 25 km south of Launceston and immediately adjacent (on the northern side) to the small historic township of Longford. A railway line runs along the south-east border of the site and the remaining surrounds are picturesque rural farmlands. The site is not space constrained but, due to its proximity to the town, there is sensitivity regarding odors and visual amenity associated with both the processing operations and any waste composted on adjacent land.

Key Project Drivers: Prior to the installation of the current three-way decanter, a single (4 tonnes per hour) two-way blood decanter was used to process both blood in the rendering facility and waste water sludge. This decanter was not well-suited to waste water sludge processing and only removed approximately 40% of the solids present while leaving the FOG component in the waste water. The waste water leaving this system therefore added significantly to the organics load being discharged – both in terms of suspended solids (SS) and biological/chemical oxygen demand. The site's existing agreement with local authorities regarding trade waste disposal costs is also about to change from a flat yearly fee to a charge based on waste water quality. As a result, trade waste disposal costs are anticipated to increase sharply and efforts are therefore being made across the site to improve waste water treatment performance. Dewatered sludge was also previously mixed in with feed mill product and but due to presence of some of the aggregating chemicals in the DAF sludge this is no longer plausible.

Sludge Details: The sludge processed by the three-way decanter is a combination of the float produced by the green stream save-all and the sludge from the red-stream DAF unit. Due to some inadvertent cross-over of the red and green stream drain lines as a result of occasional blockages in side-by-side open culverts in which these streams run, the green stream and red stream feeds to the waste water treatment system often contain elements of both stream types. Prior to being fed to either the DAF or the save-all, the red and green streams are each run through an inclined rotary screen. The feed to the DAF ranges from approximately 38-45°C, the pH is adjusted and then undergoes flocculation through two-stage polymeric addition in order to enhance the DAF performance. The sludge produced by the DAF is stored in an insulated holding tank prior to being processed within the three-way decanter.

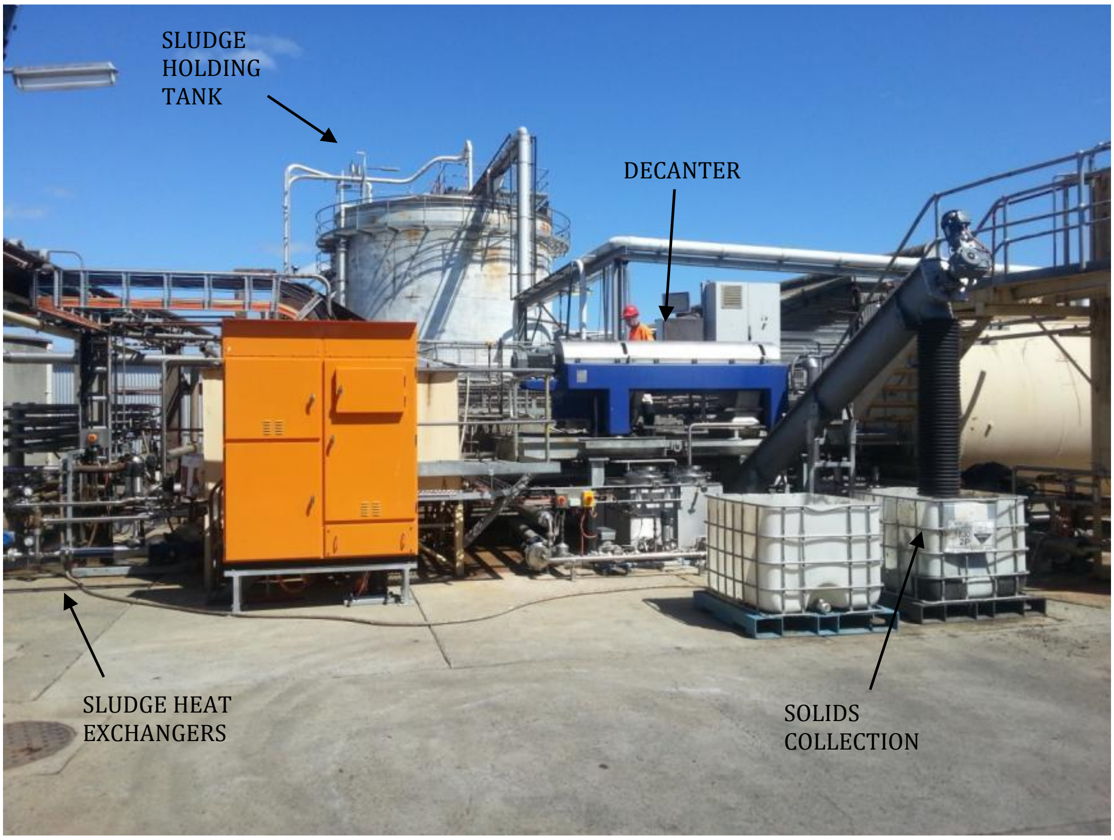


Figure 8. Longford three-way decanter installation

Decanter Installation: The decanter installation includes a single three-way decanter each with a nominal 4 m^3/hr maximum throughput. To ensure optimum separation efficiency the decanter are normally run at approximately 2 m^3/hr. Prior to processing within the decanter, the sludge is pre-heated to the production set point (95°C) by first passing it through a tube-in-tube heat exchanger (which is heated by the centrate recycle) and then through a second tube-in-tube heat exchanger which is heated by steam.

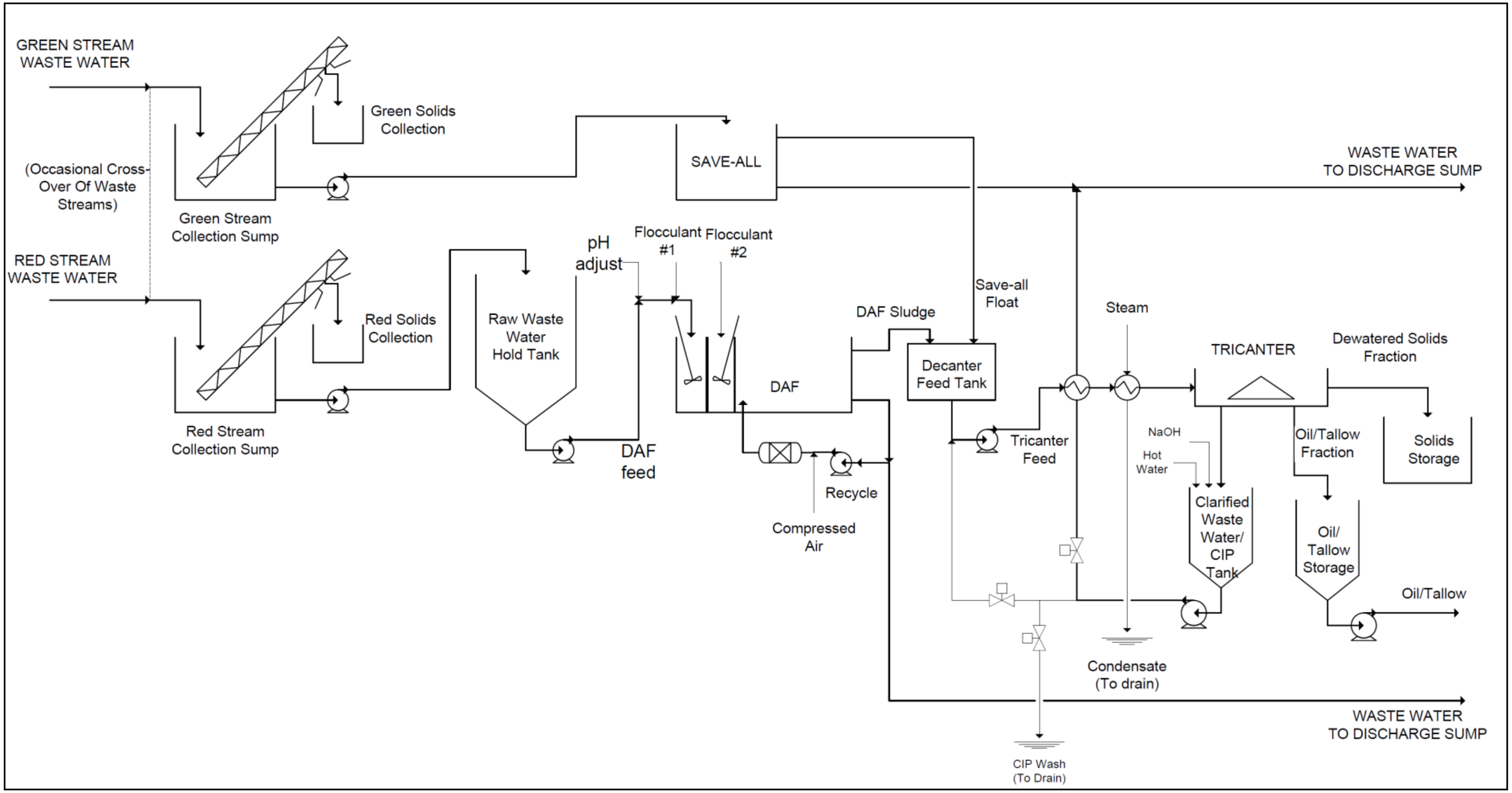


Figure 9. Process flow schematic for Longford waste water treatment system following decanter installation

The decanter is located on a raised platform in an open area adjacent to the existing save-all and DAF unit (see Figure 8). Solids are discharged by gravity to a collection bin below and are then conveyed to 1 m^3 open-topped intermediate bulk tanks (IBCs) via screw conveyor where they can then be loaded onto truck for transport offsite. FOGs from the process are discharged into a buffer tank before being pumped across to a larger tallow storage tank, ready for further processing. Centrate from each decanter is discharged into a buffer tank below the decanters and then through the preheat tube-in-tube exchangers - recovering some of its thermal energy – and then mixed with the waste water from the save-all for disposal. Figure 6 provides a block flow diagram for the decanter installation.

A clean-in-place system allows for regular flushing and chemical cleaning of process lines in order to avoid blockages and degradation of process equipment.

Figure 10. Dewatered decanter solids

System Performance: The decanter system described was commissioned in February 2014 and operates 15-17 hrs/day for approximately 250 days per year. The solids produced by the system are low in moisture and have a high nutrient content. They are currently being given away as a compost additive. The tallow produced is generally good quality and currently sold as is.

Lessons Learned:

1. A roof over the tricanter installation would be beneficial to provide all-weather shelter for operations staff.
2. Use gate or full bore ball valves instead of butterfly valves. The butterfly valves cause solids (i.e. paunch, hair, plastics) to collect and build up, eventually leading to blockages in the line.

3. System requires sound operator training to run smoothly. It would be easier to operate if there were a couple more automated set points to regulate the decanter operation depending on the nature of the feed properties.

Installed Cost: Approximately $0.8 million.

Estimated Payback: At the time of writing, the site was in the process of negotiating off-take agreements for the solid and tallow products. The value of these outputs was therefore to be established. Assuming that the value of the products is the same as those realized as the Brooklyn site, however, the simple payback for the project is likely to be longer due to certain economies of scale – both in terms of higher ratio of capital cost to decanter throughput as well as higher ratio of labor cost to throughput (due to the similar operator requirements for small systems as for large systems). As noted previously, however, the decanter installation is driven by larger site-wide process improvements which aim to strengthen the site's waste water treatment systems, lead to significant savings in trade waste charges and help to "future-proof" the business against anticipated increases in waste disposal costs.

5.3 Case Study 3 – Dinmore, QLD

Capacity: 3,700 head per day (cattle).

Site Particulars: The Dinmore processing site is located approximately 10 km east of Ipswich. The Bremer River runs along its northern boundary while the Warrego Highway/M2 runs east-west approximately 500 metres to the south. Green buffer zones surround the site, however, there is residential housing on the northern side of the river (200 metres from the main facility) and to the south of the highway. The site is not space constrained but, due to its proximity to nearby housing, there is sensitivity regarding odors associated with both the processing operations and any waste composted on adjacent land. The site's waste water treatment facility includes three large covered anaerobic lagoons (CALs) and aeration ponds. Waste water discharge quality to the Bremer River is closely monitored.

Key Project Drivers: The primary driver for the installation of a three-way decanter was to ensure maximum removal of FOGs and other floatable solids from waste water entering the CALs. FOGs and other floatable solids tend to form a scum on the surface of the anaerobic ponds and hinder their effectiveness. The CALs provide both biogas for the facility and an important step in the waste water treatment process. Their smooth performance is therefore critical to plant operations and profitability. Additional benefits of the project were the reduction in volume of solids requiring off-site disposal and the production of a concentrated oil/tallow stream which may be able to provide further revenue for the facility.

Sludge Details: The sludge processed by the three-way decanter is a combination of the floats produced by red and green stream save-all and the sludge produced following DAF treatment of the underflow from the red-stream save-all. Prior to being fed to the save-alls, the red and green streams are each run through an inclined rotary screen and then a rotary drum filter. A typical maximum particle size is 10 mm but occasionally larger material such as plastic throat plugs pass all the way to the DAF and save-alls and therefore end-up in the tricanter feed.

The feed to the DAF ranges from approximately 40-45 °C. The pH is not adjusted and the feed undergoes a two-stage aggregation process through addition of coagulants/flocculants in order to enhance the DAF performance. The sludge produced by the DAF and save-alls is stored in a 30 m^3 holding tank prior to being processed within the three-way decanter.

Decanter Installation: The decanter installation includes a single three-way decanter with a nominal 10 m^3/hr maximum throughput. To ensure optimum separation efficiency the decanter is normally run at approximately 8 m^3/hr. Prior to processing within the decanter, the sludge is pre-heated to the production set point (95°C) by first passing it through a tube-in-tube heat exchanger (which is heated by the centrate recycle) and then through a second tube-in-tube heat exchanger which is heated by steam (Figure 11).

Figure 11. Decanter feed heat exchangers

The decanter is located on a mezzanine within a three-sided shed. It is adjacent to a newly installed DAF unit (Figure 12). Solids are discharged by gravity to a trailer below and are periodically removed by means of tractor. FOGs from the process are discharged into a buffer tank before being pumped across to a larger tallow storage tank, ready for sale. Centrate from the decanter is discharged into a buffer tank and then pumped through the preheat tube-in-tube exchangers - recovering some of its thermal energy – before being mixed with the rest of the waste water that is sent to the CALs for further treatment. A clean-in-place system allows for regular flushing and chemical cleaning of process lines in order to avoid blockages and degradation of process equipment.

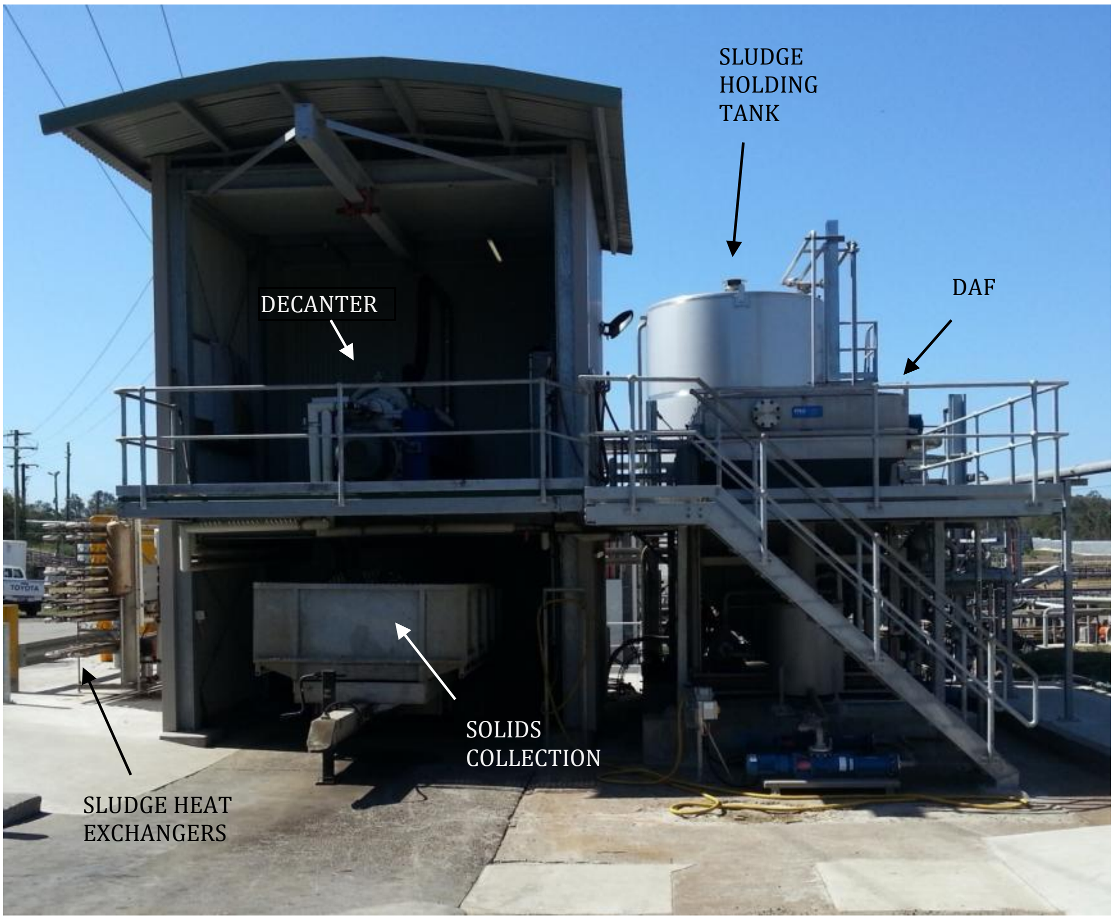


Figure 12. Decanter installation at Dinmore, QLD

System Performance: The decanter system described was commissioned in February-March 2014 and operates for approximately 6 hrs/day, 250 days a year. The usage rate is based on the amount of sludge generated. The solids produced by the system are low in moisture and have a high nutrient content. They are currently being given away as a compost additive. The tallow produced is generally good quality and currently sold as is.

Lessons Learned:

1. Occasional clogging of the sludge feed lines has occurred which has required sections of the sludge piping to be removed for access. Additional drain or flushing connections on the feed piping would therefore be useful.
2. With only one decanter installed, whenever this machine is offline for any reason the operations personnel have nowhere to store the sludge once the sludge holding tank is full.
3. A steam isolation valve close to the installation would be useful during cleaning or process upsets.

4. Use gate or full bore ball valves instead of butterfly valves. The butterfly valves cause solids (i.e. paunch, hair, plastics) to collect and build up, eventually leading to blockages in the line.
5. The current process involves storing the tallow product in the final holding tank for a number of days. The extended storage time results in a reduction in tallow quality due to increased free fatty acid content.

Installed Cost: Approximately $1 million as part of larger project.

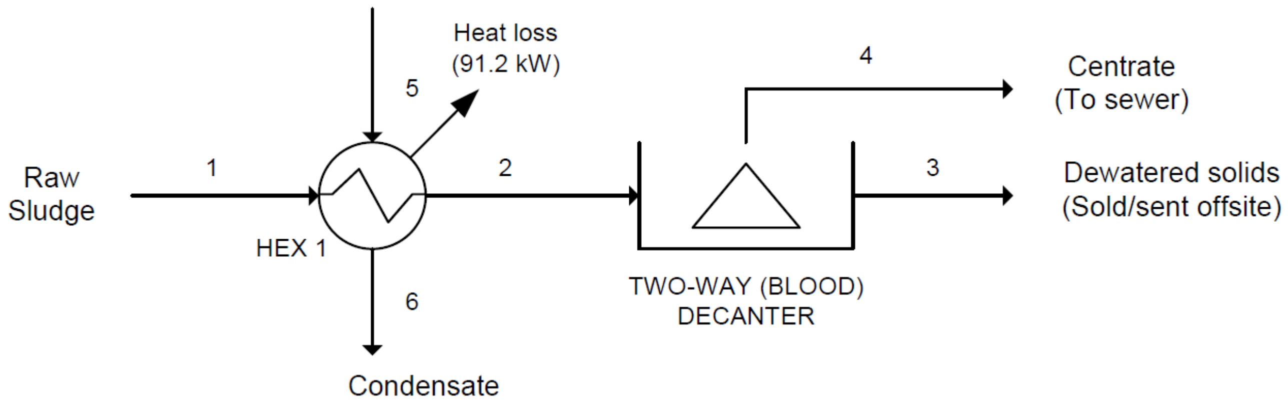
Estimated Payback: Difficult to directly quantify as the benefits of the decanter project are also tied to the performance of the larger project which also involved building covered anaerobic lagoons to further remove BOD_5, stabilise waste solids and generating biogas to augment coal-fired heat production at the site.

6.0 Cost Benefit Analysis

As a means of assisting other meat processors to assess the potential business case for installing a three-way decanter system at their site, a sample cost benefit analysis (CBA) was undertaken based on inputs for the Brooklyn (Victoria) site discussed above. This site was chosen because it was the most mature of the three case studies looked as well as having the most clearly defined inputs in terms of previous and current waste disposal costs as well as overall capital costs. That being said, there were also key process inputs that were missing – in particular, measured composition of the sludge stream to decanter and measured composition and flow rate of the decanter products – which required assumptions to be made based on literature values and those supplied as typical by vendors. The findings of the CBA conducted for the Brooklyn site are therefore not intended to be presented as a 100% accurate economic assessment of this project but rather serves to demonstrate how processors might approach assessing their own projects. As demonstrated in the case studies and other discussions presented above, it should also be noted, that a) size of the facility can play an important factor in the economics; b) location can dictate waste disposal costs and regulatory requirements and; c) simple payback periods may not be the only factor to take into account when considering a similar project.

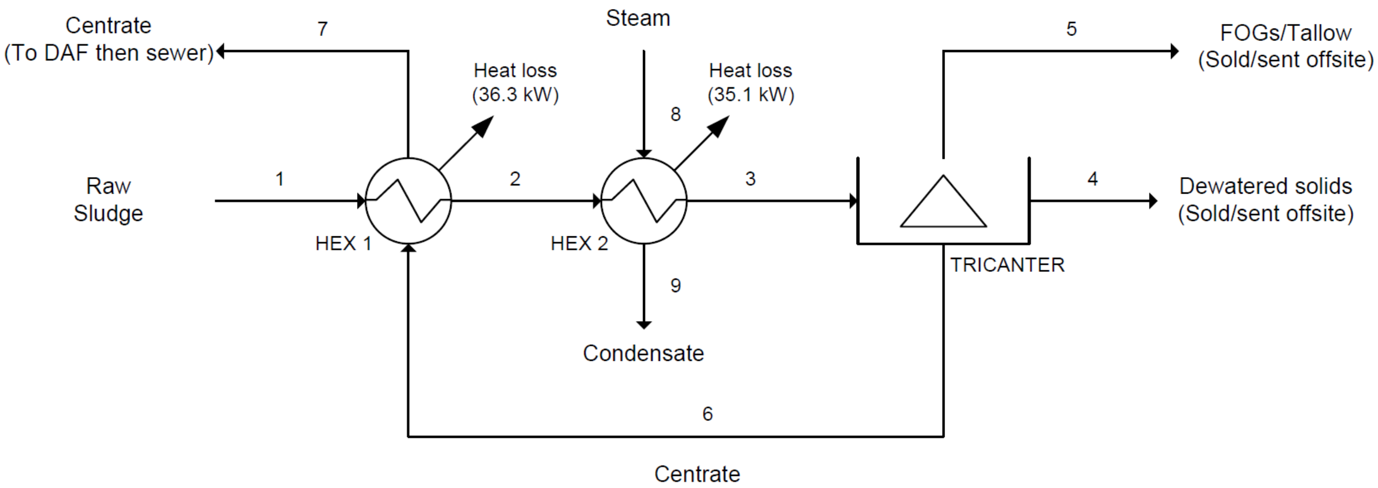
6.1 Mass and Energy Balances

In order to develop an understanding of the mass and energy flows within the sludge dewatering processes at the Brooklyn site before and after the installation of the three-way decanter, approximate mass and energy balances and block flow diagrams were developed for both scenarios. Results are presented in Figure 13 and Figure 14 below.



Stream No.		1	2	3	4	5	6
Description		Raw Sludge	Heated Sludge	Dewatered Solids	FOGs/ Tallow	Steam In	Condensate
Total Flow Rate	kg/hr	8,000.0	8,000.0	594.3	7,405.7	911.5	
Biomass Flow Rate	kg/hr	520.0	520.0	208.0	312.0		
FOGs Flow Rate	kg/hr	240.0	240.0	23.8	216.2		
Water Flow Rate	kg/hr	7,240.0	7,240.0	362.5	6,877.5		911.5
Steam flow rate	kg/hr					911.5	
Temperature	°C	38.0	90.0	90.0	90.0	179.9	179.6
Enthalpy Flow	kW	335.3	794.1	49.2	744.9	702.9	193.1

Figure 13. Illustrative mass and energy balance for sludge dewatering process at Brooklyn site prior to installing three-way decanter



Stream No.		1	2	3	4	5	6	7	8	9
Description		Sludge Feed	Pre-heated Sludge	Heated Sludge	Dewatered Solids	FOGs/ Tallow	Centrate Recycle	Cooled Centrate	Steam	Condensate
Total Flow Rate	kg/hr	8,000.0	8,000.0	8,000.0	1,114.3	344.0	6,541.7	6,541.7	352.3	
Biomass Flow Rate	kg/hr	520.0	520.0	520.0	390.0	0.7	129.3	129.3		
FOGs Flow Rate	kg/hr	240.0	240.0	240.0	44.6	180.0	15.4	15.4		
Water Flow Rate	kg/hr	7,240.0	7,240.0	7,240.0	679.7	0.7	6,559.6	6,559.6		352.3
Steam flow rate	kg/hr								352.3	
Temperature	°C	38.0	74.9	95.0	95.0	95.0	92.0	45.0	179.9	179.6
Enthalpy Flow	kW	335.3	660.9	838.2	97.4	9.6	708.1	346.4	271.7	74.6

Figure 14. Illustrative mass and energy balance for sludge dewatering process at Brooklyn site when utilizing three-way decanter

Table 1. Mass and energy balance inputs and assumptions

DESCRIPTION	VALUE	UNITS	SOURCE/REFERENCE
Decanter feed			
Total flow	8,000	L/hr	[19]
Starting solids concentration	6.5	wt%	[9, 19]
Starting FOGs concentration	3.0	wt%	[9, 19]
Decanter splits			
Solids fraction	13.93	wt%	Calculated
FOGs fraction	4.30	wt%	[9]
Centrate	81.8	wt%	[9]
Dewatered solids			
Solids capture	75	wt%	[19]
Solids Concentration	35.0	wt%	[9]
FOGs	4.0	wt%	[9]
FOGs/Tallow			
FOGs capture	75	wt%	[19]
Solids concentration	0.2	wt%	[9]
Water concentration	0.2	wt%	[9]
Specific heat capacity			
Water	4.181	kJ/kg.°C	[24]
FOGs	2.001	kJ/kg.°C	[2]
Biomass	1.95	kJ/kg.°C	[25]
Steam/Condensate properties			
Pressure of steam	1000	kPa abs	Assumed
Temperature of saturated steam at assumed pressure	179.9	°C	[26]
Specific enthalpy of saturated steam at assumed pressure	2776	kJ/kg	[26]
Specific enthalpy of vaporisation at assumed pressure	2013.4	kJ/kg	[26]
Specific enthalpy of condensate at atmospheric	762.6	kJ/kg	[26]
Temperature of condensate at atmospheric	179.6	°C	[26]
Recycle/HEX 1 heat losses	10	%	Assumed
Steam system losses	10	%	Assumed

6.2 CBA Inputs

Table 2. CBA inputs and assumptions

DESCRIPTION	UNITS	VALUE	SOURCE/REFERENCE
CAPITAL COSTS			
Installed cost of decanter plant	$	**$2,000,000**	[19]
PLANT AVAILABILITY			
Hours per day operational	hrs/day	16	[19]
Days per year operational	days/year	250	[19]
Max decanter throughput	m^3/hr	24	[19] 2 units at 12 m^3/hr
Typical decanter throughput	m^3/hr	8	[19]
OPERATING COSTS			
Steam Costs			
Average delivered price of power	$/kWh	0.12	Assumed
Average cost of natural gas	$/GJ	$6.00	Assumed
Efficiency of boiler	%	85%	Assumed
Absolute pressure of steam	kPa	1000	Assumed
Specific enthalpy of vaporisation at design P	MJ/t	2013.4	[26]
Total line losses		10%	Assumed
Approx cost to produce steam	$/t	$15.63	Calculated
	$/GJ	$7.76	Calculated
Approx Steam requirements	kg/hr	800	[20] 100 kg steam/1000 kg sludge
Steam Costs	$/hr	$6.21	Calculated
	$/t (sludge)	$0.78	Calculated
	$/yr	**$24,847**	Calculated
Waste disposal costs			
Effect of BOD load on trade waste charge	$/kg	0.9619	[27]
Effect of SS load on trade waste charge	$/kg	0.5212	[27]
Effect of N load on trade waste charge	$/kg	1.8511	[27]
Previous cost of solids disposal	$/t	$40.00	[27]
Current cost of solids disposal	$/t	-$10.00	[27] Neg value indicates revenue.
Change in cost of solids disposal	$/t	$50.00	Calculated
Sale price of tallow	$/t	$50.00	[19]
Tallow production	kg/hr	344	Calculated
Change in dewatered solids production	kg/hr	1,114	Calculated
Approx. BOD reduction	kg/hr	368	
Approx. SS reduction	kg/hr	183	
Approx. TKN reduction	kg/hr	0.7	
Savings from BOD reduction	$/yr	**$1,415,45**	

		5	
Savings from SS reduction	$/yr	**$380,867**	
Savings from TKN reduction	$/yr	**$5,140**	
Annual revenue from tallow	$/yr	**$222,857**	
Annual savings/revenue from solids	$/yr	**$222,857**	
Energy Demand of Decanter Plant			
Typical decanter Energy Requirements	kW	40	[28]
Decanter Feed Pump Power	kW	7	Rough calculation
Centrate Pump Power	kW	1	Rough calculation
Total (approx.) power requirement	kW	48	Calculated
	Kwh/yr	192,000	
Total (approx.) cost of power	$/yr	**$23,040**	
Personnel requirements			
FTE required		1	[19]
Average Labour Rate (inc. on-costs etc)	$/hr	$65.00	Assumed. Includes on-costs.
Approx. annual labour cost	$/yr	**$260,000**	
Maintenance Requirements			
Assumed % of capital cost	%	3%	Assumed
Approximate maintenance costs	$/yr	**$60,000**	
TOTAL OPERATING COSTS	**$/yr**	**$367,887**	
REVENUE/SAVINGS	**$/yr**	**$2,247,177**	
NET POSITION	**$/yr**	**$ 1,879,290**	

6.3 Indicative CBA Assessment of Brooklyn Decanter Project

Table 3. Indicative CBA assessment of Brooklyn decanter project

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Costs	Capital Costs	$ 2,000,000									
	Operating Costs		$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887
	Total costs	$ 2,000,000	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887	$ 367,887
Revenue	Total savings/revenue as a result of project		$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139
	Total revenue	$ -	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139	$ 2,145,139
	Net position (cash flow/savings)	-$ 2,000,000	$ 1,777,252	$ 1,777,252	$ 1,777,252	$ 1,777,252	$ 1,777,252	$ 1,777,252	$ 1,777,252	$ 1,777,252	$ 1,777,252
	PV factor	100%	93%	87%	82%	76%	71%	67%	62%	58%	54%
	PV of cash flow	-$ 2,000,000	$ 1,660,983	$ 1,552,321	$ 1,450,767	$ 1,355,857	$ 1,267,156	$ 1,184,258	$ 1,106,783	$ 1,034,377	$ 966,707
	Cumulative PV	-$ 2,000,000	-$ 339,017	$ 1,213,304	$ 2,664,071	$ 4,019,928	$ 5,287,085	$ 6,471,343	$ 7,578,126	$ 8,612,503	$ 9,579,210
	Discount rate	7%									
	Effective lifetime of plant	10 yrs									
	Net Present Value	$8,952,533									
	Internal Rate of Return	89%									
	Discounted Payback Period	1.20 yrs									

Note: Escalation of operating costs in terms of rising electricity, natural gas and labor prices has not been considered in this example. Neither has escalation of waste disposal charges or selling price of tallow or dewatered solids. Given that increases in waste disposal charges have tended to outstrip energy and labor price increases in recent years it is possible that the CBA assessment provided is relatively conservative.

6.4 Breakdown of Relative Cost and Savings/Revenue Sources

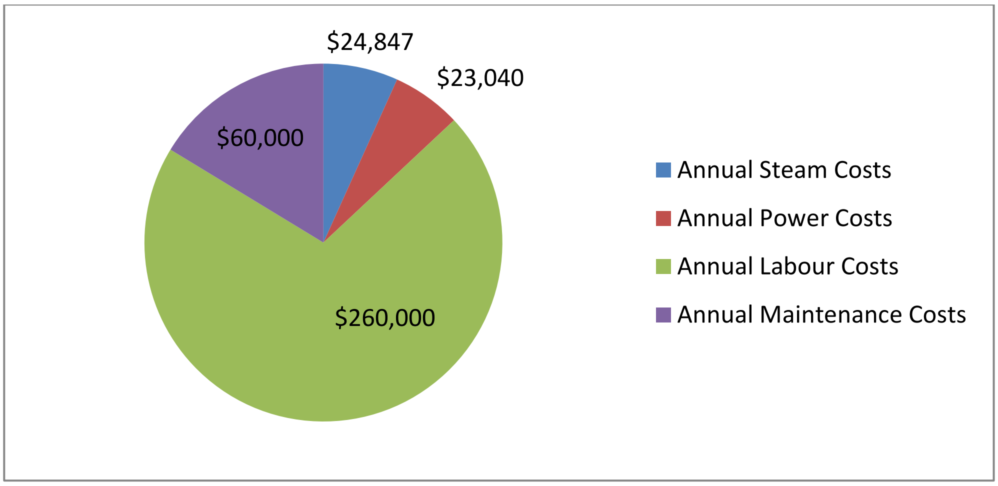


Figure 15. Illustrative breakdown of annual operating costs associated with decanter project

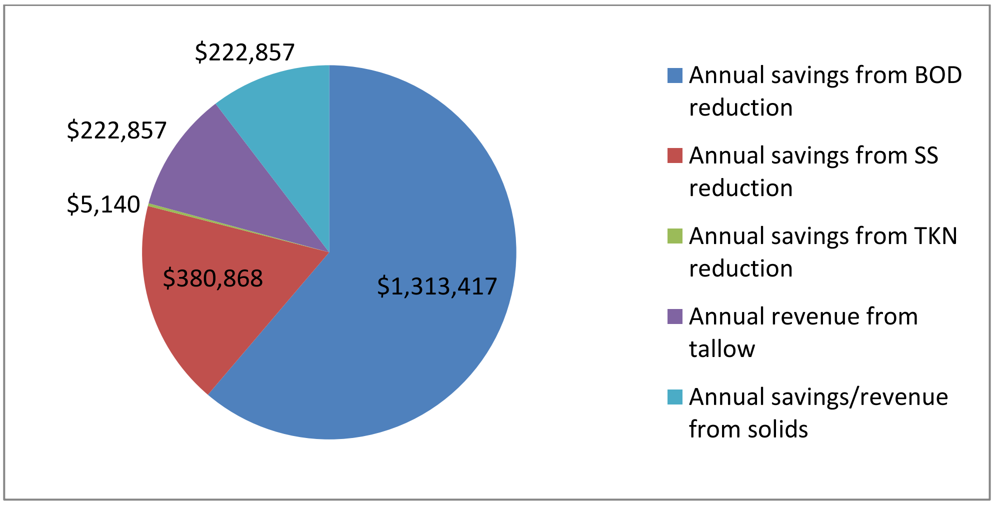


Figure 16. Illustrative breakdown of annual savings/revenue sources associated with decanter project

7.0 Conclusions

A process and cost-benefit analysis review of the use of three-way decanters for managing waste water treatment sludge produced at Australian red meat processing facilities provided the following insights:

- Three-way decanters provide a means for separating the sludge into three nominal fractions; dewatered solids, tallow and clarified waste water;
- The immediate value of three-way decanters are their ability to divert the tallow component from being discharged to trade waste or sent to secondary treatment processes. Given that the tallow results in a large contribution to the BOD_5 load within the waste water sent to sewer (Approx. 1.5-1.7 kg (BOD_5)/kg (tallow)) this can result in a substantial saving for the processor in terms of costs associated with trade waste disposal;
- The decanters systems work most effectively when the sludge is pre-heated to approximately 90-95°C. The pre-heating can be achieved more economically by using waste heat in the clarified waste water to bring the sludge up to an intermediate temperature followed by steam heating of the sludge to achieve the final required feed temperature. This approach also facilitates cooling of the clarified waste water, allowing it be recycled through the DAF or combined with the bulk waste water flow;
- The high feed temperature required for decanter operation also results in a degree of pasteurisation of the sludge. This element of the process has the potential to:
    - Improve the categorisation of the solids produced with respect to the environmental regulators;
    - Increase the number of composting sites capable of receiving this waste.
    - Decrease the associated disposal costs;
    - Provide revenue from the dewatered solids produced as a nutrient-rich compost additive.
- The regulatory environment around handling/disposal of dewatered solids from meat processors remains relatively complex but there appear to be current opportunities, particularly within Victoria, to provide input to the regulatory framework being developed/clarified and to demonstrate the value of the three-way decanter process for improving the quality of the solids produced. Such engagement should hopefully lead to a better understanding between the two groups regarding their relative position with respect to disposal of meat processing solids;
- Correctly implemented, three-way decanter systems can result in very short payback periods and substantially improved environmental performance at Australian red meat processing sites. However, it was also noted that business case for such projects is highly site specific and that a) size of the facility can play an important factor in the economics – typically the larger the more favourable a

similar project is likely to be, b) location can dictate waste disposal costs and regulatory requirements and, c) simple payback periods may not be the only factor to take into account when considering a similar project. Meat processors should therefore carefully evaluate the opportunity based on their own site conditions.

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