USE OF COUPLED BIOLOGICAL/DISSOLVED AIR FLOTATION PROCESSES FOR TREATMENT OF FOOD AND DAIRY PROCESSING WASTEWATERS

Charles C. Ross, P.E.
G. Edward Valentine, Jr.
Environmental Treatment Systems, Inc.
1500 Wilson Way, Suite 100
Smyrna, GA 30082

ABSTRACT

Over the last ten years, there has been an increased interest in the use of dissolved air flotation (DAF) for clarifying solids from biological systems in lieu of traditional gravity clarifiers. There are advantages and disadvantages to using DAF in these applications, and there are specific design considerations in the successful implementation of the technology.

KEYWORDS

dissolved air flotation, DAF, clarification, activated sludge, industrial wastewater, food processing

INTRODUCTION

Dissolved air flotation (DAF) is a relatively common wastewater treatment technology that has been used for everything from biological solids thickening at POTWs to providing primary clarification for surface water treatment to removing suspended solids (TSS) and oil and grease (O&G) from industrial wastewater. In the U.S., the technology has primarily been relegated to providing pretreatment of industrial wastewater over the years.

However, in recent years DAF has also been proven effective in the clarification of biological solids from aerobic and anaerobic treatment systems. Most biological systems using DAF for biosolids clarification to-date have been for industrial wastewater treatment although there are some applications by municipalities for algae removal and secondary clarification of aerobic processes.

Basically, DAF can be used wherever a traditional gravity or hydraulic clarifier is used for biosolids clarification. Biological treatment systems compatible with DAF clarification include:

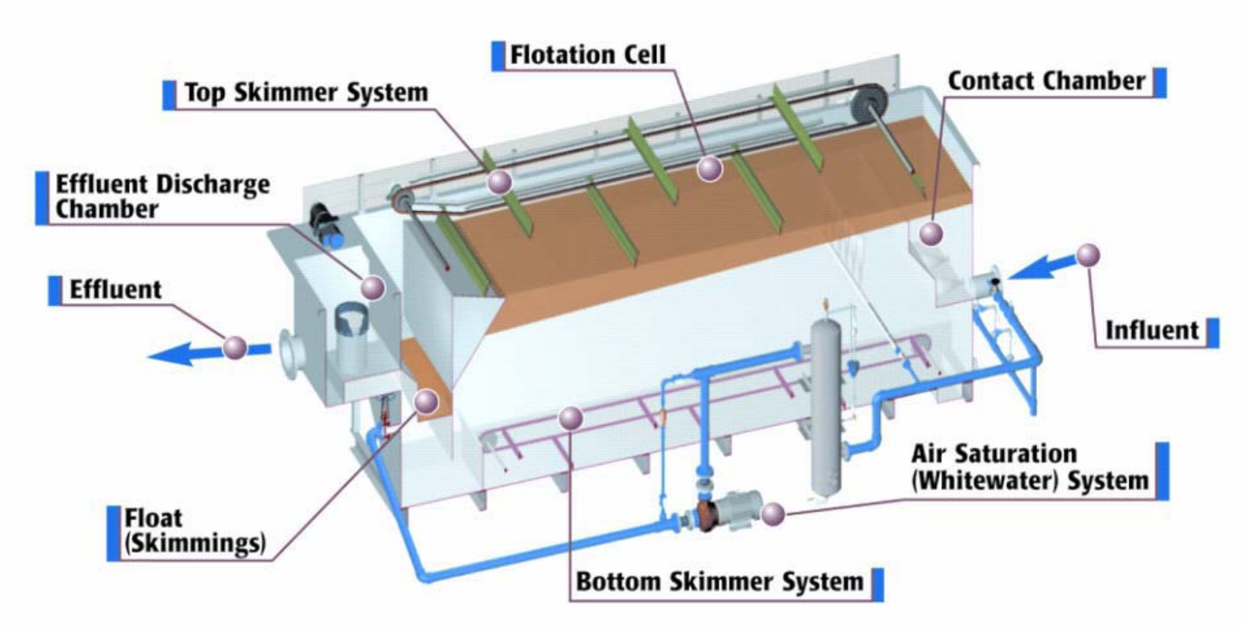
- Activated sludge
- Extended aeration
- Aerobic moving bed biological reactors (MBBR)
- Aerobic lagoons
- High-rate anaerobic systems with poor sludge granulation
- Contact anaerobic reactors
- Anaerobic lagoons

PROCESS DESCRIPTION

DAF process

DAF is a relatively simple technology that uses fine air bubbles to float attached solids particles to the surface of a flotation cell for removal from a wastewater stream. DAF units are typically circular or rectangular in shape (Figure 1) and consist primarily of a flotation cell with a float removal device (top skimmer), a bottoms settling chamber (skimmer or auger), and an air saturation or whitewater system to produce the fine air bubbles needed to float solids.

Figure 1. Typical rectangular DAF system



Comparison of DAF with gravity clarification

The main reasons for considering DAF over gravity clarification include:

- Smaller footprint. A DAF system sized for a given hydraulic and solids loading will typically take up 40-60% less space than a comparable gravity clarifier.
- Lower installed cost. Given the smaller footprint requirement, the installed cost of a DAF is typically less than a comparable gravity clarifier. However, it is generally recommended that a DAF be housed in a building or under a rain cover which may decrease the cost advantage somewhat.
- Higher mixed liquor suspended solids (MLSS). Gravity clarifiers can become rate limited when the TSS of the incoming stream exceeds 2,500 mg/L. This is not a problem for DAF systems which can handle TSS concentrations in excess of 10,000 mg/L as long as the units are designed for the solids loading.
- Bulking solids. A frequent problem with activated sludge systems, particularly those providing treatment of industrial wastewater, is the formation of bulking solids that have poor settling characteristics (Figures 2 and 3). This is a common problem with industrial treatment systems that have highly variable F:M ratios or other factors that lead to the prevalence of filamentous organisms.
- Product TSS and O&G. A DAF system is more capable of removing process TSS and O&G that may pass through a biological system, which is more common with industrial systems. Gravity clarifiers tend to have difficulty with high concentrations of O&G or product solids with poor settling characteristics.
- Higher solids sludge production. A DAF providing clarification in an activated sludge process will produce a sludge with a solids content in the 2-5% TS range. Compared to the sludge from a gravity clarifier (0.5-1.5% TS), the sludge volume generated by a DAF will typically be 1/4th to 1/10th of the volume generated by a gravity clarifier.

Figure 2. Gravity clarifier with bulking activated sludge

Figure 3. DAF clarifier with same bulking activated sludge

There are some drawbacks to using a DAF over gravity clarification:

- More energy intensive. DAF requires a high pressure pump to provide a whitewater stream (air-in-water solution) while a gravity clarifier does not require any recycle pumping or the attendant electrical usage.
- Chemical requirements. Biological solids separation requires the use of a chemical flocculent (polymer) at doses of 2-15 ppm, typically in the range of 4 ppm, while most gravity clarifiers do not normally require the use of chemical settling aids.
- More operator intensive. As indicated above, a DAF system has more mechanical components that require more operator management and maintenance. Pumps must be serviced and chemical addition must be monitored.

Design considerations

There are some basic design considerations for DAF clarification of biological solids. These are somewhat specific to the type of biological solids being clarified and the effluent quality required. For example, solids loading for a DAF treating an anaerobic effluent may be slightly different than that for an activated sludge system. Bench-scale or pilot-scale testing would be helpful in determining optimum solids and hydraulic loading rates. Also, most industrial treatment systems discharge to a POTW and are not required to provide effluent quality beyond that for normal sanitary flows.

However, typical design considerations for a DAF providing clarification in an activated sludge system include:

- Flocculation. As indicated above, DAF clarifiers typically require polymer addition to flocculate the biological particles prior to flotation. This is accomplished through the use of a flocculation tank with a mixer (usually variable speed) or a flocculation tube, a serpentine pipe with static mixing elements.
- Hydraulic loading. Most DAF systems have a hydraulic loading range of 1-5 gpm/ft^2 of actual surface area.
- Solids loading. A typical range for biological solids loading on a DAF is in the range of 3-4 lbs TSS/ft^2 of actual surface area.
- Air-solids ratio. A-S ratio of 0.0001 to 0.001 lb air/lb TSS is typically needed to float flocculated biological solids in a DAF. A variety of factors including sludge age and the flocculent used will affect the A-S needed.

CASE STUDIES

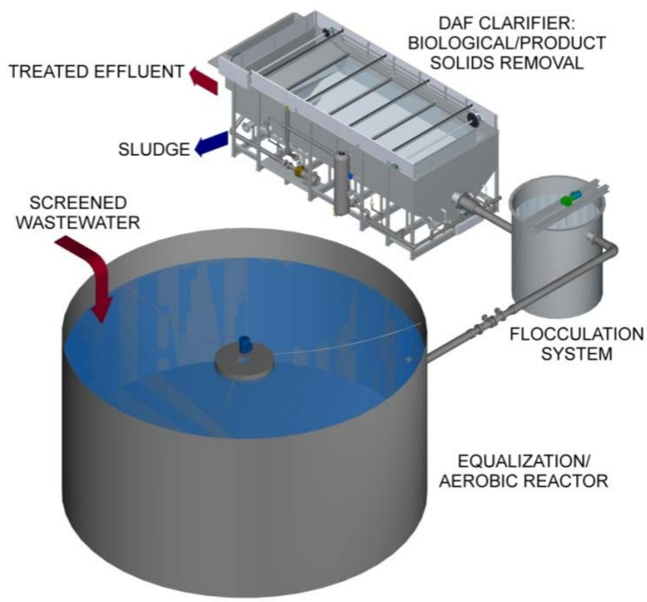
The following case studies are for industrial applications where the pretreatment system discharge goes to a POTW. The systems were designed and operated in order to provide discharge effluent quality to meet permit surcharge limits, generally in the range of untreated sanitary wastewater.

Case Study 1- Activated sludge system coupled with DAF clarification for dairy processor

A new dairy production facility needed a wastewater pretreatment system in order to meet local sewer discharge limits. The design requirements called for a system to be capable of treating BOD, TSS, and O&G concentrations of 910, 460, and 500 mg/L, respectively, with a design flow of 68,000 gpd. The system was tasked with meeting an effluent BOD, TSS, and O&G concentrations of 300, 300, and 100 mg/L, respectively. In order to reduce the operational complexity of the treatment facility, the dairy desired to provide treatment in a single process and avoid the use of pretreatment (i.e., DAF) followed by biological treatment to meet these effluent goals.

To meet this requirement, the system was designed to include fine screening to remove trash and product solids from the incoming wastewater followed by an aeration tank with a DAF to provide clarification of aerobic biological solids and product TSS and O&G that may pass through the aeration tank untreated (Figure 4). DAF was chosen for clarification since it is frequently used for the removal of product TSS and O&G , and to handle bulking biological solids that would not settle in a gravity clarifier. The aeration tank was sized to provide equalization volume to handle variability in plant flow, and the aeration system was sized to handle the combined organic loading from the incoming wastewater and the returned sludge (RAS) from the DAF clarifier.

Figure 4. High-rate activated sludge system with DAF clarifier for dairy processing facility



As indicated in Table 1, the system was able to provide the required effluent quality although the new dairy generated a BOD load up to five times the design load.

Table 1. Treatment efficiency of activated sludge/DAF system at dairy processing facility

Parameter	Aeration Tank Influent	Aeration Tank Effluent	DAF Effluent	% Removal
BOD, mg/L	1,990	na	27	99%
TSS, mg/L	750	4,000	12	99% [1]
TS, %	na	na	3	na

[1] DAF clarifier MLSS capture efficiency from Aeration Tank effluent

Case Study 2- High-rate anaerobic effluent clarification

A beverage plant was having difficulty meeting discharge permit limits on TSS while discharging effluent from a high-rate anaerobic process (UASB). The effluent from the anaerobic reactor had high concentrations of biological solids which were not being retained by the internal clarifiers in the reactor, leading to permit violations by the plant and higher COD and TSS surcharges from the municipality. Since the solids tended to float, DAF was evaluated as a means of clarification prior to discharge to the sewer.

Figure 5. Anaerobic effluent in flocculation tank

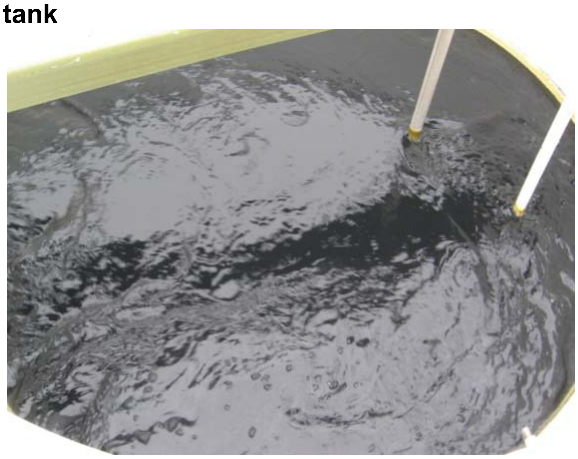


Figure 6. DAF clarifier with flocculation tank treating anaerobic effluent

After successful pilot testing, a full-scale DAF system was installed to remove the anaerobic biosolids. The anaerobic effluent was conditioned with a coagulant (ferric chloride) and flocculent (anionic polymer) in a flocculation tank (Figure 5) prior to flotation in the DAF (Figure 6). The DAF has a surface area of 100 ft^2 handling an average flow of 200 gpm.

As indicated in Table 2, the DAF successfully removed 82% of the biological solids providing an effluent quality well within permit limits. Sludge from the unit was typically in the 8% TS range and was disposed of by land application. An additional benefit was the removal of Ortho-phosphate (84%) which also reduced the plant's surcharge costs.

Table 2. Treatment efficiency of DAF clarification of anaerobic effluent

Parameter	Influent [1]	Effluent	% Removal
COD, mg/L	1,110	365	67%
TSS, mg/L	716	127	82%
Ortho-P, mg/L	92	14	84%
TS, %	Na	8	na

[1] Anaerobic system effluent

Case Study 3- Activated sludge clarification at a snack food plant

A snack food processor was required to provide additional BOD removal downstream of an existing pretreatment system in order to meet more stringent effluent requirements by the local POTW . An activated sludge process was originally selected with a conventional gravity clarifier and a belt press to dewater the biological solids prior to disposal in a landfill. When landfilling the solids was dropped as a disposal option, the plant elected to use DAF clarifiers in lieu of the gravity clarifier in order to clarify biological solids and thicken the waste sludge in a single process. This would allow the plant to generate a sludge volume roughly 80% less than that generated by a gravity clarifier.

Moreover, a high-rate aeration tank operating with a high MLSS (up to 5,000 mg/L) was required in order to fit the system in the allotted space. This also posed a problem with using a gravity clarifier which could not reliably handle such a solids load and would be more susceptible to bulking solids from a highly variable wastestream and F:M ratio. This also confirmed the need to use a DAF process for clarification since it could handle the high MLSS stream and bulking solids from the aerated tank.

Two DAF clarifiers, each with a surface area of 350 ft^2 , were installed to handle a future peak flow of 1.0 MGD with a MLSS of 5,000 mg/L. Effluent from the aerated tank was split to two separate DAF trains which also include flocculation tanks for the addition of a cationic polymer (Figures 7 and 8). The plant typically operated a single DAF unit since the actual flow averaged 0.6 MGD at that time.

Figure 7. Aerated tank effluent in flocculation tank prior to DAF

Figure 8. DAF providing clarification of aerated tank effluent

As indicated in Table 3, the DAF system typically provided a clarified effluent (Figure 9) with average TSS concentrations of 56 mg/L and COD levels of 91 mg/L, both of which were well below the 250 mg/L and 500 mg/L permit targets for TSS and COD, respectively. Sludge from the system was typically in the 2.5-4.0% TS range, just at the maximum thickness that a third-party service could land apply. This sludge solids concentration significantly reduced the volume of sludge hauled for land disposal and the operating horsepower of pumps returning the sludge (RAS) to the aeration tank and subsequent hydraulic loading on the system.

Table 3. Treatment efficiency of activated sludge/DAF system at a snack food plant

Parameter	Aeration Tank Influent	Aeration Tank Effluent	DAF Effluent	% Removal
COD, mg/L	2,182	na	91	96%
SCOD, mg/L	1,205	na	67	94%
TSS, mg/L	452	4,479	56	99% [1]
TS, %	na	na	3	na

[1] DAF clarifier MLSS capture efficiency from Aeration Tank effluent

Figure 9. Effluent from DAF providing clarification of aerated tank mixed liquor

CONCLUSIONS

Dissolved air flotation has been successfully used to clarify biological solids from a variety of aerobic and anaerobic wastewater treatment systems. In general, the systems generated relatively high solids sludge and very good effluent quality that consistently met permit effluent requirements for sewer discharge. This indicates that DAF is a suitable alternative to traditional gravity or hydraulic clarifiers for biological solids clarification. Moreover, in all of the case studies presented, gravity clarification was not an option, and DAF was the only technology that could meet the performance requirements for those applications.

REFERENCES

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