Flocculation – Flotation Pretreatment Improves Operation of MBR Installed to Treat Snack Food Manufacturing Wastewater

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ABSTRACT

Large food manufacturing company has facilities to produce their well known brand name dairy based products in rural Indiana. As is commonly case with dairy wastewater, significant amount of proteins, sugars, oil and some suspended solids are present. Company installed membrane bioreactor (MBR) System to treat such wastewater for possible reuse.

The MBR performed poorly due to membrane fouling. Manufacturer suggested that in addition to screen other primary pretreatment is needed to reduce FOG and organic TSS as low as possible prior to MBR treatment. Classical DAF and advanced hybrid centrifugal – dissolved air flotation (GEM) were pilot tested. Both systems performed well, but GEM removed FOG and TSS to lower amount and produced drier sludge. The full scale GEM System has been installed in June 2010. Dual high molecular weight flocculants and GEM flotation remove TSS below 50 mg/l, FOG below 2 mg/l and produce sludge with 20% solids. Data are currently collected to evaluate how such pretreatment improves operation of the MBR.

KEYWORDS: snack food wastewater, MBR fouling, pretreatment, DAF vs. GEM flotation

INTRODUCTION

At their rural Indiana facility, large food manufacturing company currently uses a Membrane Bio-Reactor (MBR) [GE ZENON] to treat their wastewater stream. The water from the plant is collected in an approximately 200,000 gallon outdoor Equalization Tank (EQ Tank). The water is collected from the manufacturing and cleaning of machinery used for the production of Coffee Mate, milk, chocolate milk as well as other similar brand name products. The influent water was shown to be very turbid and cloudy, containing high levels of Total Suspended Solids (TSS) and Fats, Oils and Grease (FOG). From the EQ tank, the water is pumped through a basket screen and continues to a 500 GPM aerobic MBR for further treatment – removal of BOD.

GE Zenon ZeeWeed aerobic MBR combines suspended growth bioreactor with reinforced hollow fibers ultrafiltration. MBR combines aeration and solid liquid

separation into a simple, small footprint, efficient system. Poor settling that often happens in conventional aerobic activated sludge bioreactors used to treat high strength industrial wastewater is thus eliminated. Membranes can also handle more biosolids than clarifiers. ZeeWeed process can typically be operated at mixed liquor suspended solids (MLSS) concentrations as high as 8,000 to 12,000 mg/l. Elevated biomass concentration allows for treatment of high strength industrial wastewater.

ZeeWeed ultrafiltration membranes use permeate pump to apply vacuum and draw treated water through the hollow fiber reinforced UF modules. Intermittent air flow is introduced to the bottom of the membrane modules, producing turbulence that scours the external surface of the hollow fibers. This scouring action transfers rejected solids away from the membrane surface, significantly reducing membrane fouling and flow rate loss. Such design allows operation at significantly higher TSS than standard pressure driven UF membrane modules.

A primary treatment system for reduction of TSS and FOG was not installed prior to the MBR system. The MBR is used to reduce BOD and TSS and separate effluent water from biosolids through a external membrane tank system. The waste biosolids (mixed liquor) solids from MBR are sent to a centrifuge for sludge thickening which is achieved through the addition of polymer.

The amount of FOG in the plant effluent has caused continuous membrane fouling, with significant decrease in flow rate and increase in cleaning cost with time. Plant engineers decided to compare performance of classical dissolved air flotation (DAF) and advanced hybrid centrifugal – dissolved air flotation system (the GEM) as primary treatment choices to remove as much FOG and TSS as possible, while producing as dry sludge as feasible.

PILOT TESTS

The performance of the classical DAF system (Krofta – Ecolab) with standard chemical approach (cationic low molecular weight epiamine coagulant overcharge followed with few ppm of medium molecular weight anionic emulsion flocculant), was compared with novel approach based on the GEM System: high molecular weight cationic flocculant overcharge followed by ultrahigh molecular weigh anionic flocculant (dual flocculant approach – see Figure 1).

The removal rates of TSS, FOG and COD and turbidity were compared. According to GE ZENON (MBR manufacturer), the lower influent FOG, TSS, turbidity and COD, the more successful and economically feasible operation of the MBR is. Table 1 compares the performance of the DAF and GEM Systems.

Figure 2 shows the GEM system.

The GEM system is a hybrid centrifugal – dissolved air flotation system based on liquid-liquid hydrocyclone technology (Colic et al., 2008). It is designed so that 100% of the

influent is aerated and coagulants and flocculants are introduced into the hydrocylone heads at the same time with pressurized air. This approach results in the formation of large porous flocs that are separated from water inside the hydrocyclone columns. Flocs formed under centrifugal force contain up to 20% solids and are easy to further dewater. Controlled centrifugal mixing inside hydrocylone heads and columns results in full adsorption of added flocculants. This is important to prevent flocculation of microorganisms in MBR or fouling of membranes with any free remaining polymer residue. Dual flocculant approach assures that any cationic flocculant overdose co - precipitates with anionic flocculant, and floats with the sludge.

The GEM System consistently reduced FOG to less than 2 mg/l. TSS were reduced to below 50 mg/l most of the time. Turbidity was most of the time reduced below 20 NTU. COD/BOD removals of 40% - 50% were mostly observed. Collected sludge with more than 21% solids by weight was obtained. No membrane fouling with cationic polymer was observed. As indicated in the Table 1, DAF System performance was significantly lower. Cost of chemicals for DAF and GEM treatment is comparable (around 1.5 US$ per 1,000 gallons).

On average, the stream was treated at approximately pH 8.5. When CWT used a 3 part chemical regime, chemical dosages ranged between 50-100 ppm of epiamine Coagulant, 5-50 ppm of Cationic Flocculant, and 5-20 ppm of Anionic Flocculant. During tests with 3 part chemical regimes, the average chemical dosage was approximately 85 ppm Coagulant, 20 ppm Cationic Flocculant, and 10 ppm Anionic Flocculant. During tests with 2 part (Cat/Ani only) chemical regimes, the average chemical dosage was approximately 110 ppm Cationic Flocculant and 10 ppm of Anionic Flocculant. DAF used on average 120 ppm of epiamine or blend coagulant followed by 10 ppm of emulsion anionic flocculant.

The ppm of chemicals required for each test varied depending on the time of day and how dirty the influent stream was before treatment. The ideal combinations of chemicals are expected to fluctuate within 10 ppm above or below the average.

GEM System has a footprint that is around 30% of that of the DAF. As water quality changes often it was also important that using dual flocculant approach one can perform the jar test much faster (few minutes). GEM System also responds to changes in chemical dosage in minutes. When pinflocs (fine flocs) occurred, DAF performed better in TSS removal. However when using dual flocculant approach this rarely happens (2-5% of the time). Intense controlled vortex mixing inside hydrocyclone heads activates high molecular weight flocculant more efficiently (uncoiling process occurs next to the hydrocyclone wall – see Figure 3). It is therefore possible to use very high molecular weight products that cannot be used in the DAF System. The higher the molecular weight of flocculants, the larger and more stable flocs are formed (see Figure 4).

Based on these pilot studies, CWT and plant engineering teams designed and installed a full scale 500 GPM GEM System in June 2010. The performance of the System is currently being evaluated.

Table 1. Comparison of the GEM and DAF Systems Performance.

	TSS/mg/l av.	FOG/mg/l av.	Turbidity/NTU av.	Sludgesolids%
GEM eff.	55	1.4	28	22
DAF eff.	150	18	110	6

*av. = average

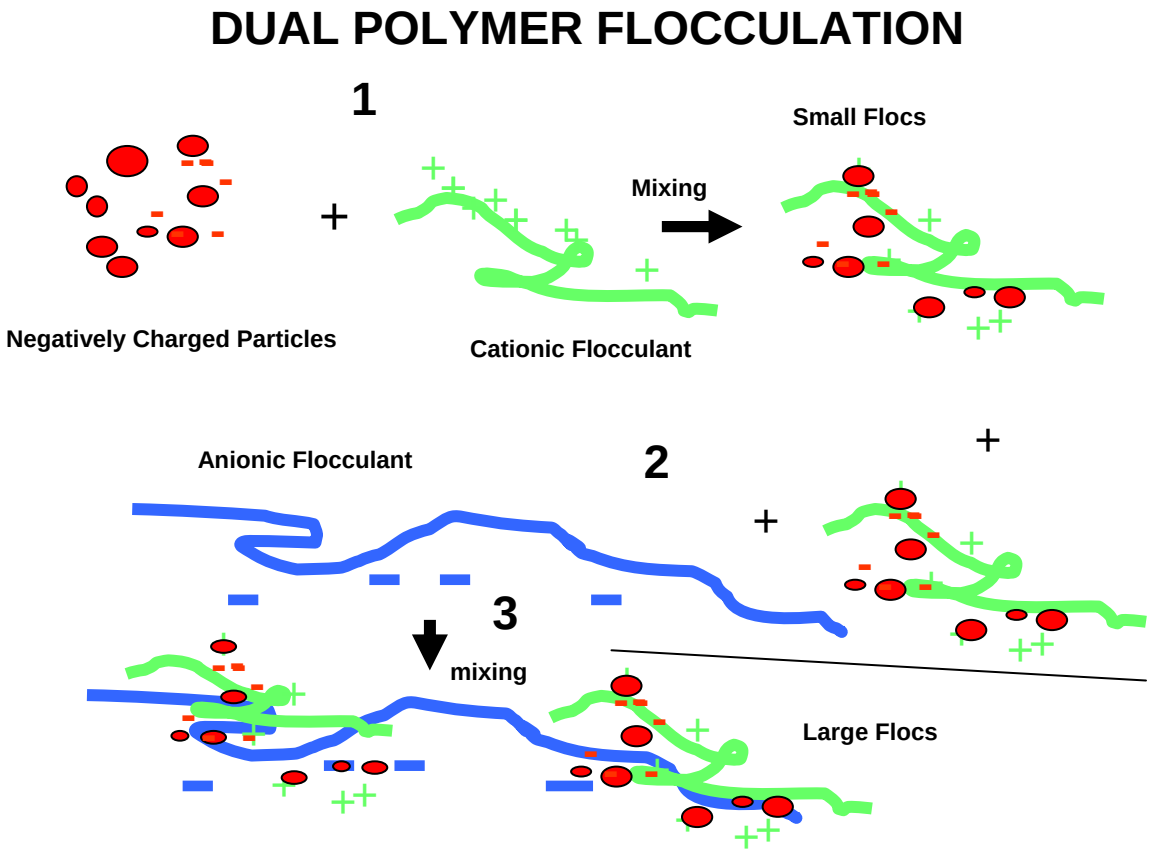

Figure 1. **Dual polymer flocculant approach**.

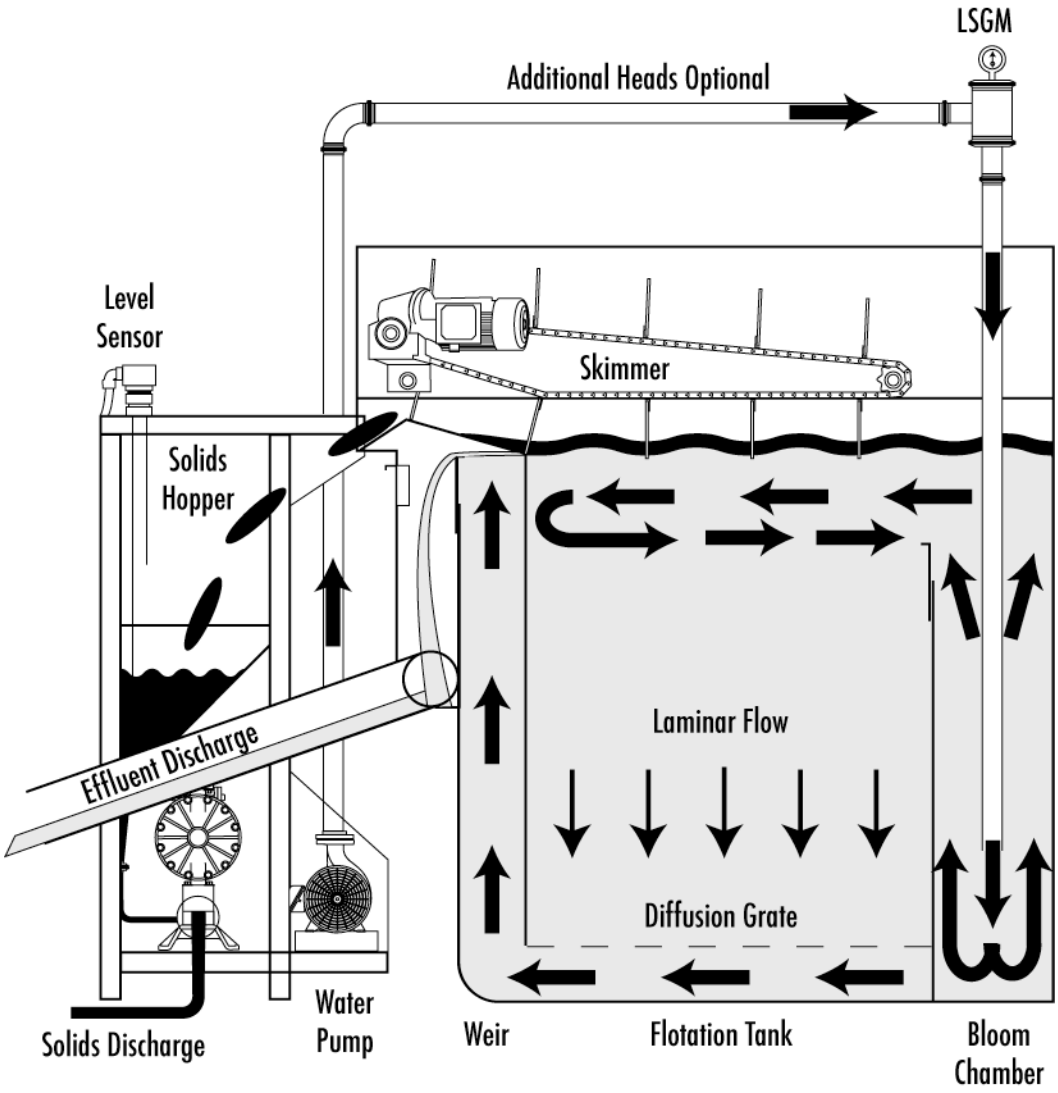

Figure 2. Schematic Presentation of the GEM System.

UNCOILING (ACTIVATION) OF POLYMERIC FLOCCULANTS

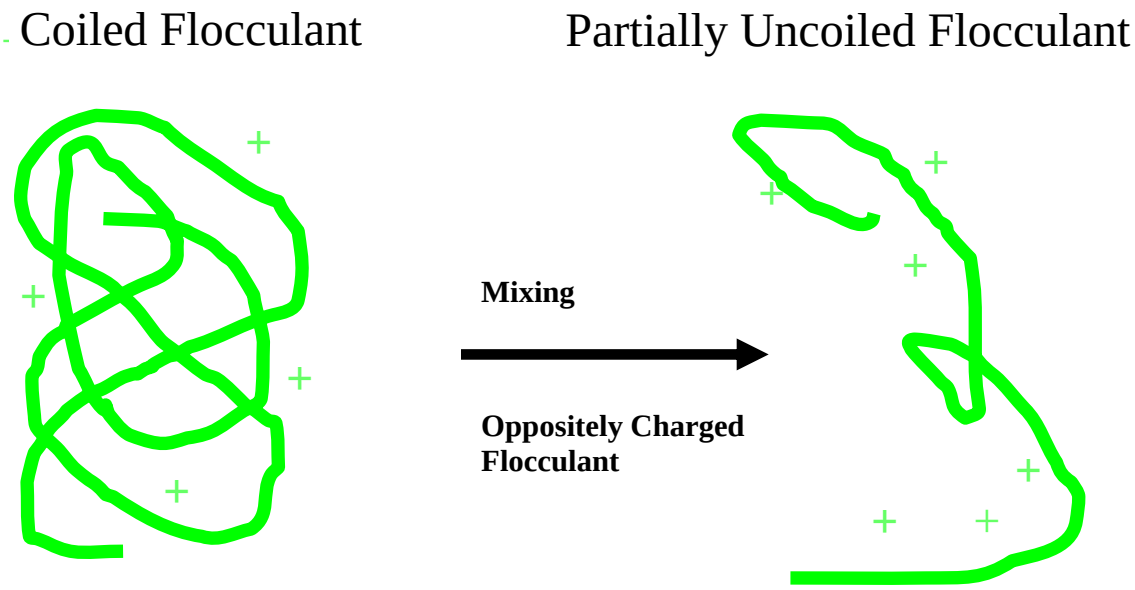

Figure 3. Uncoiling (activation) of high molecular weight flocculant.

Figure 4. Fast 50 ml hand mixed jar testing with dual high molecular weight flocculants.

Table 2. COD Reductions: Lab tests indicated that the GEM System reduced COD by approximately 42%, on average:

Date:	Time:	Influent:	Effluent:	% Reduction:	Dosage/coag/cat/ani
9/10/2009	9:20 AM	2910	2290	21.31%	0/100/10
9/10/2009	11:30 AM	2840	1770	37.68%	0/140/20
9/10/2009	1:45 PM	3450	1930	44.06%	0/140/20
9/10/2009	2:45 PM	3660	1990	45.63%	0/80/10
9/10/2009	3:30 PM	3590	2020	43.73%	0/80/10
9/10/2009	5:00 PM	4060	1940	52.22%	0/80/10
9/11/2009	9:30 AM	3410	2202	35.43%	0/180/10
9/11/2009	10:30 PM	4030	2210	45.16%	0/160/10
9/11/2009	11:15 AM	3410	2360	30.79%	0/160/10
9/11/2009	12:50 PM	3720	2040	45.16%	0/160/20
9/11/2009	1:15 PM	3720	2120	43.01%	0/100/10
9/11/2009	1:40 PM	3720	2140	42.47%	0/50/10
9/11/2009	2:00 PM	3680	2170	41.03%	0/130/10
9/11/2009	5:00 PM	3540	2150	39.27%	0/70/10
9/11/2009	6:00 PM	3440	2250	34.59%	0/120/10
9/12/2009	9:30 AM	4120	2480	39.81%	0/130/20

9/12/2009	10:10 AM	4430	2420	45.37%	0/80/10
9/12/2009	10:40 AM	4430	2420	45.37%	0/100/10
9/12/2009	11:05 AM	4430	2590	41.53%	0/110/10
9/14/2009	9:45 AM	6330	3430	45.81%	80/30/20
9/14/2009	10:15 AM	3210	1450	54.83%	80/50/20
9/14/2009	10:45 AM	3690	1290	65.04%	80/50/20
9/14/2009	2:20 PM	5900	3200	45.76%	80/20/15
9/14/2009	3:00 PM	3600	2970	17.50%	80/20/15
9/14/2009	4:30 PM	4790	3100	35.28%	80/20/10
9/14/2009	5:00 PM	4460	2940	34.08%	100/20/10
9/15/2009	9:00 AM	4800	3350	30.21%	70/10/10
9/15/2009	10:00 AM	4760	2770	41.81%	70/15/10
9/15/2009	11:45 AM	6850	3000	56.20%	80/15/10
9/15/2009	12:15 PM	5930	2840	52.11%	100/20/10
9/15/2009	2:30 PM	6210	2520	59.42%	100/40/10
9/15/2009	3:15 PM	7390	3400	53.99%	30/10/10
9/15/2009	5:00 PM	12700	6390	49.69%	100/20/10
9/16/2009	8:30 AM	3810	3060	19.69%	100/50/20
9/16/2009	10:00 AM	5040	2960	41.27%	100/30/10
9/16/2009	11:45 AM	5120	2300	55.08%	100/15/10
9/16/2009	2:45 PM	3800	2180	42.63%	100/30/10
9/16/2009	4:45 PM	4490	2030	54.79%	100/10/5
9/16/2009	6:15 PM	5220	2160	58.62%	100/10/10
9/17/2009	9:00 AM	4300	2460	42.79%	100/10/10
9/17/2009	9:45 AM	2730	2170	20.51%	100/5/5
9/17/2009	10:30 AM	2710	1890	30.26%	80/5/5
9/17/2009	11:00 AM	2650	2070	21.89%	55/5/5

Note: DAF on average reduced COD's by 28%.

Table 3. FOG Reductions: Lab results indicated that the GEM System reduced FOG by approximately 99%, on average:

Date	Time:	Influent FOG (ppm)	GEM Effluent FOG (ppm)	GEM % FOG Removal	Coag/Cat/Ani
9/10/09	4:30 PM	100.0	< 1.0	> 99%	0/80/10
9/11/09	11:00 AM	26.0	< 1.0	> 99%	0/160/10
9/14/09	10:45 AM	42.0	< 1.0	> 99%	80/50/20
9/15/09	11:45 AM	290.0	7.0	97.6%	80/15/10

DAF reduced FOG's by 89% on average.

Table 4: TSS Reductions: Lab tests indicated that the GEM System reduced TSS by approximately 91% on average:

Date:	Time:	Influent:	Effluent:	% Reduction:	Coag/Cat/Ani:
9/10/2009	9:20 AM	180	133	25.93%	0/100/10
9/10/2009	11:30 AM	350	40	88.57%	0/140/20
9/10/2009	1:45 PM	400	67	83.33%	0/140/20
9/10/2009	2:45 PM	425	0	100.00%	0/80/10
9/10/2009	3:30 PM	400	0	100.00%	0/80/10
9/10/2009	5:00 PM	425	0	100.00%	0/80/10
9/11/2009	9:30 AM	240	60	75.00%	0/180/10
9/11/2009	10:30 PM	260	0	100.00%	0/160/10
9/11/2009	11:15 AM	260	0	100.00%	0/160/10
9/11/2009	12:50 PM	260	40	84.62%	0/160/20
9/11/2009	1:15 PM	260	0	100.00%	0/100/10
9/11/2009	1:40 PM	140	33	76.19%	0/50/10
9/11/2009	2:00 PM	260	80	69.23%	0/130/10
9/11/2009	5:00 PM	260	40	84.62%	0/70/10
9/11/2009	6:00 PM	433	33	92.31%	0/120/10
9/12/2009	9:30 AM	480	50	89.58%	0/130/20
9/12/2009	10:10 AM	433	33	92.31%	0/80/10
9/12/2009	10:40 AM	433	33	92.31%	0/100/10
9/12/2009	11:05 AM	433	67	84.62%	0/110/10
9/14/2009	9:45 AM	567	0	100.00%	80/30/20
9/14/2009	10:15 AM	600	0	100.00%	80/50/20
9/14/2009	10:45 AM	600	0	100.00%	80/50/20
9/14/2009	2:20 PM	350	50	85.71%	80/20/15
9/14/2009	3:00 PM	333	0	100.00%	80/20/15
9/14/2009	4:30 PM	500	75	85.00%	80/20/10
9/14/2009	5:00 PM	450	50	88.89%	100/20/10
9/15/2009	9:00 AM	533	75	85.94%	70/10/10
9/15/2009	10:00 AM	400	40	90.00%	70/15/10
9/15/2009	11:45 AM	520	40	92.31%	80/15/10
9/15/2009	12:15 PM	450	50	88.89%	100/20/10
9/15/2009	2:30 PM	600	75	87.50%	100/40/10
9/15/2009	3:15 PM	850	100	88.24%	30/10/10
9/15/2009	5:00 PM	850	50	94.12%	100/20/10
9/16/2009	8:30 AM	600	50	91.67%	100/50/20
9/16/2009	10:00 AM	900	25	97.22%	100/30/10
9/16/2009	11:45 AM	733	0	100.00%	100/15/10
9/16/2009	2:45 PM	667	0	100.00%	100/30/10
9/16/2009	4:45 PM	600	0	100.00%	100/10/5
9/16/2009	6:15 PM	733	0	100.00%	100/10/10
9/17/2009	9:00 AM	200	25	87.50%	100/10/10
9/17/2009	9:45 AM	467	25	94.64%	100/5/5
9/17/2009	10:30 AM	250	0	100.00%	80/5/5
9/17/2009	11:00 AM	200	0	100.00%	55/5/5

DAF System reduced TSS by 88% on average.

FULL SCALE GEM PRETREATMENT INSTALLATION

Two full scale 750 GPM GEM Systems have been installed to pretreat wastewater ahead of MBR System. System includes redundancy so that during storms (storm flow) all collected water can be treated. During normal operation, if one GEM needs maintenance, another unit can still be used to pretreat most of the influent. As of July 2010 System is operating. Data are currently being collected to evaluate how GEM pretreatment improves the performance of the MBR downstream.

CONCLUSIONS

Food manufacturer installed MBR System to treat dairy based wastewater. Screen pretreatment could not remove oil and fine TSS. Membrane fouling plagued the operation of the large expensive MBR System from the installation. Manufacturer suggested that removal of oil and fine solids will solve the problem.

Pilot studies have been performed comparing classical DAF System with appropriate chemistry (epiamine coagulant followed by medium MW anionic emulsion flocculant) with that of a novel hybrid centrifugal – dissolved air flotation (the GEM System). GEM System works best with high molecular weight high charge granular dual flocculant approach. Pilot studies showed that the GEM System with dual flocculant approach removed FOG, TSS and BOD more efficiently. It also produced much drier sludge. A full scale GEM System was installed in June 2010 and is now fully operational.

REFERENCES

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