CASE STUDY: CONTAMINANTS REMOVAL FROM SNACK FOOD MANUFACTURING WASTEWATER

[1]Miroslav Colic, Clean Water Technology, Inc.
Wade Morse, Clean Water Technology, Inc.
Ariel Lechter, Clean Water Technology, Inc.
[1]Clean Water Technology, Inc.
6860 Cortona Dr., Building A
Goleta, CA 93117

ABSTRACT

This presentation describes the full-scale installation of the wastewater treatment system at the Portion Pack Industries (Division of Heinz) plant in Chatsworth, California. The plant manufactures various products including salad dressing, sauces, ketchup, mayonnaise, honey mustard, toppings, condiments and other snack food products. More than twenty different products are manufactured at the same facility. Produced wastewater, therefore, varies on an hourly, daily and seasonal basis.

Wastewater resulting from the manufacturing process contains significant amounts of suspended solids (TSS), fats, oil and grease (FOGs), and suspended and dissolved organics (COD and BOD), with occasional high salinity (sodium chloride). TSS and FOGs can sediment and deposit in pipes, pumps and tanks at the municipal treatment plant (POTW). It is therefore advisable to remove such contaminants on site and avoid costly fees and fines.

Pilot studies indicated that hybrid centrifugal – dissolved air flotation (the GEM System) can almost completely remove TSS and FOGs and significantly reduce COD and BODs. In Spring 2007, a system including large underground equalization tanks, screen, coagulation, flocculation, GEM System flotation, sludge draining and pH controls was installed. The treatment system removes TSS and FOGs to less than 20 and 1 mg/l respectively, while producing sludge with more than 20% solids loading. The system responds very fast (within minutes) to changes in wastewater quality. CODs and BODs are also reduced (50-75% reductions). Contaminants removal results in significant savings in fees and fines.

KEYWORDS

Snack food manufacturing wastewater treatment, flocculation – flotation, TSS, FOG and BOD removal

INTRODUCTION

Food processing industries occupy an important position economically and generate large volumes of mostly biodegradable wastes. Different sources contribute to the generation of wastewater in food processing industries. Product manufacturing, cleaning in place, storm drains, product discarding, and packaging all result in production of liquid waste. Wastewaters released from these industries are turbid, with high concentrations of biodegradable pollutants, such as sugars and proteins. Suspended solids (TSS), fats, oil and grease (FOGs), colloidal and dissolved materials contribute to the chemical oxygen demand (COD) and biological oxygen demand (BOD). Salts such as sodium chloride are also sometimes present.

High concentration wastewater (10% or more of contaminants) can be concentrated for the resource recovery. Low concentration wastewater can be discharged to the sewer. Medium concentration wastewater usually has to be treated to remove at least sedimentable solids and fats, oil and grease. Such pollutants can deposit in pumps, pipes, sewers and municipal treatment plant tanks.

Management of wastewater from the snack food manufacturing industry presents multiple challenges. Dozens of products are often produced and packaged at the same facility. Cleaning in place is performed with strong chemicals such as detergent, bleach and peracetic acid that can influence downstream wastewater treatment processes. Therefore, produced wastewater often varies by hour, day and season. Recent regulatory changes resulted in the need to remove such contaminants more efficiently. Robust technologies that can respond fast to changes in wastewater strength have to be applied to treat such streams. Fewer operators with less training, reduced operation budgets and frequent plant capacity increases result in the need for treatment systems that are simple to install and operate; flexible; have a small footprint; and are easy to expand.

A stepwise approach to wastewater treatment commonly yields the best results in the most economic way. The primary treatment deals with the removal of suspended solids, colloidal materials and large screenable and settleable solids. As already mentioned, in the treatment of food wastewater, solids and colloids should be removed fast and with low shear technologies in order to avoid dissolution or deposition in pumps, pipes or elsewhere. For snack food processing wastewater, the primary treatment processes are flow equalization, screening, sedimentation, the pH adjustment, coagulation - flocculation – flotation, and microfiltration. Detailed description of those steps in food processing wastewater treatment can be found elsewhere on this CD (Colic et al., 2007).

CASE STUDY: WASTEWATER TREATMENT SYSTEM AT PORTION PACK INDUSTRIES (PPI) SNACK FOOD MANUFACTURING PLANT

PPI is the leading producer of portion control products in the country. Over 2500 recipes and 100 types of portion packed foods are available. At one such plant in Chatsworth, California, over 20 different products are currently manufactured and packed. The plant manufactures salad dressings, pickles, sauces, mayo, ketchup, honey mustard, and various other products. Wastewater resulting from the manufacturing and packaging process contains significant amounts of TSS, FOGs, COD, BOD and salt. The City of Los Angeles has many municipal industrial wastewater treatment plants that are very efficient in removing dissolved biodegradable organic materials. However, TSS and FOGs are depositing in pipes, pumps, and tanks. Therefore, high fees and fines are imposed to companies that produce wastewater with a significant amount of such contaminants.

PPI plant produces an average of 180,000 GPD of wastewater. As mentioned earlier, such wastewater is highly variable. The pH can vary between 4.7 and 12.7, TSS between 200 mg/l and 5,000 mg/l, FOG between 10 and 2,000 mg/l, and COD's between 3,000 and 25,000 mg/l.

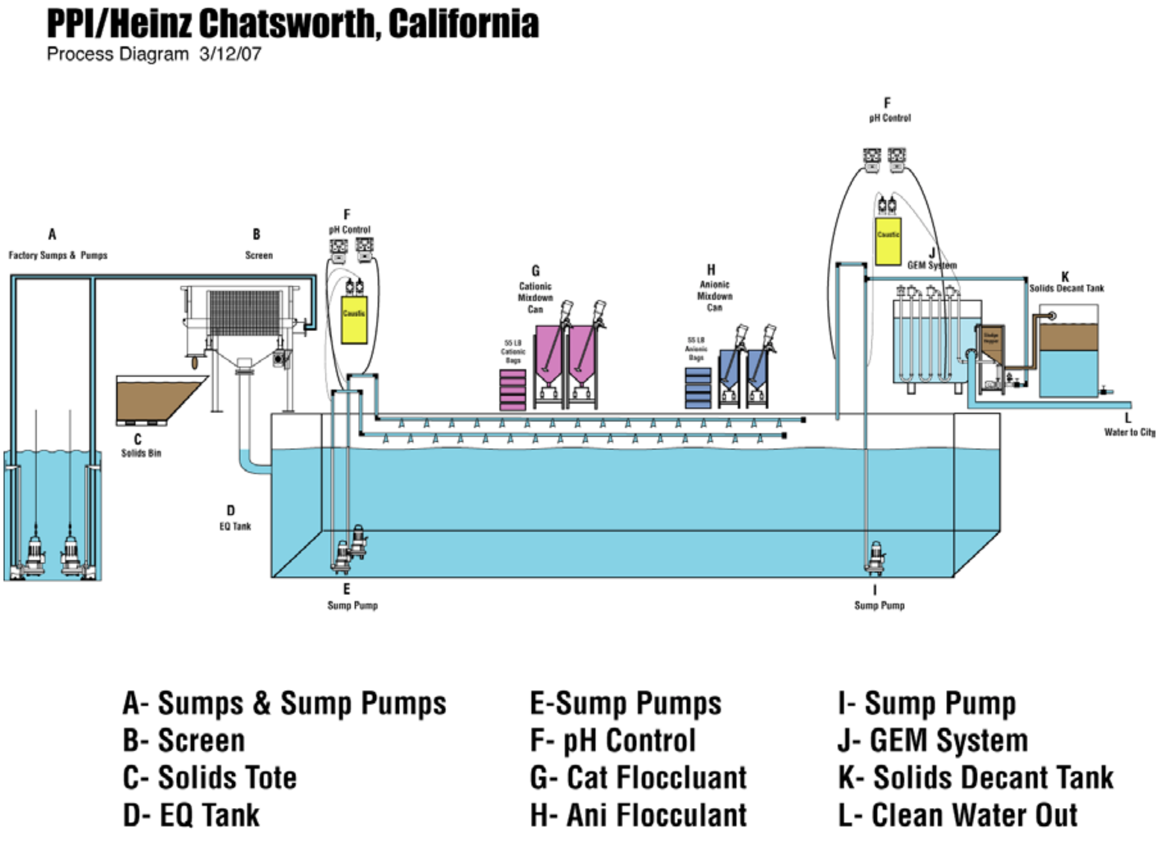


Figure 1. Schematic presentation of the wastewater treatment system installed at PPI/Heinz plant.

In 2001, PPI and CWT teams started an analysis of various options to treat this problem in the most feasible way. Daily, weekly and seasonal changes in the wastewater strength and treatability have been analyzed. Long term laboratory and pilot studies were performed over a five-year period to assess the best treatment choice. The decision was made to remove TSS, FOGs and colloidal materials along with suspended COD/BODs.

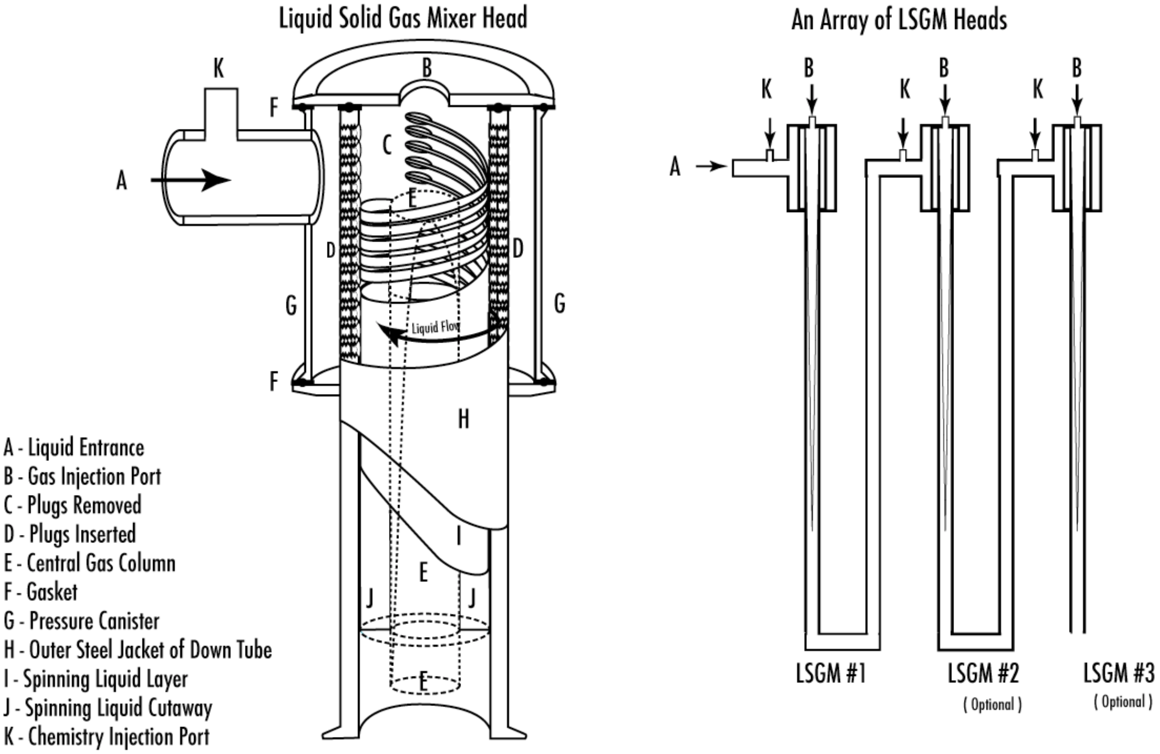
In January 2007, a system designed to treat up to 150 GPM was installed. A large underground tank was installed to allow for mixing, equalization and the pH adjustment of up to 70,000 gallons of wastewater with different compositions. A rotating drum screen with self cleaning and an opening size of 800 micron is used prior to equalization tank to remove large solids that would settle in tanks, pipes etc. The pH is adjusted inside the tank to 5.5. Sulfuric acid and sodium hydroxide are used to adjust the pH.

Coagulation, flocculation and flotation are performed inside the GEM System that will be described below. The schematic presentation of the installed system is illustrated in Figure 1. After flotation sludge was collected in sludge tank and pumped to solids decant tank. Clean water is pumped to the City sewer.

The Hybrid Centrifugal – Dissolved Air Flotation System: Gas Energy Mixing Management (GEM)

Description and Principles of Operation

Figure 2 – Schematic Presentation of the LCPP/LSGM



In dissolved-air flotation, bubbles are formed by a reduction in the pressure of water pre-saturated with air at pressures higher than atmospheric and up to 120 psi. The supersaturated water is forced through needle valves or special orifices, and clouds of bubbles 20 to 100 microns in diameter are produced. Yet, to avoid clogging of such orifices with particles, only 20% of already cleaned water is pressurized and recycled to the wastewater stream. This results in a low-energy mixing of the main wastewater stream and the bubble stream. Treatment chemicals, coagulants and flocculants have to be added in mixing tanks upstream. Floc separation happens in this tank, which requires quiescent conditions and a large footprint.

We proposed that a more efficient flotation system could be developed by combining high-energy centrifugal mixing of a liquid cyclone system (we termed it the liquid cyclone particle positioner, LCPP) with dissolved air as a source of flotation bubbles. Coagulants and flocculants can be delivered *in situ* directly into the flotation unit. The liquid – liquid hydrocyclone column was replaced with the LCPP for more efficient mixing of treatment chemicals, which occurs during bubble formation and nucleation. Such a procedure results in flocs, which are very porous and loaded with entrained and entrapped air.

As shown in Figure 2 the LCPP also acts as a liquid-solid-gas mixer (LSGM). Replacing the classical hydrocyclone head with the LCPP provides extremely energetic mixing by sequentially transporting liquid and entrained particles and gas bubbles throughout a centrifugally rotating liquid layer. Micro turbulence in such vortices results in all particles and bubbles down to colloidal and molecular size acting as little mixers. Axial and radial forces inside the LCPP help mix coagulants and flocculants with the particles. Uncoiling of polymer and better mixing of ultrahigh-molecular-weight polymers is achieved in the LCPP. Such efficient mixing is important for proper flocculation of suspended particles.

Further modification of LCPP heads, as opposed to hydrocyclone heads, introduced multiple holes with plugs inside the LSGM heads, as shown in Figure 3. By changing the number of plugs, we can modify the mixing energy and head pressure from very low to very high. In this way, we can mix the low-molecular-weight coagulant at relatively high energy and high-molecular-weight flocculants at relatively medium and low mixing energy to promote final large floc formation.

Figure 4 presents a schematic of the GEM flotation system. It should be noted that for the sake of clarity only one LSGM head is presented. If more treatment chemicals are added, the LSGM head can be used to properly mix every additional chemical at its proper mixing energy (one mixing head per addition). Water and gas are introduced into the LSGM on top and pumped through the LCPP chamber. After rapid mixing (seconds), pressure is released with the cavitation plate. Nucleating bubbles and flocs are well mixed. As mentioned before, this results in the formation of large flocs full of entrained and entrapped air. Such flocs are already separated from water inside the LCPP nucleation chamber. As flocs enter the tank, they rise quickly to the top where they are skimmed and sent to solids dewatering devices.

As compared to other centrifugal flotation systems, the GEM system uses less energy, since there is no need for air blowers for air sparging. This also results in less noise. Controlled mixing energy produces stable flocs with much less carryover and higher solids loading. The footprint for this system is still only 10 to 20% of the classical DAF or clarifier devices. A blanket of small bubbles inside the tank acts as a "gas filter," filtering out clean water while preventing the transport of small pinpoint flocs into the clean water stream. Also, when wastewater with surfactants is treated, for some reason no foaming occurs inside the GEM system. Finally, it is possible to install sensors close to the nucleation chamber and observe any disturbance in flocculation performance almost instantaneously. This can be used to install turbidity-driven, chemical-additive dosage-control systems. Such systems can save significant amounts of money and produce a better quality of outgoing wastewater effluent. A detailed description of the GEM system can be found in Morse et al. (2004a, 2004b).

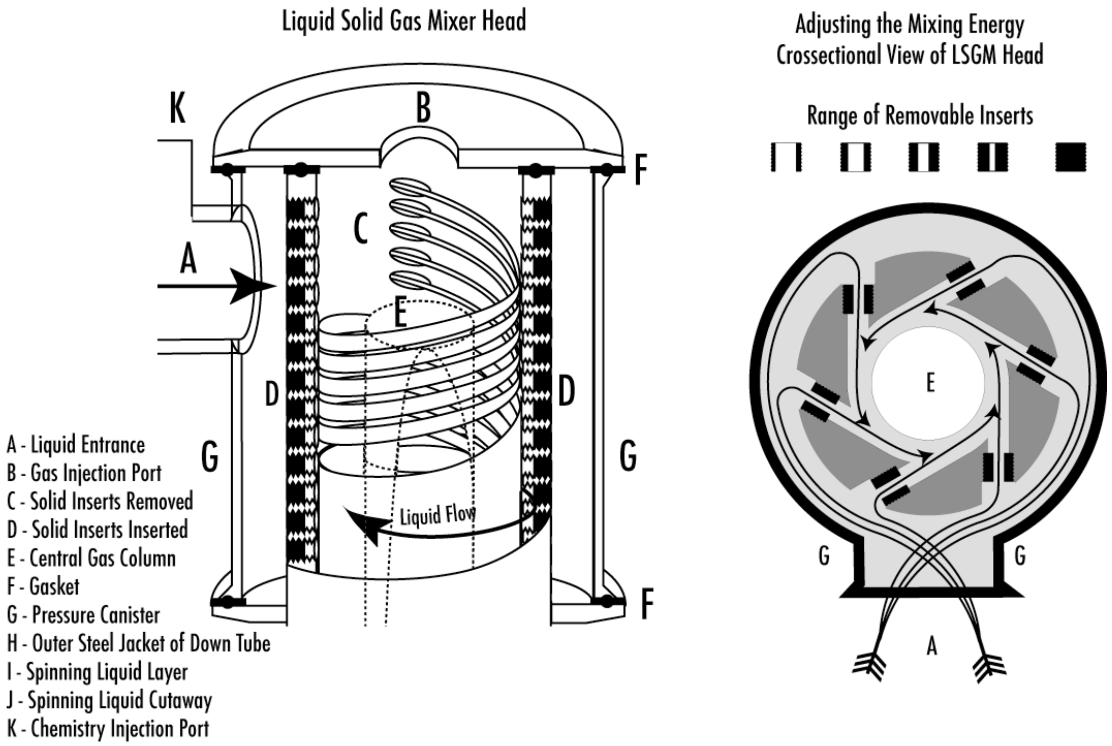
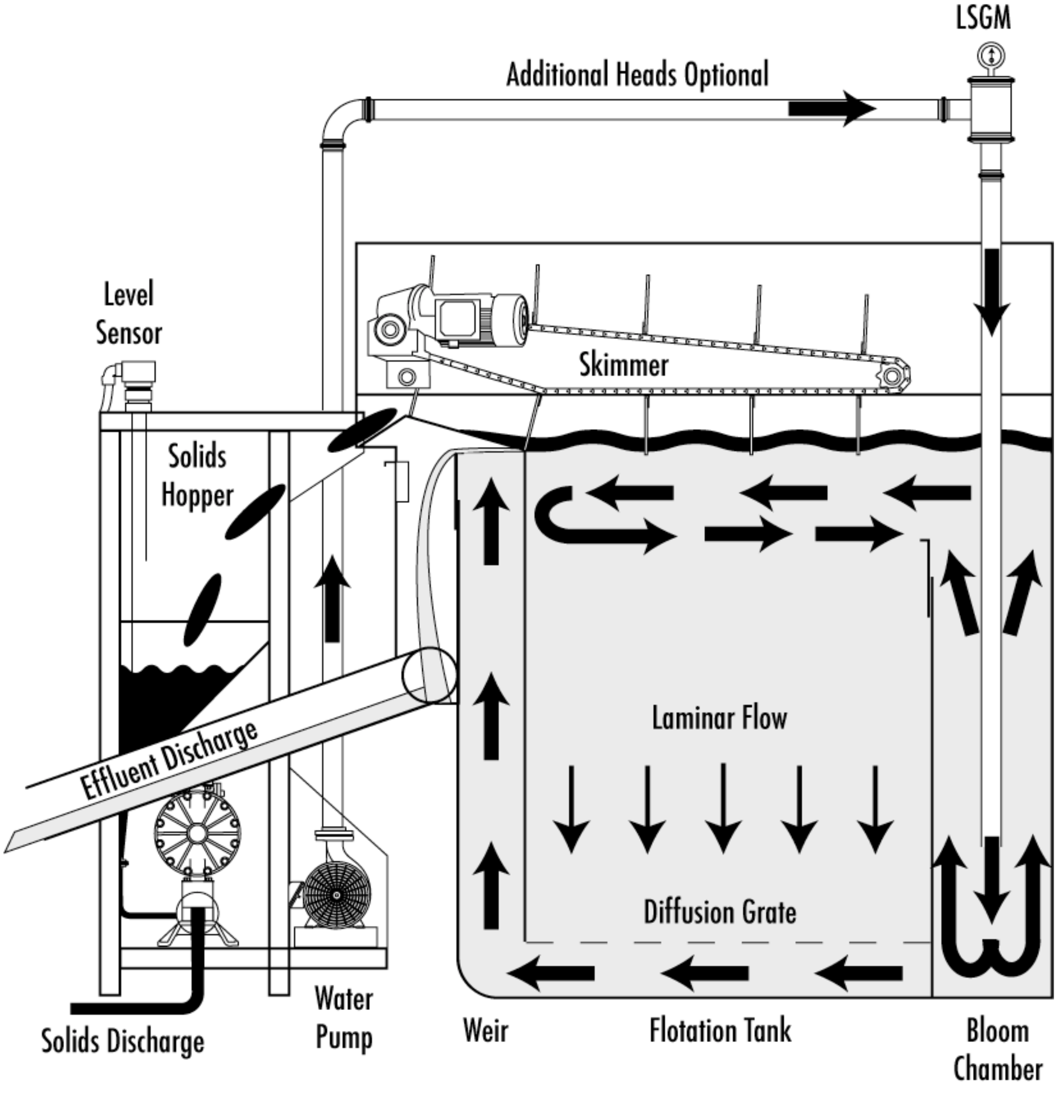


Figure 3 – Schematic Presentation of the LSGM Heads

Other Centrifugal Flotation Systems

Swirl flow of fluids and mixing with coagulants, flocculants, and air bubbles occurs inside the air-sparged hydrocyclone (ASH) and other derived centrifugal flotation systems (CFS). Several versions of inverted ASH with upward water flow have been reported. Hydrocyclone flotation systems with induced or dissolved air have also been tested. All these techniques incorporate a vortex finder similar to the classical ASH with the attendant problems discussed earlier. The advantage of such techniques is that they do not use large separation tanks. This results in a smaller footprint and reduced cost of equipment compared to DAF, and induced-air flotation.

Figure 4 – Schematic Presentation of the Hybrid Centrifugal – Dissolved Air Flotation System



Modified versions of the jet (Jameson cell) flotation system have also been developed and applied. In a recent advancement of the Jameson cell technology, a new "low shear" method is used to mix the air, untreated wastewater, and flocculants. As in the previously described induced-air BAF system, untreated wastewater and flocculants are gently introduced into the top of the cylinder used for centrifugal mixing (termed the downcomer for Jameson cell systems). A portion of the clean effluent is recycled back into the top of the downcomer. The recycle effluent passes through an orifice, accelerating the liquid to produce a simple liquid jet. The kinetic energy of the jet results in air being entrained into the downcomer in much the same way as air might be entrained into a bucket of water using a hose. Air is dragged down into the liquid and broken up into small bubbles by the turbulence in the top of the downcomer. The Jameson cell thereby utilizes the energy of the fluid to induce air into the cell, rather than requiring an external compressor or blower. As in the case of the bubble-accelerated flotation (the BAF system) (see Colic et al. 2007 on this CD), the presence of air bubbles at the time of flocculation is extremely beneficial, as it results in the bubbles being entrapped with the actual floc structure. The incorporation of bubbles in the floc structure provides buoyancy and allows particles to be floated independent of their surface characteristics. The downward velocity of the bubble/liquid mixture in the downcomer is designed such that all bubbles have to descend and emerge into a reservoir (or cell) at the bottom of the downcomer. The reservoir acts as a disengagement zone, allowing the aerated floc structures to float to the surface to form a sludge layer. As in the case of BAF and GEM, separation already happens inside the centrifugal force column (in this case downcomer). The sludge overflows the reservoir into a launder, while the cleaned effluent passes to the next stage in the process.

Other modifications of jet flotation include the DAF jet (dissolved-air mode) and the addition of one more cylinder around the downcomer to lead separated flocs towards the top of the separation tank (Feris et al., 2004). While these modifications increase the cost and result in a more complicated system, they also increase the separation efficiency.

Another turbulent *in situ* centrifugal flotation system, termed flocculation flotation (FF), was recently developed (daRosa and Rubio, 2005). As in the case of GEM, BAF, and the modified jet-flotation cell, polymer and air are added at the same time inside a centrifugal mixing system. Dissolved air is used for smaller bubbles. As in the case of BAF and the GEM system, large flocs entrained with air develop when high-molecular-weight flocculants are used. Multiple cylinders around the downcomer are used, similar to the modified jet-flotation cell. The air excess leaves through the centrifugal cylinders at the top, and the flocs float very fast within seconds after leaving the downcomer cylinder. A novel flocculation and helical mixing system has also been developed by the same group (Carissimi and Rubio, 2005).

Coagulation and Flocculation of the PPI wastewater

Coagulation and flocculation were performed inside the GEM System hydrocyclone columns and heads. Variable mixing energy inside the LCPP with centrifugal forces mixing enabled application of viscous high molecular weight high performance coagulants and flocculants. Quaternary polyamine (organic polyelectrolyte) coagulants produced sludge with the highest amount of solids. High molecular weight granular cationic flocculants followed by high molecular weight anionic flocculants (dual flocculants approach) produced best TSS removals, turbidity and FOG reductions and sludge with the highest solids loading. Coagulant and flocculants were prepared and hydrated in chem. – tanks at 0.5% and premixed for at least 45 minutes to achieve full hydration and activation. Coagulants and flocculants were dosed with the progressive cavity pumps capable of delivering viscous solutions against pressures up to 120 psi. The average removals of TSS and COD over 24 hours are illustrated in Table 1.

Sample	pH	COD's/ppm Before	COD's/ppm After	TSS/ppm Before	TSS/ppm After
1	12.7	5760	4990	270	15
2	12.7	5858	4770	320	25
3	5.5	6200	4860	350	25
4	5.3	6590	4590	350	30
5	9.3	6350	4450	400	25
6	9.3	6590	4810	350	15
7	10.1	7350	4890	320	10
8	8.8	6270	4830	310	10
9	7.3	6430	4920	310	15
10	6.9	5580	4790	270	15
11	6.7	6670	4930	650	20
12	6.1	6560	4430	980	22
13	8.6	12300	4340	2800	25
14	6.2	11000	4400	3132	6
15	5.8	16000	4400	3000	8
16	5.5	18000	4340	3200	22
17	5.5	18000	4010	2300	15
18	5.5	19000	3550	2200	25
19	5.5	19000	3880	4500	25
20	13.5	18000	3600	4400	30
21	10.2	20000	5760	4100	12
22	7.1	21000	5840	3100	15
23	6.6	19000	5690	2150	11

After treatment pH of samples was around 5.7
Turbidity before treatment was over 1000 NTU for all samples, less than 20 NTU for all samples

Table 1.

Numerous coagulants were tested in jar and pilot studies. Ferric (III) and aluminum (III) salts required highest dosages (100-3000 mg/l) and produced sludge with low solids content (2-5%), which was difficult to drain. Prepolymerized aluminum coagulants such as polyaluminum chloride (PAC) and aluminum chlorohydrate (ACH) required lower dosages (50-1,500 mg/l) and produced better sludge (3-7% solids) and clarification efficiencies (TSS and turbidity removal). The best results were achieved with quaternary polyamine and epiamine coagulants. Such organic polyelectrolytes were also most economically feasible, with lowest dosages (20-200 mg/l) and best solids loading sludge (8-28%).

Numerous flocculants were also tested. Brine flocculants were least efficient (50-200 mg/l dosages needed), emulsion flocculants somewhat efficient (30-120 mg/l dosages), and granular high molecular weight cationic polyacrylamides most efficient and economically feasible (10 – 40 mg/l dosages).

The actual photo of the wastewater treatment system installed at PPI Chatsworth plant is presented in Figure 5.

Figure 5. Actual photo of the system installed at PPI/Heinz plant at Chatsworth, California.

CONCLUSIONS

Removing TSS and FOGs from snack food manufacturing wastewater is often satisfactory since downstream municipal plants can easily handle dissolved BODs. A system including a large equalization tank, screen, coagulation, flocculation, hybrid centrifugal – dissolved air flotation and sludge drainage was installed and performed well at one such plant in Los Angeles County. TSS and COD can be removed almost completely to less than 20 and 1 mg/l respectively. Produced sludge can be drained to more than 20% solids. The system responds within minutes to changing compositions of wastewater. As expected, dissolved organic materials cannot be removed with coagulation – flocculation – flotation treatment. Contaminants removal results in significant savings in fees and fines.

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