Advanced Pretreatment Enables MBBR Treatment of High Strength Candy Manufacturing Wastewater

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ABSTRACT

Bimbo – Ricolino candy manufacturing plant in Mexico City was discharging wastewater with high amount of fats oil and grease and dissolved sugars. Local regulatory agency requested that suspended solids, oil and grease and dissolved BOD be almost completely removed prior to discharge to municipal plant. The available real estate in Mexico City was very limited. A multistep treatment system was designed and installed. System includes self cleaning rotary drum screen, grease trap, flocculation – flotation, UASB anaerobic reactor, moving bed biofilm reactor, clarifier and multimedia filters. Most of the time system can remove TSS, FOG and BOD almost completely. Occasionally when chocolate candy is manufactured extremely high BOD's are present in the waste stream. On such occasions, residual BOD's are somewhat higher. Home made modifications to both bioreactors (combination of fixed and suspended media) increased the system performance during such high BOD episodes.

KEYWORDS: candy manufacturing wastewater, GEM System, modified UASB reactor, modified MBBR, TSS, FOG, BOD removal

INTRODUCTION

Bimbo Ricolino, international manufacturer of specialized candy located in Mexico City, Mexico has been very successful in global candy niche markets. Leading the line are "Clown Pops", chocolate covered marshmallows with clown face. Chocolate covered peanuts, strawberry – flavored pectin jelly and chocolate covered corn flakes are also very popular in North and South American markets. The increased production resulted in wastewater with significantly higher amount of TSS, FOG, sugar and colorants.

This was noticed by regulatory agencies and municipal water treatment plant. Ricolino agreed with the participating agencies that they will build their own wastewater treatment plant which will at most times produce wastewater of the same quality as that of the municipal plant effluents (TSS and BOD below 30 mg/l).

Ricolino plant has very limited indoors free real estate. Classical treatment approach for candy manufacturers (build and operate large volume anaerobic bioreactor) was therefore not feasible. Multistep advanced small footprint technologies were evaluated. Additional problems included high concentrations of contaminants and large variations in contaminants concentrations. Many advanced technologies were tested in the laboratory and pilot studies. Multistep advanced treatment system was designed and installed. System included grease traps, self cleaning rotating drum screen (880 microns openings), equalization tanks, flocculation – flotation (the GEM System), modified UASB anaerobic bioreactor, modified moving bed biofilm reactor (MBBR), clarifier and multimedia filters. Schematic presentation of the treatment system is shown in Figure 1.

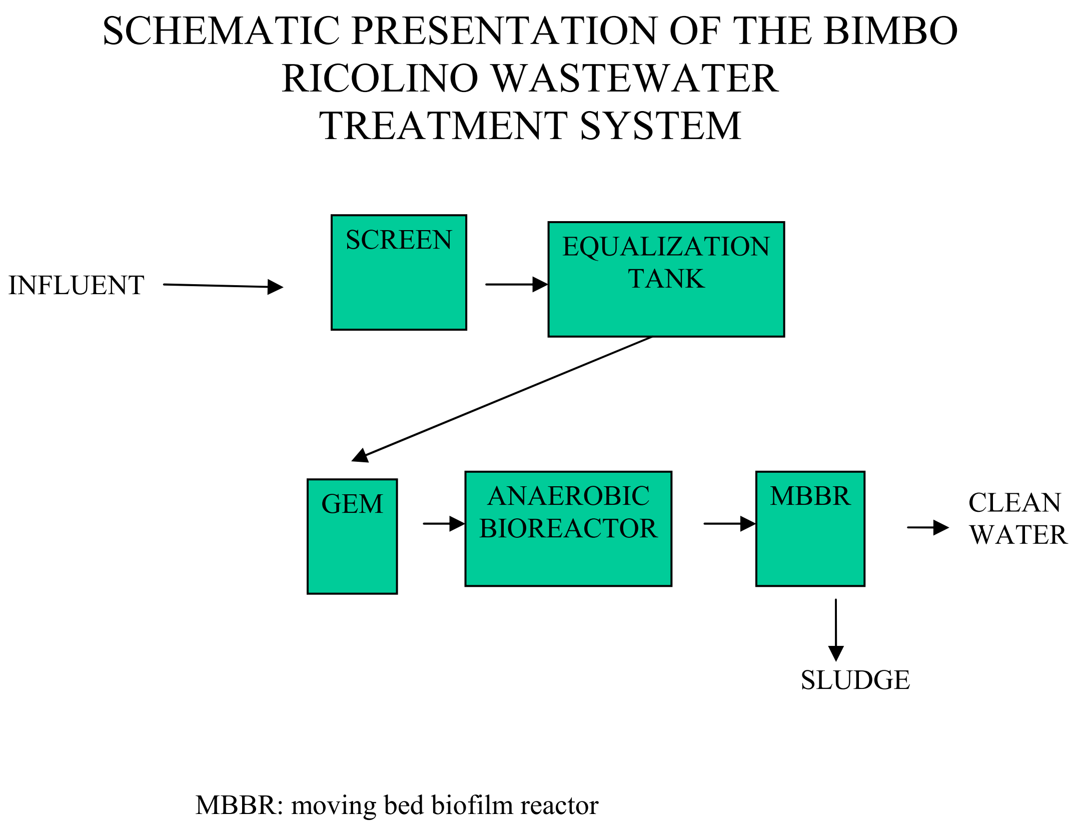

Figure 1. Schematic presentation of the Bimbo – Ricolino wastewater treatment plant

TREATMENT SYSTEM

Wastewater characteristics

Wastewater comes from washing room, boiling and pulvex grinding facilities. Such concentrated streams are diluted with cleaning in place (CIP) streams and sanitary waste. Average total flow is 20,000 gallons per day. In 2006 average TSS were 400 mg/l, COD 2,500 mg/l, FOG 350 mg/l and BOD 1,200 mg/l. After production increases in 2007 average TSS increased to 1,250 mg/l, FOG to 950 mg/l and BOD to 8,000 mg/l. When chocolate candy is manufactured boiling room wastewater can contain up to 100,000 mg/l of BOD. Grain grinding facilities also can discharge streams with up to 80,000 mg/l of BOD. Good mixing and dilution with other streams inside the equalization tanks is absolutely necessary.

Jar tests identified that flocculation – flotation can reduce TSS to less than 100 mg/l, FOG to around 12 mg/l and BOD to around 5,000 mg/l. Since water is to be treated in the bioreactors, flocculation – flotation is performed at pH 7.3. Organic coagulants and flocculants are used to achieve best contaminant removal efficiencies and driest sludge. Low molecular weight epiamine coagulant is followed by granular high molecular weight, high charge cationic polyacrylamide and then anionic high molecular weight medium charge polyacrylamide. Such approach is termed dual flocculant flocculation and is schematically presented in Figure 2. Some representative jar tests are presented in Figure 3. Coagulant is dosed at concentrations between 20 and 100 mg/l, cationic floculant at dosages between 5 mg/l and 30 mg/l and anionic flocculant at constant dosage of 10 mg/l. Average cost of chemicals to treat the wastewater is around 1 dollar per 1,000 gallons. The incoming pH of the mixed streams inside EQ tanks varies between 3.8 and 12.5. The pH adjustment in the treatment systems is absolutely necessary. Turbidity of the incoming streams is usually over 1,000 NTU. After flocculation – flotation turbidity varies between 5 and 25 NTU. Dissolved BOD's after treatment consist mostly of sugars, proteins, food colorants and food additives. Such ingredients are highly biodegradable. After flocculation – flotation wastewater contains around 15 mg/l of TKN and 25 mg/l of phosphate.

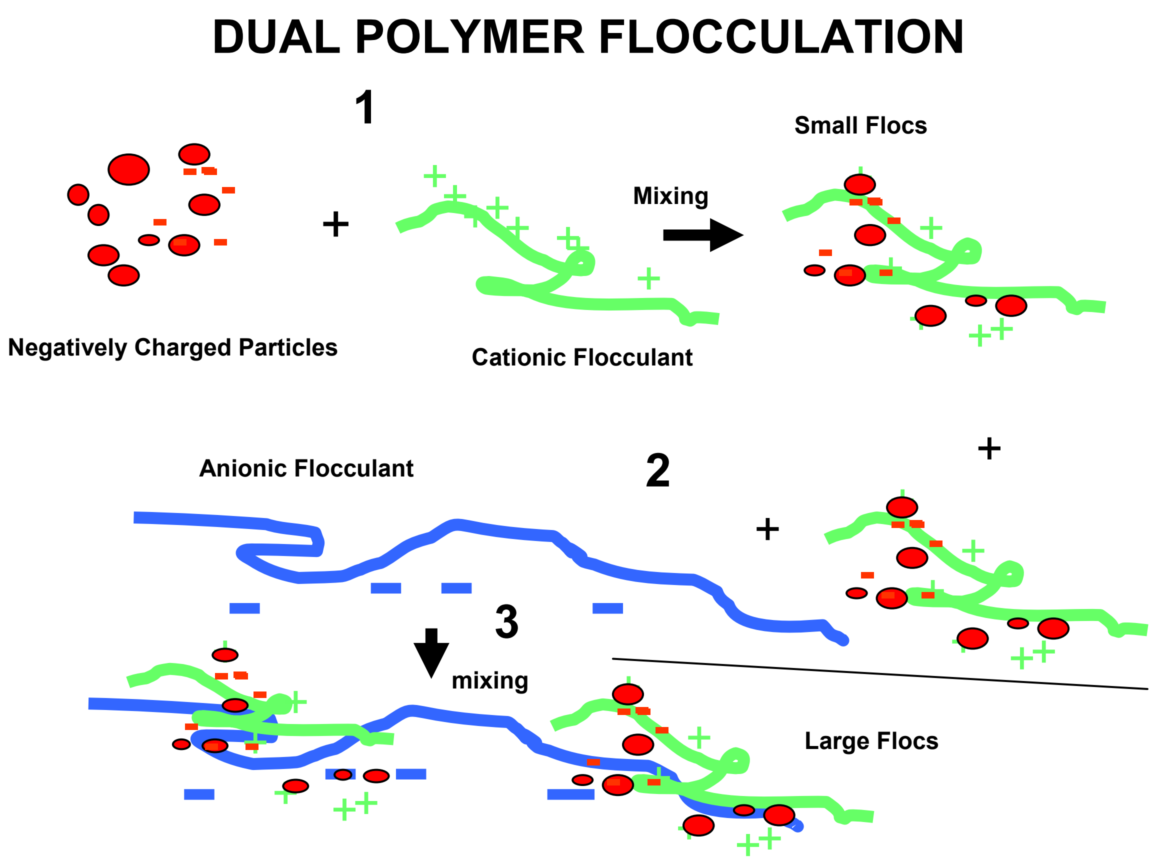

Figure 2. Dual polymeric flocculant approach.

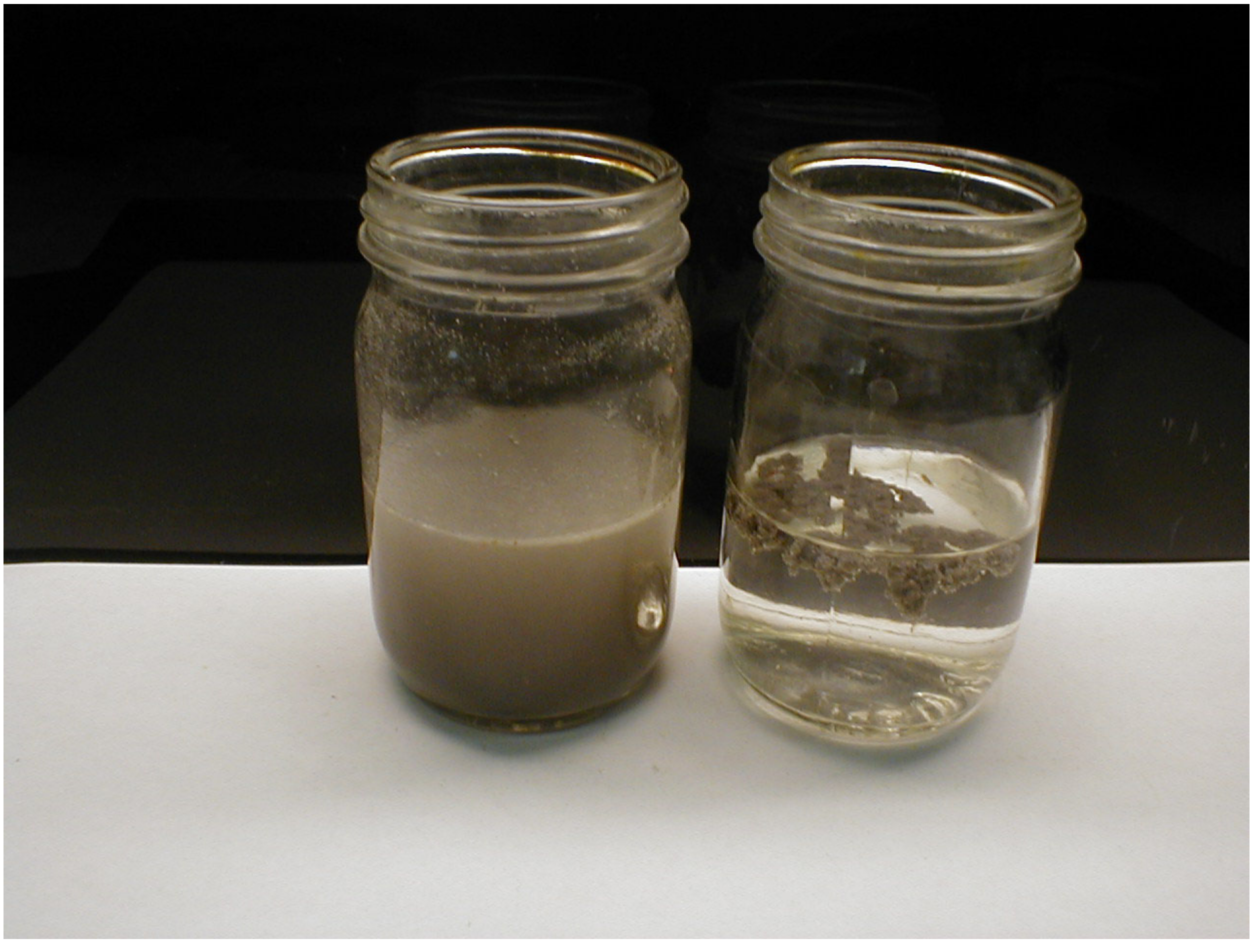

Figure 3. Jar test of chocolate containing wastewater from Ricolino plant.

Primary Treatment - Flocculation flotation with the GEM System.

Introduction to Flotation Systems

The GEM System is basically a hybrid centrifugal hydrocylone – dissolved air flotation. Flotation is a gravimetrically based solid-liquid separation technology. Most fats, oil and grease and light particles present in food manufacturing wastewater have low density and cannot be separated by sedimentation.

One of the key steps in the flotation method is the introduction of air bubbles into water. In early flotation machines coarse bubbles (2 to 5 mm) were introduced into the contaminated wastewater by blowing air through canvas or other porous material. Air can also be introduced with impeller mixers as in Induced Air Flotation Systems. Another flotation method called dissolved air flotation (DAF) is common in the treatment of oily wastewater (Kiuri, 2001). In DAF, a stream of wastewater is saturated with air at elevated pressures up to 5 atm (40-70 psi). Bubbles are formed by a reduction in pressure as the pre-saturated water is forced to flow through needle valves or specific orifices. Small bubbles are formed and continuously flowing particles are brought into contact with bubbles (Ross et al., 2003). Such bubbles rise very slowly to the surface of the tank. This is the main driver of the large dimensions of the DAF tanks.

To avoid clogging of such orifices only a fraction of already pretreated water is aerated and then recycled into the tank where bubbles nucleate under already preformed flocs. Therefore, the number of bubbles is limited and treatment of high strength food manufacturing wastewater with high TSS and FOG loads is often inefficient.

To answer these problems, centrifugal (Miller, 1981), jet and cavitation flotation (Clayton et al., 1991) systems have been developed. In these systems centrifugal forces have been used to produce smaller bubbles and enhance mixing of particles with treatment chemicals such as coagulants and flocculants. Centrifugal flotation systems are based on liquid/liquid hydrocylone technology. Contact of air, contaminants and treatment chemicals occurs inside the hydrocylone column under the influence of centrifugal forces. Solid-liquid separation occurs inside the column. This results in much faster response flotation units with smaller footprint. Flotation tanks are used only for sludge skimming. However, larger bubbles cannot remove small particles and dissolved air flotation still produces better contaminant removal efficiencies. To answer that problem, we developed the hybrid centrifugal – dissolved air flotation system, which we termed the GEM (gas – energy mixing) System. This system will be described below.

The Description of the GEM System

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 (Morse et al., 2001; Morse et al, 2004). Coagulants and flocculants can be delivered *in situ* directly into the flotation hydrocyclone unit. Pressurized air can be delivered to

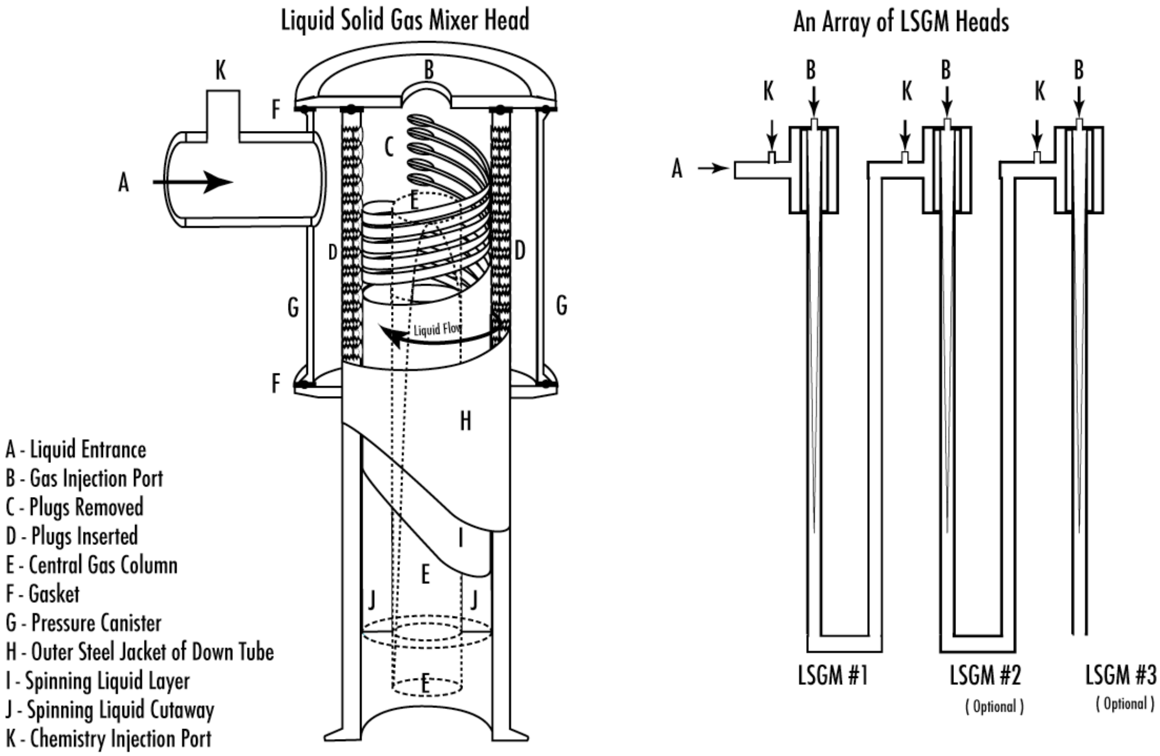

Figure 4. Schematic Presentation of the LCPP/LSGM.

LCPP heads at the same time as flocculants. Such a procedure results in flocs, which are very porous and loaded with entrained and entrapped air.

As shown in Figure 4 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. Microturbulence 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 (and more concentrated emulsions) is achieved in the LCPP. Such efficient mixing is important for proper flocculation of suspended particles. Centrifugal mixing also results in less floc breakage than with commonly used impeller or floc tube mixers.

Further modification of LCPP heads, as opposed to hydrocyclone heads, introduced multiple holes with plugs inside the LSGM heads, as shown in Figure 5. 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 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.

Hybrid centrifugal – dissolved air flotation technology (The GEM System developed at CWT [see Figure 6]) provides the best of both centrifugal and dissolved air systems: efficient continuous flow mixing and in line flocculation with the nucleation and entrainment of fine dissolved air bubbles. This development has resulted in systems with very efficient removal of particulate contaminants, a small footprint, drier sludge, durable long lasting flocs, fast response

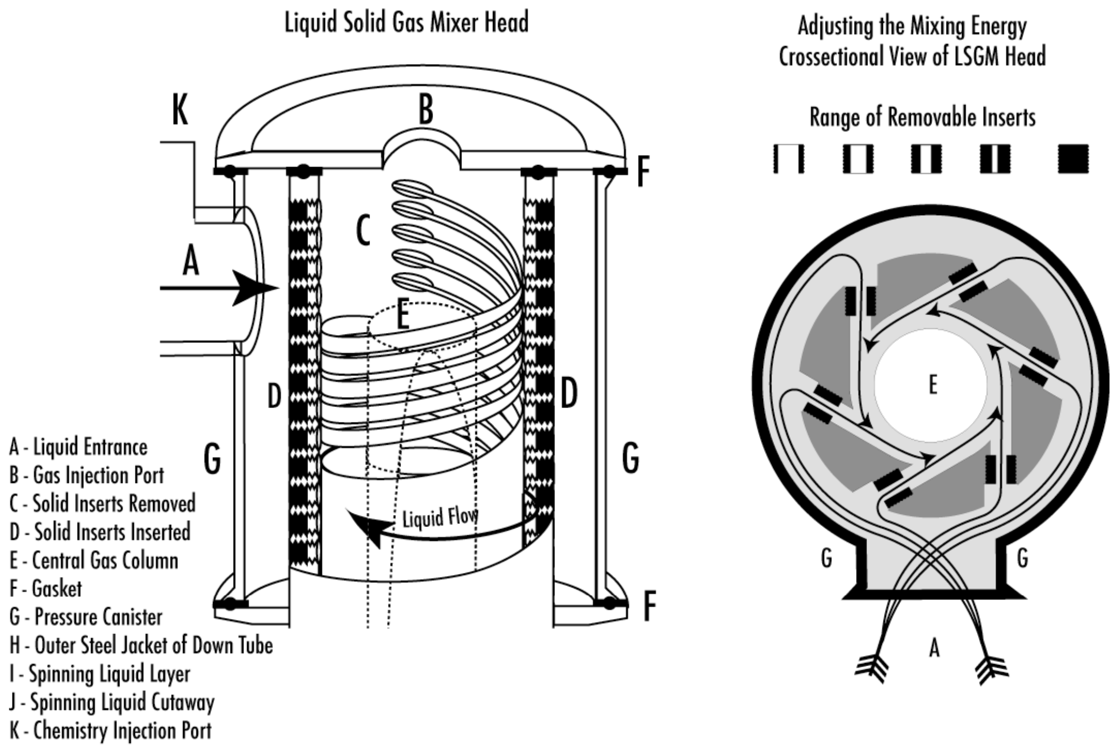

Figure 5. Schematic Presentation of the LSGM Heads.

and treatment of the total wastewater stream (no recycling characteristic for DAFs). The design of on-line turbidity or fluorescence driven sensors for automatic control of coagulant and flocculant dosage is also underway. Computational fluid dynamics (CFD) has been used to design better flotation tanks with a vortical flow pattern that results in the formation of a dense air bed inside the tank (Ta et al, 2001; Desam et al., 2001). Such fine bubble layers prevent sedimentation of already floated heavier particulates, which results in significantly higher flotation rates.

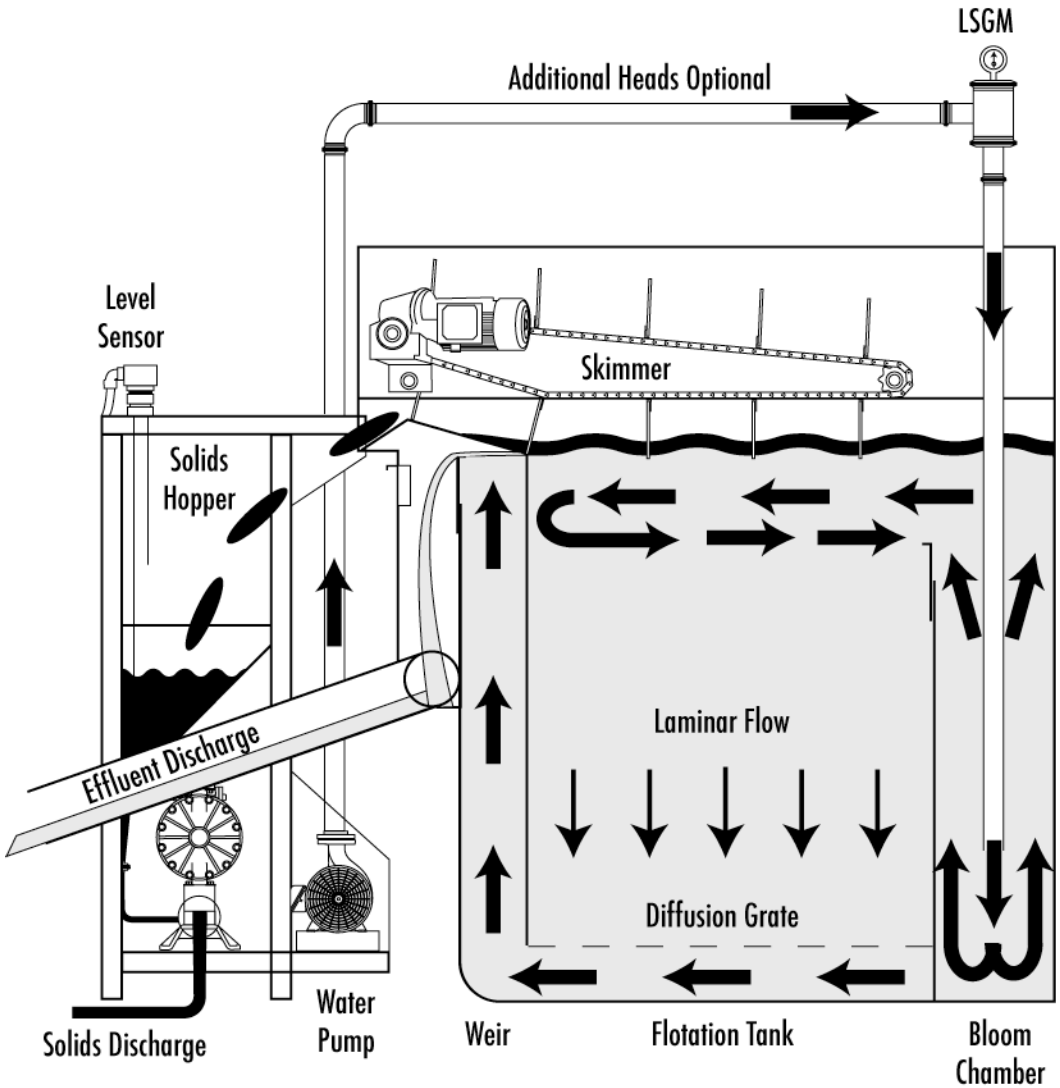

Figure 6. Schematic Presentation of the Hybrid Centrifugal – Dissolved Air Flotation System.

Using the above described dual flocculant approach and the GEM System, average TSS removals were 95% (1,300 mg/l to 50 mg/l) , COD removal 30% (8,000 to 5,500 mg/l) and FOG removal 96% (950 to 12 mg/l). Residual dissolved organic contaminants (sugars, proteins) were removed with anaerobic and aerobic bioreactors.

Secondary Treatment: Anaerobic Bioreactor

A modified UASB anaerobic reactor was installed to reduce dissolved COD from 5,000 to under 1,500 and dissolved BOD from 2,500 to less than 750 mg/l. The reactor efficiency is 70% or higher. It is an ascending flow advanced UASB reactor that was modified so that in addition to the suspended microorganisms it was also filled with 150 m^2 of media (plastic lamellae) to enhance and control the flow and enhance microorganisms grain formation. Circular tank made of fiberglass with diameter of 3.50 meters and height of 4.70 meters, with bacterial support volume of 40 m^3 is a key part of the reactor. The treatment capacity is around 85 m^3/day of wastewater. The anaerobic biodegradation produces methane gas, which is received in an expulsion bell on the top of the tank and subsequently released into the atmosphere. The clarification is carried out inside the bioreactor with inclined plate clarifier. Upon solid/liquid separation, most sludge is returned to the reactor. First sludge drain has to be performed three months after the startup. Sludge is already mostly stabilized and can be land applied.

Secondary treatment: Moving Bed Biofilm reactor (MBBR)

Activated sludge and sequence batch reactors were developed for the treatment of municipal wastewater treatment, where concentration of contaminants is low and almost constant. Biofilm bioreactor processes are increasingly being favored for food processing wastewater treatment. There are several reasons for that: smaller footprint, less sludge produced, no return activated sludge needed, biosolids that are easier to separate are produced, and attached biomass is more specialized (higher concentration of relevant organisms) at a given point of the process train.

Moving bed biofilm reactors (MBBR) are a hybrid of activated sludge and biofilter processes (Odegaard, 2004; Joslin and Farrar, 2005). Contrary to most fixed film bioreactors, MBBR utilize whole tank volume for biomass. However, contrary to activated sludge reactor, MBBR does not need return activated sludge (RAS). This is achieved by having a biomass grow on plastic high surface area carriers that move freely in the water volume of the reactor kept within the reactor volume by a sieve arrangement at the reactor outlet. At the bottom of the tank, large bubble aeration system assures mixing and floating of plastic carriers with attached biomass.

The biofilm carrier is made of high density polyethylene (0.95 $g/^{cm3}$) and shaped as small cylinders with a cross on the inside of the cylinder and "fins" on the outside. The original cylinders have a length of 7 mm and diameter of 10 mm. Later, various shapes and sizes were introduced by numerous manufacturers. One of the important advantages of the moving bed biofilm reactor is that the filling fraction of carrier in the reactor may be subject to needs. That means that by increasing the filling fraction one can increase surface area and capacity of the reactor to reduce BOD's without additional tanks. Microorganisms growing on such media are also much more resistant to pH and toxic shock as well as fluctuations in BOD's. Produced biosolids are also easy to separate and dewater.

The MBBR installed as a part of this system was installed in HDPE tank of 25,000 liters. The bioreactor tank was filled 50% with the Anox Kaldness plastic media (375 m^2/m^3). One Aerzen air blower model GM10S with the suction capacity of 6.83 m^3/min, normal condition stream of 285 NM^3/hr is used for aeration. Dissolved oxygen is kept at 2.5 mg/l or higher. The reactor reduces COD from 1,500 mg/l to less than 100 mg/l and BOD from 750 mg/l to less than 50 mg/l. Clarifier and sand filter are used to separate biosolids from the effluent. Resulting stream has TSS below 30 mg/l. Separated biosolids are returned to the MBBR to enhance its efficiency. Therefore, the MBBR becomes almost an IFAS system (combination of fixed and suspended biosolids).

Table 1. The performance of the GEM – anaerobic bioreactor - MBBR – clarifier system (average numbers for 30 days period- September 2008)

	Before GEM	After GEM	After anaerobic reactor	After MBBR
TSS/mg/l	1,250	50	1,500	25
FOG/mg/l	950	12	1	1
BOD/mg/l	8,000	5,500	1,750	30

CONCLUSIONS

The wastewater treatment plant installed to treat total wastewater flow at Bimbo Ricolino Mexico City plant produces effluent with satisfactory quality. The treatment plant consists of grease trap, screen, flocculation – flotation, UASB anaerobic reactor and MBBR followed with clarifier and sand filter. Most of the time plant produces effluents with TSS and BOD below 30 mg/l and FOG below 10 mg/l. Occasionally plant wastewater contains large amount of BOD (over 10,000 mg/l in influent). On such days, BOD's in the effluent are higher. The local municipality is satisfied with the facts that TSS and FOG's are reduced to similar levels as those in the municipal treatment plant. The real estate needed to install additional anaerobic bioreactor capacity needed to treat high levels of dissolved BOD's is unfortunately not available. Fortunately, such high BOD's get diluted with the City municipal wastewater (local plant services over 3 million people).

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