ELIMINATION OF DAF SLUDGE DISPOSAL
THROUGH RESOURCE RECOVERY

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ABSTRACT

A common approach to wastewater pretreatment in the food industry is the utilization of dissolved air flotation (DAF) cells. DAF units are common for BOD, TSS, and FOG reduction when wastewater is discharged to a municipal wastewater treatment plant. A growing problem for all DAF systems is that of sludge disposal. In the operation of a DAF, contaminants are removed in the form of a concentrated float, or sludge, skimmed from the surface. Because of the large volume of water in these skimmings and the increasingly stringent government regulations on their disposal, the costs associated with handling DAF sludge can be very high and are expected to get higher.

A sludge separation system currently being used at poultry, pork, and frozen food plants offers a cost effective alternative to typical landfill or land application. This system can separate the sludge into oil, water and solid components by means of heat and centrifugal force.

Fat is discharged from the system as a finished product containing 1% or less solids and moisture. Solids are recovered at typically 50-60% moisture. Separated water can be returned to the wastewater stream. Operating costs for the pretreatment plant are typically offset by selling the recovered fat to a renderer, grease processor, or stabilized and sold to a feed mill. In the case of meat or poultry processing, the recovered solids can be sold to a renderer or dried and sold to a feed mill. In addition, sludge disposal costs can be completely eliminated, turning a costly disposal problem into a profitable operation.

Actual operating and performance data from field installations are covered in this paper.
INTRODUCTION

A crucial problem facing food processors today is waste disposal. Increasing environmental pressures have prompted food processing plants to reassess their wastewater treatment practices. Both State and Federal regulations governing wastewater discharge have put increased constraints on both municipal and industrial wastewater treatment plants which discharge directly to the environment. Consequently, the municipalities have put increasingly stricter discharge limits on the major wastewater generators. Therefore, whether the wastewater generators have been discharging to a municipal wastewater treatment plant or directly to the environment, they have been forced to upgrade their wastewater treatment methods.

Pretreatment

A variety of wastewater treatment practices are utilized throughout the food industry. However, dissolved air flotation is used extensively whether the food plant is solely pretreating the wastewater before discharge to a municipality, or utilizes secondary treatment for discharge directly to the environment.

The principle function of a DAF is for reductions in Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), and Fats, Oil and Grease (FOG). As the most common pretreatment component, a DAF can typically reduce TSS and FOG by 90 to 99%. In many cases BOD can be reduced by up to 75 to 85%. However, in some cases, since the DAF's principle of operation is through flotation, streams containing high levels of soluble BOD may only be reduced by 10-40%.

Although the most effective DAF units are those utilizing high flow technology, all units operate on the same principles. Raw plant wastewater is screened and pumped to the DAF where a chemical coagulant is used to initiate solids agglomeration prior to injection to the DAF. Air is then dissolved in the water, under pressure, just before the addition of a chemical flocculant. After addition of the flocculant, which is used to create large particles which are easy to float, the water is pumped into the DAF. Here small air bubbles are released into the water due to the drop in pressure. The small air bubbles adhere to the flocculated solids and fat and rise to the surface of the DAF. The solids, or sludge, are then removed by means of a mechanical scraping device.

A properly designed/sized DAF will typically discharge a wastewater stream containing 300 mg/l or less TSS and 100 mg/l or less FOG. Installations with low fractions of soluble BOD can typically discharge a wastewater stream with 300 mg/l or less BOD. A well designed screening, DAF, and chemical system is usually adequate for reduction and/or elimination of surcharges when discharging to a municipality. However, an unwanted by-product, sludge, is created in the treatment of the wastewater by dissolved air flotation.
Sludge Disposal Problem

The volume of sludge generated will vary with the plant, type of DAF and its operation. On poorly designed or poorly operated units, the total volume of sludge can be 3% or more of the total wastewater flow. For a plant discharging 1 MGD this would represent 30,000 GPD of sludge to be disposed of in some way. In these cases the sludge will typically contain in excess of 95% moisture. In reality, the plant is obligated to pay for disposal of a by-product which is almost all water.

On more efficiently designed DAF units, with an effective chemical program, sludge production will typically be between 1-2% of the total wastewater flow. This alone can result in a sludge volume reduction of 33 to 66% which will also result in significant savings in disposal costs.

One of the more popular routes for sludge disposal in the past, especially for the meat and poultry industries, has been rendering. Several problems in processing this sludge have resulted in a significant reduction in the number of renderers willing to take DAF sludge. Since the sludge will typically contain 90-97% moisture, versus offal which is at 67% on average, the evaporation cost for the DAF sludge is usually prohibitive. In addition, many renderers feel that the combination of high moisture and polymers contained in the sludge will cause a coating problem in the cookers which inhibits heat transfer and increases the cost of processing. Sludge age is also another factor that creates both processing and cost problems for the renderer. After 24 hours of standing, raw DAF sludge undergoes a dramatic increase in Free Fatty Acids (FFA) of the fat and overall rancidity of the sludge.

More recently, the few renderers who still process DAF sludge require that the sludge be less than 24 hours old and that producers pay a dewatering charge for sludge containing a moisture level in excess of 80%. This has forced many producers to search out other methods of disposal.

One alternative that has been used in place of rendering is land application. Typically the processor, through an agreement with local farmers, or though utilization of their own land, will either apply the sludge to the surface of the land at agronomic rates or blend surface spread sludge with the soil. In addition to the associated cost of this disposal method, stricter environmental laws are limiting this approach. Industry experts predict that this disposal route will soon be eliminated altogether. Other considerations such as odor problems and over the road spills, can present major public acceptance issues. Except in the most remote installations, this can be a liability that can have costly ramifications.

A second alternative is that of sub-soil injection. Rather than spreading the sludge and tilling it (land application), sub-soil injection uses equipment to inject the sludge just under the soil surface. This method curbs aesthetic concerns, conserves nutrients, and controls odor problems. While sub-soil injection is preferred in more densely populated areas, its cost is higher than land application.

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In regions where land application is not viable, or when the intrinsic nutrient level is low (frozen food plants), landfill or composting are usually the only alternatives. Tipping fees at the disposal site will vary widely by region. However with the increasing number of landfills being permanently closed, the cost of this disposal route is expected to rapidly escalate. In the long term there appears to be a limited future for this alternative.

In reviewing the common practices for DAF sludge disposal, there is no method that particularly stands out as a desirable solution. For each practice, the disposal cost is high and growing and valuable recoverable resources are lost in the DAF sludge. In addition, for all the common practices other than rendering, potential liabilities from such things as haulage spills and improper disposal are a constant threat. Clearly, the food industry is in need of a long term and cost effective management option. Part of the solution is to recognize that much of the "waste" sludge actually has nutrient and by-product value. Recovering salable by-products would not only reduce or eliminate disposal costs but could provide a revenue stream to help offset the costs of operating the wastewater plant.

A PROVEN SYSTEM FOR RESOURCE RECOVERY

In 1985 a division of Bird, Inc. began field studies for a new alternative to DAF sludge disposal. Preliminary laboratory studies had indicated that a combination of heat and centrifugal force could break down sludge into three principle components: oil, water, and solids. Further analysis indicated that the protein values of the solids from meat and poultry processing plants offered the possibility of recovering the material for animal feed.

The system, as developed for commercial utilization, is shown in Figure 1. DAF sludge is pumped to a heat tank where it is heated by means of direct injected steam. After a minimum residence time, the heated sludge is pumped to a 3-phase centrifuge. The centrifuge splits the sludge into three distinct components; oil, water, and solids under a centrifugal force of approximately 3,000-4,000 times that of gravity.

![3-Phase Separation System](image)

**FIGURE 1.** 3-Phase Separation System

The heart of the system is the 3-phase centrifuge. Using centrifugal principles, the design of the centrifuge increases the settling velocity of a particle within the bowl to
several thousand times that of a particle in a simple gravity settling tank. A cross-sectional view of the 3-phase centrifuge is shown in Figure 2. Basically, the unit can be described as a horizontal scroll-type centrifuge featuring continuous solids discharge as well as the separation and discharge of two liquids. The bowl can be broken down into two sections: the cylindrical or clarifying section, and the conical or dewatering section.

**FIGURE 2. Principles of 3-Phase Centrifugal Separation**

Feed slurry is introduced through a stationary feed pipe located at the axis of rotation. The slurry is brought up to full rotational speed in an acceleration chamber and distributed through feed ports to the inner diameter of the cylindrical bowl. At this point the slurry begins to separate at centrifugal forces equivalent to 3,000-4,000 times that of gravity. The higher specific gravity solids settle against the bowl wall while the liquids of lower specific gravity form concentric layers in the bowl.

Settled solids are conveyed to the conical section of the bowl where they are dewatered as they are carried out of the liquid pool. The lighter liquid (oil) floats to the surface of the pool and is discharged over an adjustable weir. The heavier liquid (water) is discharged through an internal pump at a larger radius than the oil overflow. On-line adjustment of the water discharge radius insures independent discharge of two distinct liquid phases without intermixing.

**TYPICAL RESOURCE RECOVERY PRETREATMENT SYSTEM**

A typical pretreatment process utilizing Bird Environmental 3-phase separation technology, is shown in Figure 3. Wastewater from the plant is screened, treated with chemicals and pumped to the DAF unit. The flocculated solids and the oil and grease float to the surface of the unit and form a sludge. The clarified water stream is discharged as the underflow from the unit. Typically this underflow is discharged directly to a municipal wastewater treatment system or depending on the plant’s flow scheme can be discharged to an additional on-site biological treatment system. The flotation sludge is removed by means of a mechanical scraping device and is discharged into a sludge compartment. This sludge typically contains 85 to 95% moisture, 4 to 10% solids, and 1 to 6% fats, oil, and grease.
The DAF sludge is then pumped to a heat tank where the sludge is heated to approximately 180-200°F. Once heated, the sludge is pumped to a 3-phase centrifuge which separates the sludge into three phases or streams; fat, solids, and water.

The first is a clarified fat stream which is discharged from the centrifuge by gravity at typically less than 0.5% moisture and 0.5% or less insolubles. This fat product can be sold to a yellow grease processor or renderer or stabilized and sold directly to a feed mill.

The second stream consists of solids which have been separated and dewatered in the centrifuge. These dewatered solids are typically discharged at from 45 to 65% moisture depending on the wastewater treatment operation and the type of food plant. The solids can be added to the plant’s offal and sold to a renderer or further dried, and sold to a feed mill. In cases where the solids have a low nutrient level, such as solids from a frozen food plant, the dewatered sludge is hauled to a landfill or composting facility.

The final stream produced by the centrifuge is the clarified water stream (tailwater) which is recycled back to the head of the DAF system or discharged directly to biological treatment depending on the application and the wastewater plant’s flow scheme. This can be accomplished without causing any upsets to the wastewater treatment and without any additional costs or special processing.

**ECONOMICS**

A typical mass balance for the 3-phase centrifuge processing 1 MGD of wastewater at a poultry plant is shown in Figure 4. This mass balance shows that when processing 60 tons/day of raw DAF sludge the centrifuge produces 10 tons/day of dewatered solids and 2.42 tons/day of clarified fat. Since both the clarified fat and the dewatered solids have value as revenue producing by-products, a poultry plant, by recovering these
resources, can both reduce or eliminate its sludge disposal cost and produce revenues to help offset its operational costs.

![Diagram](image)

**FIGURE 4.** Typical 3-Phase Centrifuge Mass Balance for Poultry Application

Based on the data from the material balance, a typical economic analysis was developed for a 1 MGD poultry wastewater plant and is given in Table 1. This analysis shows that for a 1 MGD wastewater flow, the DAF system produces approximately 15,000 gallons of sludge per day. Based on a 24 hour day, a 5 day week, and 50 weeks per year, the annual sludge production figure is 3.75 million gallons. Using this annual sludge production, three methods of disposal: land application; subsoil injection; and rendering were evaluated in this analysis. Although disposal costs vary from one region of the country to another, the typical poultry industry disposal costs range from 5¢ to 6¢ per gallon of sludge for land application and approximately 8¢ per gallon for subsoil injection. The majority of the rendering facilities throughout the country will not accept raw DAF sludge. However, the few that do, charge from $4 to $5 per 1,000 pounds of sludge.

Using the average cost for each disposal method and the 3.75 million gallons of sludge production, the analysis shows an annual sludge disposal cost of $206,250 for land application, $300,000 for subsoil injection, and $135,000 for a rendering facility. These figures show that whether the poultry plant uses land application, subsoil injection, or a rendering facility, the disposal cost of DAF sludge is already very expensive and industry predictions are that it will become increasingly more expensive with each passing year.

The Bird Environmental DAF sludge separation system can solve this costly sludge disposal problem by eliminating this disposal cost and generating new revenue for the plant through resource recovery. Based on the mass balance and the economic analysis, the system will produce 161,250 gallons (3,225 gallons per week) of clarified fat every year which creates new income opportunities for the plant. The poultry plant can sell this fat to a renderer or a yellow grease processor for an average price of 3.5¢ per pound and generate $42,328 per year. If the plant chooses to stabilize this fat by heating and adding an antioxidant, it can generate a revenue of $129,731 per year by selling it to a feed mill.

Recovered solids also present an opportunity to generate revenue. Based on the
mass balance and the economic analysis, the system will produce 5 million pounds of solids per year. Since these solids are at 58% moisture and offal is at 67% moisture, these solids can be mixed with the plant’s offal and sold to a renderer for an average sell price of approximately 2.75¢ per pound. This will generate an income stream of $137,500 per year. With additional processing, drying to 4% moisture, the poultry plant can sell these solids to a feed mill for use in the production of a poultry grade meal. Based on a price of $275 per ton for poultry meal and a $21,060 annual cost for evaporation, the plant can generate $279,721 per year in revenue.

To summarize what this will mean to the poultry wastewater plant in terms of annual savings versus the first year investment for a Bird Environmental DAF sludge separation system, two plant operational methods were evaluated in the analysis. The first method assumes the poultry plant was using land application for DAF sludge disposal and will sell both the clarified fat and dewatered solids produced by the system to a rendering facility. This is a conservative profile and shows a total annual savings of approximately $386,000.

The second method assumes the poultry wastewater treatment plant was disposing of its DAF sludge by subsoil injection and will sell both the clarified fat stream and the dewatered solids stream from the system to a feed mill. This profile shows a total annual savings of approximately $709,400.

Therefore, depending on how the poultry wastewater plant was disposing of its DAF sludge, and how its chosen to sell both the clarified fat stream and the dewatered solids stream from the system, the plant’s total annual savings can range from approximately $386,000 to $709,400.

When these figures for total annual savings are compared to the total first year investment of $307,600, which includes the capital expenditure plus operations and maintenance, it is clear to see how the economics for a resource recovery approach to the problem versus a disposal approach begins to make sense. It is important to note that this comparison is between total annual savings and first year investment. In subsequent years the plant’s only cost will be for operation and maintenance making the plant’s annual return on its investment even more attractive.

It should be pointed out that the option of having the plant dispose of its sludge to a rendering facility was not included in the analysis. The reason for this is that the majority of the rendering facilities will not accept raw DAF sludge and therefore, this would not be a viable option for some plants. However, if the plant’s annual cost of disposing of its DAF sludge to a rendering facility, $135,000, is substituted for the land application cost in method 1, the total annual savings would be approximately $314,800. Even in this conservative case, the economics of the Bird Environmental DAF sludge separation system are attractive.
TABLE 1 - ECONOMIC ANALYSIS

**Typical Poultry WWTP**

- **Plant Flow (Wastewater):** 1.0 MGD
- **DAF Skimmings (Sludge) Production:** 15,000 Gals/Day
- **Skimmings (Sludge) Composition:**
  - 87.75% Moisture
  - 5.75% Fat
  - 6.50% Solids

**Sludge Disposal Cost**

**Annual Sludge Production:**
- 15,000 Gals/Day x 5 Day/Wk x 50 Wks/Yr = 3.75 Million Gals/Yr

**A) Land Applications**
- **Cost of Sludge Disposal:** 5-6 $/Gal
- **Annual Disposal Cost:** 3.75 Million Gals/Yr x 5.5 $/Gal = $206,250/Yr

**B) Subsoil Injection:**
- **Cost of Sludge Disposal:** 8 $/Gal
- **Annual Cost Disposal:** 3.75 Million Gals/Yr x 8 $/Gal = $300,000/Yr

**C) Rendering Facility:** (Majority will not accept raw DAF sludge)
- **Cost of Sludge Disposal:** $4-5/1000 Lbs
- **Annual Disposal Cost:** 3.75 Million Gals/Yr x 8.0 Lbs/Gal x $4.50/1000 Lbs = $135,000/Yr

**Resource Recovery Revenue**

**System Oil Production**
- **Clarified Volume:** 3,225 Gals/Wk (645 Gals/Day)

**A) Sale of Clarified Oil to Rendering Facility**
- **Sales Price:** 3.5 $/Lb
- **Oil Volume:** 3,225 Gals/Wk
- **Revenue:** 3,225 Gals/Wk x 7.5 Lbs/Gal x 3.5 $/Lb x 50 Wks/Yr = $42,328/Yr

**B) Sale of Clarified Oil to Feed Mill**
- **Sales Price:** 11 $/Lb
- **Oil Volume:** 3,225 Gals/Wk
- **Gross Revenue:** 3,225 Gals/Wk x 7.5 Lbs/Gal x 11 $/Lb x 50 Wks/Yr = $133,031/Yr
Table 1 - continued

Additional Cost to Stabilize Fat:
- Heating & Cooling Cost: $700/yr
- Antioxidant Cost: $2600/yr
- Total Additional Cost: $3300/yr

Net Revenue from Sale of Oil to Feed Mill:
$129,731/yr

System Solids Production
- Solids % Moisture: 58%
- Solids Production: 10 Tons/Day

A) System Solids Added to Offal
- Sales Price of Offal: 2.75 $/Lb
- Solids Production: 20,000 Lbs/Day
- Revenue: 20,000 Lbs/Day x 2.75 $/Lb x 5 Days/Wk x 50 Wks/yr
$137,500/yr

B) System Solids Sold to Feed Mill
- Poultry Meal Sales Price: $275/Ton at 4% Moisture
- Solids Production: 20,000 Lbs/Day at 58% Moisture

20,000 Lbs/Day x 0.42% Total Solids = 8,400 Lbs/Day of Total Solids

Typical Poultry Meal is 4% Moisture

\[ \frac{8,4000 \text{ Lbs of Solids}}{0.96} = 8,750 \text{ Lbs/Day of Solids at 4\% Moisture} \]

- Gross Revenue:
  \[ \frac{8,750 \text{ Lbs/Day}}{2,000 \text{ Lbs/Ton}} \times 275/\text{Ton} \times 5 \text{ Days/Wk} \times 50 \text{ Wks/yr} \]
  $300,781/yr

Pounds Moisture to be Evaporated from Dewatered Solids to Attain 4% Moisture - 20,000 Lbs/Day x 0.54% Moisture = 10,800 Lbs/Day Moisture
- Evaporation Cost:
  10,800 Lbs/Day Moisture x 1.3 Lbs Steam/Lb Moisture = 14,040 Lbs Steam/Day

14,040 Lbs Steam/Day x 5 Days/Wk x 50 Wks/yr x $6/1000 Lbs Steam $21,060/yr

- Net Revenue from Sale of Solids to Feed Mill:
$279,721/yr
Table 1- continued

Economic Evaluation

A) Method I

Assumptions:
1) Poultry wastewater treatment plant is disposing of its DAF sludge by land application.
2) The clarified oil stream will be sold to a rendering facility.
3) The solids will be mixed with the offal material and sold to a rendering facility.

Typical Annual Savings:

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Disposal Costs</td>
<td>$206,200</td>
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<tr>
<td>Clarified Fat</td>
<td>42,300</td>
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<td>Dewatered Solids</td>
<td>137,500</td>
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<td>Total Savings</td>
<td>$386,000</td>
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</tbody>
</table>

B) Method II

Assumptions:
1) Poultry wastewater treatment plant is disposing of its DAF sludge by subsoil injection.
2) The clarified oil stream will be sold to a feed mill.
3) The dewatered solids will be sold to a feed mill.

Typical Annual Savings:

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<table>
<thead>
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<tbody>
<tr>
<td>Disposal Cost</td>
<td>$300,000</td>
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<td>Clarified Cost</td>
<td>129,700</td>
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<td>Dewatered Solids</td>
<td>279,700</td>
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<td>Total Savings</td>
<td>$709,400</td>
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C) Typical First Year Investment for Bird Environmental DAF Sludge Separation System

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<table>
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<tbody>
<tr>
<td>Capital Expenditure</td>
<td>$257,900</td>
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<td>Operation &amp; Maintenance</td>
<td>49,700</td>
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<td>Total 1st Year Investment</td>
<td>$307,600</td>
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CASE STUDIES

Since the first commercial installation in 1985, about twenty 3-phase systems have been put into service on DAF sludge dewatering. These systems are currently operating on DAF sludge from poultry, pork and frozen food processing plants. The characteristics of the sludge from each of these facilities are unique. The effectiveness of the system in processing the sludge from each type of operation is governed, to a certain extent, by the method of particle coagulation and flocculation, and the actual composition.
of the materials in the sludge (i.e. starches, manure, fine solids, coarse solids, etc.). In addition, each operation has different objectives where the system discharges are concerned. These differences exist not only between industries, but are prevalent among operations in the same industry (poultry processors).

To meet specific discharge objectives or to effectively process a variety of sludges, the Bird Environmental DAF sludge separation system must be optimized for each particular plant. In general, optimization of a plant entails a trade-off between solids dryness and tailwater clarity. That is, in cases where the major concern is maximum solids dryness an increase in tailwater solids content usually results. Similarly, operating the system to produce the cleanest tailwater discharge results in a small increase in cake moisture. Either objective can be achieved while maintaining a pure fat discharge (<1% moisture and insolubles). The examples that follow illustrate these concepts.

Table 2 is a survey of operating data from three poultry plants. In each case, the system had been optimized according to the plant’s discharge objectives. Although the method of coagulation was different for each plant, the composition of the raw sludge was relatively consistent. The data presented here illustrates how different waste streams are affected by the system technology.

At Plant 1 in table 2 the objective was to produce a dry cake and pure fat with less concern for the clarity of the tailwater. This particular plant has its own rendering facility and uses the cake discharge from the system to produce a feed grade meal. They desire high dewatering efficiency so that the solids can be dried effectively. As a result of the low daily sludge production (approximately 10,500 gallons), this plant is able to process sludge at 8 GPM and are also able to maintain a relatively clean tailwater discharge (.5 - 1.0% TSS and < 1% FOG).

The objective of Plant 2 was a compromise between the tailwater clarity and cake discharge moisture. This plant is trying to minimize the amount of solids recirculated from the 3-phase separation system back to the DAF unit while producing a cake discharge acceptable to an outside renderer. Note, that the cake moisture has increased slightly to 58% (from 55% in Plant 1), but a substantial improvement in tailwater clarity resulted. The total suspended solids were only .04% in concentration and no oil and grease was observed.

In Plant 3, although it is landfilling its solids, solids dryness is not the main concern. Since the plant’s DAF unit is not very efficient and high solids recirculation may have an effect on the discharged effluent, maximum tailwater clarity is the main objective. In order to produce tailwater with TSS and FOG levels of 0.2% and 0.4%, respectively, a cake moisture level of 70% results.

As was mentioned previously, the quality of the fat was maintained at < 1% moisture and insolubles regardless of the plant objective. Also, the free fatty acids level was below 10% in each case, which is typical for fresh sludge. It is also important to note that in each case the recirculated tailwater had no effect on the DAF operation, and discharge restrictions are consistently met.
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<th>Process Objective:</th>
<th>Dry cake, maximum fat quality</th>
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<tbody>
<tr>
<td></td>
<td>Wastewater:</td>
<td>0.7 MGD</td>
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<tr>
<td></td>
<td>Recovered Fat:</td>
<td>&lt;1% moisture and insolubles</td>
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<td></td>
<td>Cake Solids:</td>
<td>4.8% FFA</td>
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<td></td>
<td>Tailwater:</td>
<td>55% moisture</td>
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<td></td>
<td>DAF Coagulant:</td>
<td>Alum</td>
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<th>Best tailwater with dry cake &amp; good fat</th>
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<td></td>
<td>Wastewater:</td>
<td>1 MGD</td>
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<tr>
<td></td>
<td>Recovered Fat:</td>
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<td></td>
<td>Cake Solids:</td>
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<td></td>
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