

# **Flocculation-Flotation Enables Anaerobic-Aerobic Bioreactors Treatment and Reuse of High Load Tortilla Manufacturing Wastewater**

\*Miroslav Colic, Eric Acha, Luis Rubio, Ariel Lechter

Clean Water Technology, Inc., Los Angeles, CA 90061

Email: mcolic@cleanwatertechnology.com

## **ABSTRACT**

Tortilla manufacturing plant produces high strength wastewater with TSS as high as 40,000 ppm, COD as high as 30,000 ppm and BOD as high as 25,000 ppm. The treatment System was built to reuse up to 80% of water for irrigation, floor washing or similar low grade applications. The System includes centrifuges, flocculation - flotation, anaerobic USAB bioreactor and aerobic extended aeration bioreactor followed by clarifier and chlorination. The treatment System produces water with TSS below 40 ppm, COD below 60 ppm and BOD below 20 ppm. Removing solids with centrifuges and flocculation - flotation significantly reduced the size of anaerobic bioreactor and enhanced the performance of the System

**Keywords:** high strength food manufacturing wastewater, reuse, UASB bioreactor, flotation, centrifugation, extended aeration

## **THE PROBLEM**

El Milagro tortilla manufacturer built a new plant close to Austin Texas. Manufacturing process produces heavy load wastewater with TSS as high as 40,000 ppm, COD as high as 30,000 ppm and BOD as high as 25,000 ppm. Company is environmentally conscience and planned 80% water reuse for irrigation purposes.

## **GOALS AND OBJECTIVES**

CWT and El Milagro engineers designed and built the System to treat such heavy load wastewater for 80% reuse for irrigation. The System had to be economical to operate as fully automated as possible. Laboratory pilot primary treatment tests showed that centrifuge has to be used to remove heavy load of TSS to below 5,000 ppm prior to screening and flocculation-flotation. After flotation process, the goal was to reduce TSS below 100 ppm and FOG below 10ppm. Such stream at up to 50,000 GPD will then be treated with modified UASB anaerobic bioreactor followed by extended aeration aerobic bioreactor and clarifier solid/liquid separation

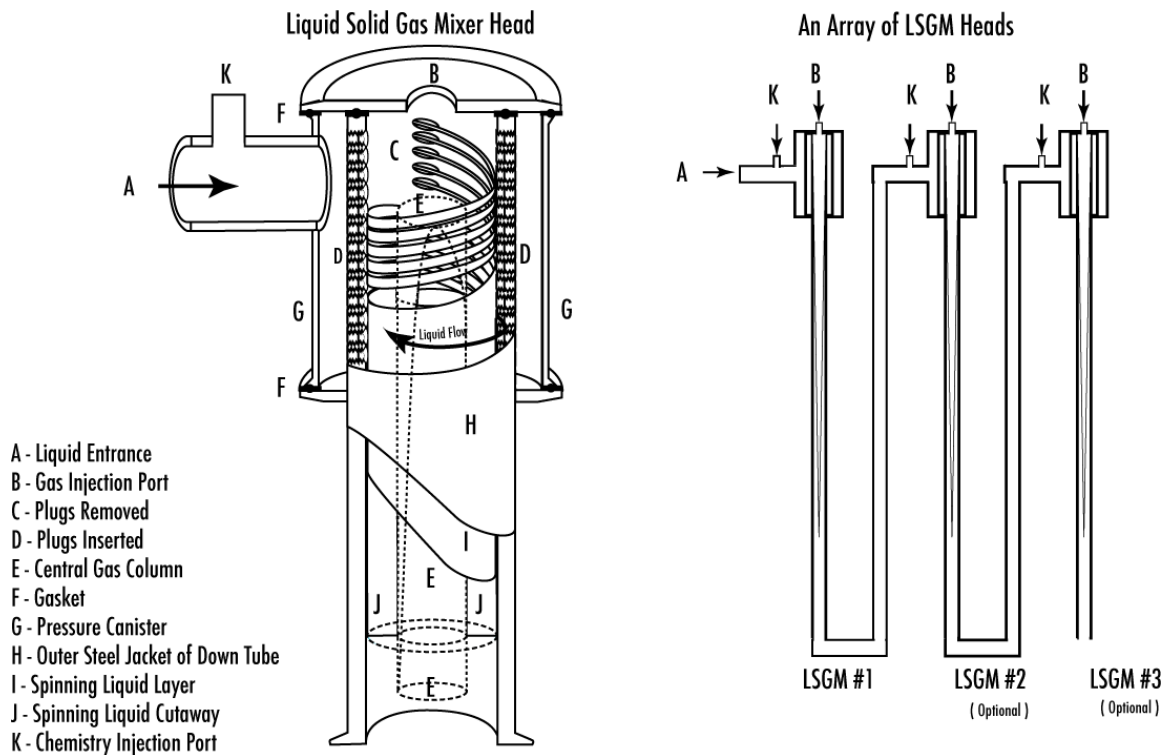
## **FULL SCALE INSTALLATION**

In 2012 as the plant was still built the installation of the full scale treatment system started. Centrifuges are used to remove heavy solids loading with great success. The flocculation-flotation GEM System is then used to further reduce TSS to below 100 ppm, FOG below 10 ppm and COD usually below 10,000 ppm, often below 5,000 ppm.

The GEM System is a hybrid centrifugal - dissolved air flotation with aeration of 100% of the stream (no recycle). Solid/liquid separation occurs inside the solid/liquid hydrocyclones and tanks are only used for skimming of sludge. Such design enables the System to run at higher HRT than the classical DAF's . To achieve that with fibrous solids one has to use high molecular weight high charge granular cationic polyacrylamides flocculants. Also pressure release orifice has to be cleaned on average once a week to remove any solids deposits. Detailed description of the GEM System follows below.

## **THE DESCRIPTION OF THE GEM FLOTATION SYSTEM**

We proposed that a more efficient flotation system (than current DAF's) 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. Coagulants and flocculants can be delivered *in situ* directly into the flotation hydrocyclone unit. Pressurized air can be delivered to



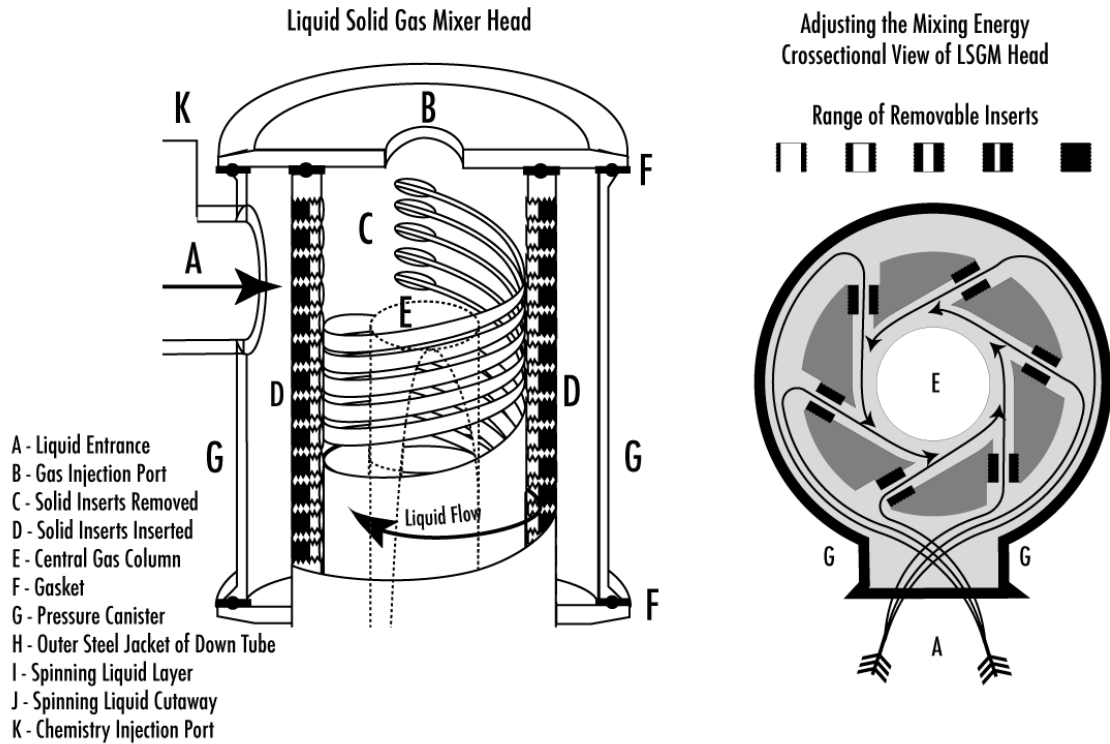
**Figure 1 – Schematic Presentation of the LCP/LSGM**

LCP 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 1 the LCP also acts as a liquid-solid-gas mixer (LSGM). Replacing the classical hydrocyclone head with the LCP 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 LCP 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 LCP. 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 LCP heads, as opposed to hydrocyclone heads, introduced multiple holes with plugs inside the LSGM heads, as shown in Figure 2. 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 3]) 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



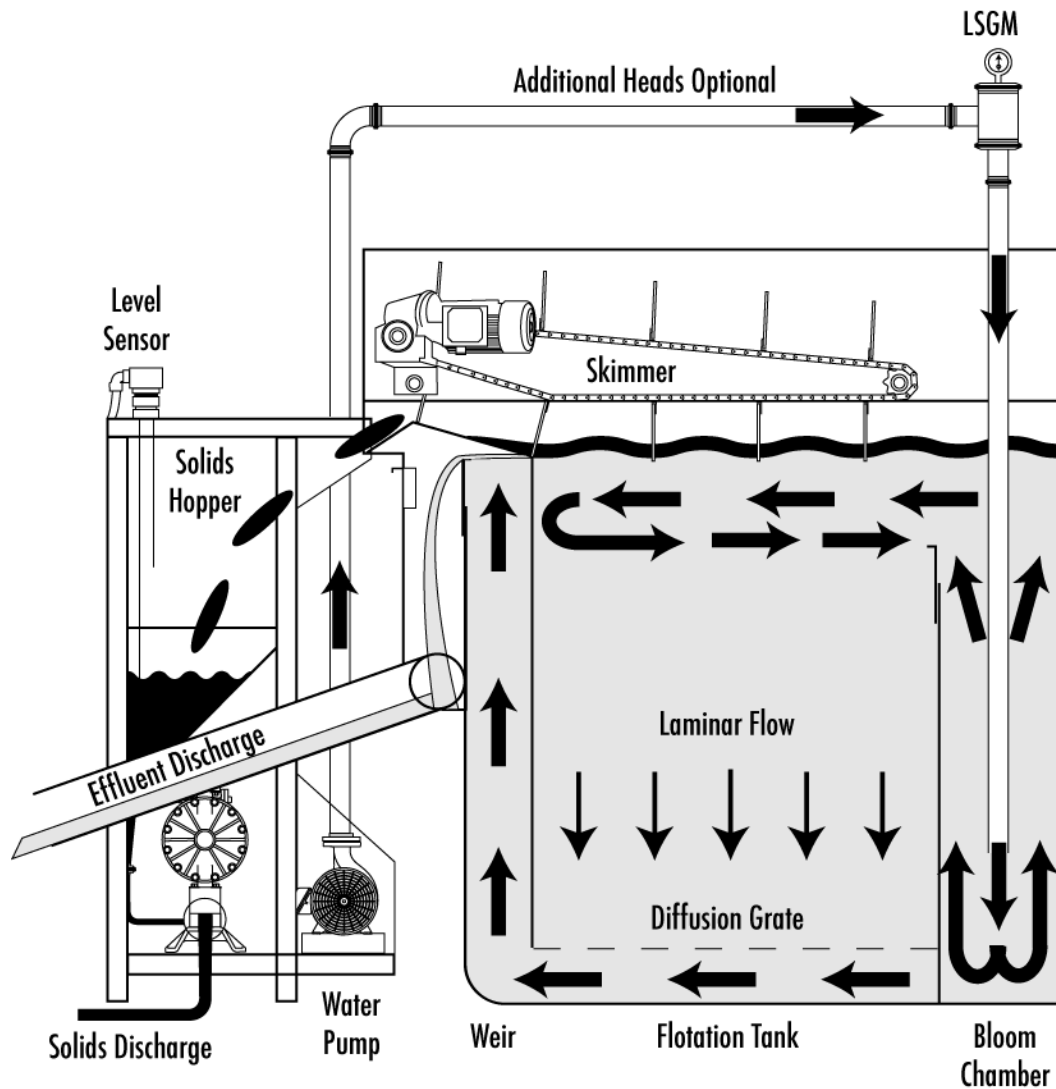
2 – Schematic Presentation of the LSGM Heads

Figure

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. Such fine bubble layers prevent sedimentation of already floated heavier particulates, which results in significantly higher flotation rates.

### **SYNERGISM OF CHEMICAL AND MECHANICAL ASPECTS OF THE SOLID/LIQUID SEPARATION SYSTEMS**

Solid/liquid separation processes are only as efficient as the weakest “link in a chain”. New generation of high performance flotation units can only deliver if appropriate chemicals are used to coagulate and flocculate particles and emulsions in wastewater.



**Figure 3 – Schematic Presentation of the Hybrid Centrifugal – Dissolved Air Flotation System**

Coagulation, flocculation and flotation are among the most effective approaches to remove fats oils and grease, suspended solids and colloidal materials (even some proteins and macromolecules) from any industrial wastewater, such as for instance food processing. Solids, colloids and macromolecules present in food processing wastewater are generally charged. Charge stabilization often produces very stable colloidal suspensions. Solids and colloids that are charge stabilized repel each other and produce systems that have a tendency to “swim” within the wastewater bulk, rather than sediment or float. Surface charge has to be neutralized in order to get particles close together so that other attractive forces such as hydrophobic or van der Waals forces result in formation of larger aggregates that either sediment or attach to bubbles and float. Most colloids, macromolecules and solids in food processing wastewater are of organic nature. Ionization of carboxyl and amino groups from fatty acids or proteins produces

some charge. Oil and grease particles are often emulsified and charge is present in the surfactants used as emulsifying agents. Many neutral colloids will preferentially adsorb hydroxyl ions and become negatively charged.

Most colloids present in any food processing wastewater are negatively charged, probably due to preferential adsorption of hydroxyl ions and widespread surface availability of carboxyl groups. The surface charge/dissociation of such groups is pH dependent. It is possible to find a pH at which total surface charge is zero (point of zero charge). At such pH colloids are quite unstable. However, coagulants and flocculants are designed so as to promote even faster, more efficient destabilization of colloids with growth of large, stable aggregates. The pH, therefore, should be adjusted close to the point of zero charge, in order to save on dosage of coagulants and flocculants needed to neutralize the surface charge. If surface charge is fully neutralized, the performance of flocculants is low.

Once the pH is adjusted, coagulation and flocculation process follow. Coagulation is addition of oppositely charged ions or molecules in order to neutralize surface charge and destabilize colloidal suspensions. Inorganic coagulants such as sulfate or chloride salts of trivalent iron (Fe[III]) or aluminum (Al[III]) have been quite popular in food processing wastewater treatment. However, such salts hydrolyze as part of coagulation process and produce oxohydroxyde sludge that is bulky and difficult to dewater. Prehydrolyzed –inorganic polymeric aluminum reagents such as polyaluminum chloride (PAC) or aluminum chlorohydrate (ACH) are more efficient in charge neutralization. Such salts also produce less bulky sludge. Cationic polyelectrolytes (organic low molecular weight polymers) such as quaternary polyamines produce less sludge that is easier to dewater. Such reagents are also much more efficient in charge neutralization. Therefore, the dosages needed to neutralize surface charge with polyelectrolytes are often more than order of magnitude lower compared to dosages of aluminum or iron salts. However, ferric salts have to be used if blood clarification is to be achieved. Precipitation of phosphate or sulfide ions also can be achieved only with inorganic ions. Finally some proteins can be removed with proper pH adjustment and use of inorganic coagulants.

Flocculation is a process of formation of large stable flocs that either sediment or float. Flocculants are reagents that achieve flocculation. Flocculants are large polymeric molecules that bind together smaller flocs produced by coagulation. Synthetic high molecular weight polyacrylamides are the most commonly used flocculants. Cationic polyacrylamides can neutralize residual negative surface charge and also bind smaller flocs together. Flocs may also be overcharged with coagulants and cationic flocculants, with subsequent use of anionic polyacrylamide. Such approach, termed dual flocculants approach, will be described in detail later in this manuscript (also see Figure 4).

Several steps are involved in the coagulation and flocculation processes. First, coagulants are added to the wastewater with the precise dosing pumps. Then coagulants are mixed with the particles in the high energy mixing process in order to uniformly distribute adsorbed coagulant molecules or ions. Upon initial charge neutralization, flocculants are added. Even more precise dosing is needed in order to avoid under or overcharging of particles. Flocculants are mixed with less energy in order to avoid breakup of formed flocs or even polymer molecules, which are large delicate chains. On the other hand, enough mixing intensity is needed to achieve uniform

distribution of polymer and adsorption on all particles, rather than over - absorption on nearby particles only. (Mixing is also needed to activate polymeric flocculants. Such giant molecules are coiled into the tight coils. Linearization is needed to achieve polymer configuration that can bind numerous smaller flocs together (see Figure 5).

Wastewater samples tested while developing the system described in the manuscript were coagulated and flocculated at numerous pHs ranging from 3 to 11. For most samples, best flocculation can be achieved at pH between 5 and 6. Removal of fine emulsions and proteins is also most efficient in this pH range. Some wastewater samples had a very small amount of TSS and colloidal materials. For such samples, the pH was adjusted between 7 and 9. Similar approach was used for samples with colloidal materials that are almost neutral. Increasing pH above 8 results in higher surface charge and stronger adsorption of flocculants. At pHs below 5, performance of flocculants was found to be sub optimal with smaller, weaker flocs and more carryover in laboratory flotation tests. At pHs above 9, consumption of coagulants and flocculants was very high.

Numerous inorganic, organic and blend coagulants were tested with food processing wastewater. Ferric (FeIII) and aluminum (III) sulfate require the highest dosages and produce sludge with the lowest % solids that is most difficult to dewater and dry. As wastewater becomes loaded with TSS and FOGs, the necessary dosages to achieve coagulation can be as high as 6,000 mg/l. These two coagulants also interfere with the performance of flocculants, producing “pinpoint” floc with very small particles and high amount of carryover (often over 200 mg/l) in laboratory flotation tests. However, if water is rich in blood proteins, small amount of ferric coagulant (10-60 ppm) is needed to clarify wastewater and reduce foaming problems.

Prepolymerized inorganic coagulants suffer from similar deficiency, namely large dosages needed; carryover after flotation produced, and sludge with low % solids produced. Needless to say, dosages are lower than that of monomeric ferric or aluminum ions based coagulants. The most popular reagents from this group are polyaluminum chlorides, (PAC) with various basicity and aluminum chlorohydrate (ACH). Also, inorganic coagulants produce sludge with tendency to sediment, rather than to float.

Organic polyelectrolyte coagulants are the most advanced new generation of coagulant reagents. Usually, those are small cationic polymers with 100% backbone charge. Polyethylenimine were the first reagents used for such purpose. Modern quaternary polyamines, epiamine, and polydiallyldimethyl chlorides (polyDADMAC's) are most often used in wastewater treatment

applications. Such reagents do not interfere significantly with the performance of flocculants. They also produce sludge with high solid % and dosages needed to coagulate the wastewater can be an order of magnitude lower than that of inorganic reagents. Total cost of wastewater treatment is actually lower when using such reagents rather than inorganic coagulants. Low molecular weight epiamines and quaternary polyamines (10,000 – 25,000 D) coagulated food processing wastewater with the lowest dosages and least interference with the performance of flocculants downstream. Higher molecular weight and crosslinked polyamines (weight over 50,000 D) interfered with the performance of flocculants, and surprisingly were less efficient in coagulating wastewater colloidal contaminants. If combination of ferric and polyamine coagulants are needed, it is often better to add them separately than as a blend. Blend coagulants contain fixed ratio of ferric to polyamine coagulants. However, when treating changing wastewater influents, the ratio of amount of ferric and polyamine ions can vary quite significantly. From economic standpoint, blend coagulants are also very expensive.

Flocculants are the key component of any successful flotation wastewater treatment. We tested granular, emulsion, direct dispersion and brine flocculants. Flocculants with molecular weight between 1,000,000 D and 70,000,000 D were tested. Flocculants with charge (mole%) between 2 and 100% were tested and the effects of ionic strength (salinity, temperature, pH and surfactant present were studied). In all cases studied, granular high molecular weight, high charge polyacrylamides performed best. Such reagents yielded best flocs, sludge with the highest % solids, and least amount of TSS in the effluent. Dual flocculant approach in which addition of cationic flocculant is followed by addition of anionic flocculant always yielded the best performance (Fan et al., 2000). Emulsion flocculants produced smaller flocs, sludge with less solids and more TSS in the effluent. The higher the % active polymer in the emulsion, the better the performance. The same applies for brine and direct dispersion flocculants. Granular high charge (50% or more), high molecular weight (5,000,000 D or higher), cationic polyacrylamides were always the cheapest solution, with the best performance, and lowest dosage needed for efficient flocculation. At high temperature (over 40° Celsius) or high salinity (over 10,000 micromhos/cm) cationic flocculants could not flocculate colloidal components anymore. Cationic polyamine coagulants were then used to overcharge colloids with the subsequent addition of granular or emulsion ultrahigh molecular weight polyacrylamides. Medium charge mole % (20-30%) or very high charge % flocculants (100%) were needed to achieve flocculation at high salinity.

# DUAL POLYMER FLOCCULATION

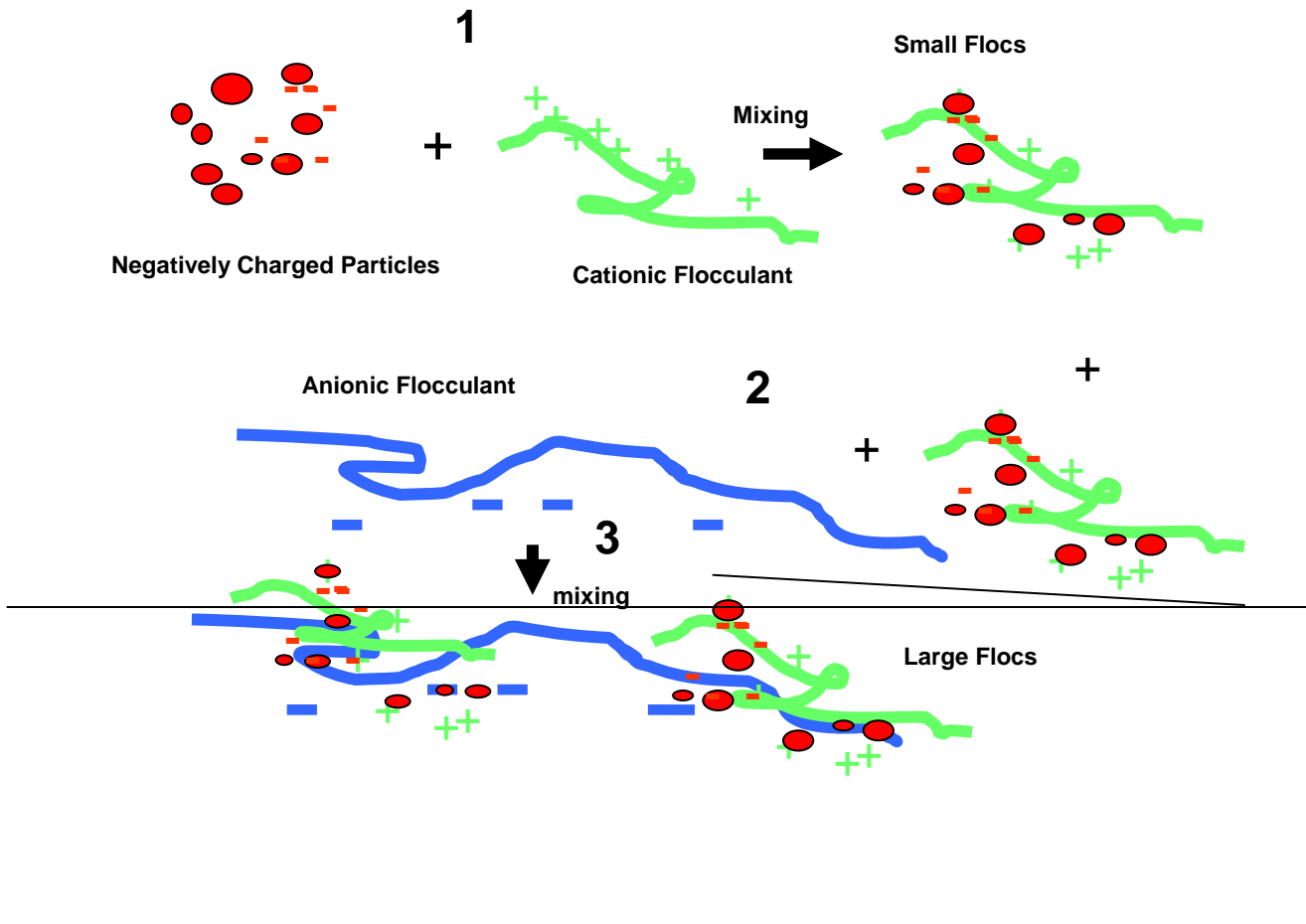
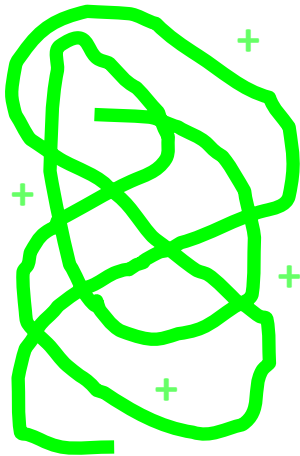


Figure 4. Dual polymeric flocculant approach.

# UNCOILING (ACTIVATION) OF POLYMERIC FLOCCULANTS

Coiled Flocculant

Partially Uncoiled Flocculant



Mixing  
→  
Oppositely Charged  
Flocculant

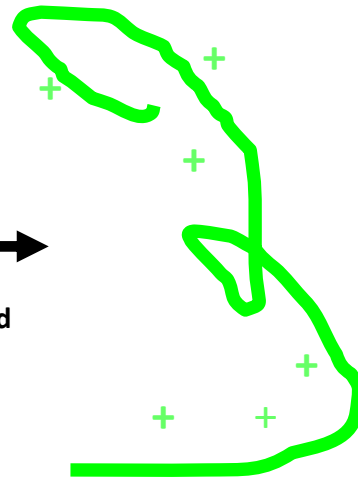


Figure 5. Uncoiling of high molecular weight polymeric flocculant molecules.

## **EL MILAGRO-A BRIEF DESCRIPTION OF THE BIOLOGICAL PROCESS**

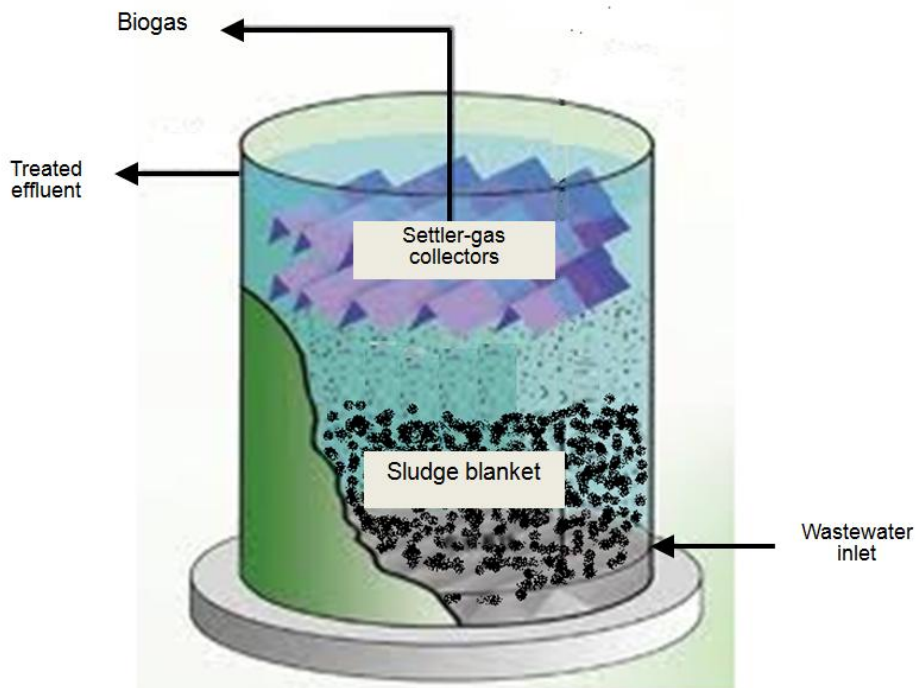
### **Upflow Anaerobic Sludge Blanket (UASB) Reactor**

The concept of the UASB reactor consists of a vessel in which the wastewater flows upward through an anaerobic sludge bed comprised of self-immobilized microbial communities. The wastewater is fed into the bottom of the reactor through distribution pipes that extend throughout the width of the reactor. As the wastewater passes through the sludge bed, it comes in contact with the microorganisms and anaerobic degradation occurs. The treated effluent leaves through an outlet at the top of the reactor. The produced biogas causes hydraulic turbulence as it moves upward through the reactor, providing adequate mixing within the system and eliminating the need for mechanical mixing. Granule (biomass) retention is facilitated by the presence of a three-phase separator (solid-liquid-gas separator or settler-gas collector) specially designed at the top of the reactor, where the water phase is separated from sludge solids and gas. The range of wastewaters successfully treated using UASB technology is constantly expanding to include, not only high-strength industrial wastewaters, but also recalcitrant, toxic and low-strength wastes. The high biomass concentration within the UASB reactor results in rapid transformation of the contaminant to biogas, allowing for the application of high loading rates due to its design with a highly active biomass concentration. In other words, the soluble Chemical Oxygen Demand (COD) is readily converted to biogas, which is composed mainly by methane (65-70%) and carbon dioxide (30-35%) The produced biogas is collected through the settler-gas collectors, conducted to the biogas chamber and exits through a manifold and into a main line where it is collected for recovery or burning it.

Its advantages are:

- High organic removal capacity (80-90% of COD removal)
- Short hydraulic retention time
- Low energy demand, in contrast it produces biogas which is a fuel gas

- Long experience in practice
- Minimizes the energy required in the next aerobic step, specially if it is compared with a whole aerobic facility
- The withdrawal sludge is completely digested and is adequate for agricultural purposes or soil amendments. It must be purged through a progressive cavity pump.



**Figure 5. Schematic of the UASB reactor**

In this case, the biological treatment starts with the anaerobic process based on UASB reactor concept. As already mentioned before, during anaerobic degradation the organic matter is mainly converted to methane, carbon dioxide and water. In order to have operational stability and flexibility, the anaerobic process was divided in two modules with the same internal design.

Firstly, the wastewater is pumped to each UASB reactor by means of centrifugal pumps, and the inlet flow rate is uniformly distributed at the bottom through a distribution pipeline arrangement. Once this, the wastewater passes through sludge bed composed by granular anaerobic sludge (biomass). This biomass treats the organic pollutants and they are converted to biogas. There are settler-gas collectors (solid-gas-liquid; SGL separator) at the reactor top. This SGL separator

captures the biogas produced during anaerobic degradation, avoiding that it comes out within the treated water. The biogas collected is transported to the biogas flare. The biogas velocity into the UASB reactor will be high and in order to avoid an excessive solid (biomass) evacuation in the outlet by this biogas effect, a pre-SGL separator (first line of settler-gas collectors) was placed in the middle of the reactor height as well as a packing media specially designed for biomass detention, thus a sedimentation step occurs into the SGL separator and the most solids that could have been transported at the top reactor (mainly anaerobic biomass), they shall be retained and returned back to the bottom only by a simply physical sedimentation. The treated effluent (biogas-free and clarified water) is collected by weirs (launders) placed at the top. The anaerobic outlet falls in a splitter box where a part of this liquid (one time the design flow rate) will continue to the next aerobic step (two reactors) and the other one shall be divided in two, then half time the design flow rate will be recycled to the feeding tank of the primary treatment (GEM system) and the other half time the design flow rate will be returned to the feeding tank of the UASB reactors. The fact of recycling half time of design flow rate has a double purpose: the wastewater pollutant dilution and to realize the calcium precipitation as calcium carbonate ( $\text{CaCO}_3$ ), due to this kind of wastewater has a high calcium concentration that should be removed before entering to the biological process.

The anaerobic effluent has sodium bicarbonate presence that was naturally produced in the UASB reactor, and then this bicarbonate shall react with the calcium forming calcium carbonate precipitate that can be removed in the GEM system by flotation. However, a sodium carbonate dose might be added although the main objective of this recycled anaerobic effluent would avoid the use of chemicals.

The wastewater characteristics and design conditions of the anaerobic process are the following:

**Table 1. Wastewater Characteristics to UASB reactor**

<i>Description</i>	<i>Unit</i>	<i>Value</i>
Flow rate (Q)	l/s	3.79
Inlet Chemical Oxygen Demand (COD)	mg/l	20,000
Inlet Biochemical Oxygen Demand (BOD)	mg/l	14,000
Inlet Total Suspended Solids (TSS) <sup>1</sup>	mg/l	100
<sup>1</sup> Assume 75% of TSS are Volatile Suspended Solids (VSS)		

**Table 2. UASB Reactor Design**

<i>Description</i>	<i>Unit</i>	<i>Value</i>
<b>Design conditions</b>		
COD Removal	%	76.3
BOD Removal	%	86.6
Outlet Chemical Oxygen Demand (COD)	mg/l	4,744
Outlet Biochemical Oxygen Demand (BOD)	mg/l	1,877
Outlet Total Suspended Solids (TSS)	mg/l	150
Hydraulic retention time (HRT)	h	44.2
Organic Loading Rate	KgCOD/m <sup>3</sup> d	10.9
<b>Basin design</b>		
Total effective volume	m <sup>3</sup>	602.3
Number of basins	-	2
Required effective volume per basin	m <sup>3</sup>	301.15
Diameter	m	6.6
Effective depth	m	8.8
Free board	m	1.0
Total depth	m	9.8
<b>Biogas production</b>		
Biogas production rate (1atm, 0°C)	Nm <sup>3</sup> Biogas/kg COD <sub>removed</sub>	0.42
Biogas produced (1atm, 0°C)	Nm <sup>3</sup> Biogas/d	2,112.0
Biogas produced (site conditions)	m <sup>3</sup> Biogas/d	2,357.5
Methane content	%	70

## Activated sludge process

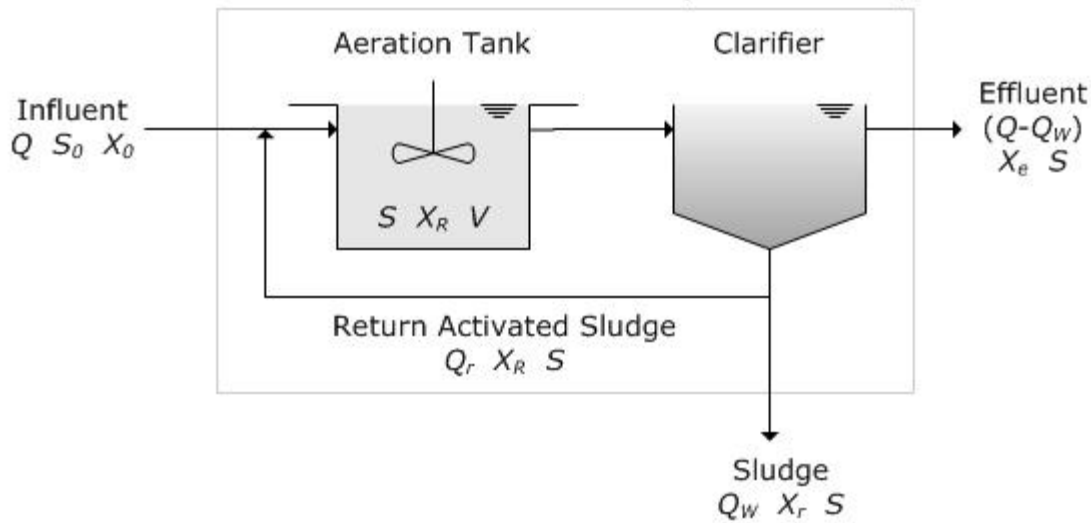
The activated-sludge process is a biological method of wastewater treatment that is performed by a variable and mixed community of microorganisms in an aerobic environment. These microorganisms derive energy from carbonaceous organic matter in aerated wastewater for the production of new cells (60%) in a process known as synthesis, while simultaneously releasing energy through the conversion of this organic matter into compounds that contain lower energy, such as carbon dioxide and water (40%), in a process called respiration. As well, a variable number of microorganisms in the system obtain energy by converting ammonia nitrogen to nitrate nitrogen in a process termed nitrification. This consortium of microorganisms, the biological component of the process, is known collectively as activated sludge.

The overall goal of the activated-sludge process is to remove substances that have a demand for oxygen from the system. This is accomplished by the metabolic reactions (synthesis-respiration and nitrification) of the microorganisms, the separation and settling of activated-sludge solids to create an acceptable quality of secondary wastewater effluent, and the collection and recycling of microorganisms back into the system or removal of excess microorganisms from the system. The main physical parts of the process are the following:

- Aeration tank where air (or oxygen) is injected in the mixed liquor by means an air blower.
- Settling tank (usually referred to as "final clarifier" or "secondary settling tank") to allow the biological flocs to settle, thus separating the biological sludge from the clear treated water.

Its advantages can be described as follows:

- A final effluent of high quality is produced such that it does not require high dilution for disposal.
- It is a good polishing step for treating effluents from anaerobic reactors.
- High organic removal capacity (80-90% of BOD removal).



**Figure 6. Schematic of the activated sludge process**

Subsequently the wastewater splitter box has two independent compartments. The first compartment has four divisions, and each division was designed to receive a quarter of the anaerobic effluent. Two divisions shall allow recycling anaerobic effluent while the other two divisions shall be utilized to feed the two aerobic reactors. The other compartments shall receive and distribute the return activated sludge in two divisions. The return activated sludge shall be sent to the splitter box through a centrifugal pump. Also the waste activated sludge has to be extracted from the system by means of a pump.

The anaerobic effluent is mixed with return activated sludge to form mixed liquor. The mixed liquor is aerated for a specified length of time. During the aeration the activated sludge organisms use the available organic matter as food producing stable solids and more organisms. The suspended solids produced by the process and the additional organisms become part of the activated sludge. The solids are then separated from the wastewater in the secondary clarifier. The solids are returned to the influent of the aeration tank (return activated sludge). Periodically the excess solids and organisms are removed from the system (waste activated sludge). Failure to remove waste solids will result in poor performance and loss of solids out of the system over the secondary clarifier tank effluent weir. In order to obtain a higher settling surface, the secondary clarifier has been provided with a bed of tube settlers.

Finally, the clarified effluent can be discharged to the sewer system or it can be post-treated (disinfection and filtration) for reuse purposes.

The wastewater characteristics and design conditions of the anaerobic process are the following:

**Table 3. Wastewater Characteristics to Aerobic reactor (Activated Sludge process)**

<i>Description</i>	<i>Unit</i>	<i>Value</i>
Flow rate (Q)	l/s	3.79
Inlet Chemical Oxygen Demand (COD)	mg/l	4,744
Inlet Biochemical Oxygen Demand (BOD)	mg/l	1,877
Inlet Total Suspended Solids (TSS) <sup>1</sup>	mg/l	150
<sup>1</sup> Assume 75% of TSS are Volatile Suspended Solids (VSS)		

**Table 4. Aerobic Reactor Design**

<i>Description</i>	<i>Unit</i>	<i>Value</i>
<b>Design conditions</b>		
COD Removal	%	>86.7
BOD Removal	%	>89.3
TSS Removal	%	83.3
Outlet Chemical Oxygen Demand (COD)	mg/l	<630

Outlet Biochemical Oxygen Demand (BOD)	mg/l	<200
Outlet Total Suspended Solids (TSS)	mg/l	25
Hydraulic retention time (HRT)	h	128.6
Sludge age	d	27.4
Design F:M	Kg BOD/kg VSS-d	0.13
Mixed liquor suspended solids (MLSS)	mg/l	4,000

### Basin design

Total effective volume	m <sup>3</sup>	1,752.16
Number of basins	-	2
Required effective volume per basin	m <sup>3</sup>	876.08
Diameter	m	13.1
Effective depth	m	6.5
Free board	m	0.5
Total depth	m	7.0

### Air requirements

Air requirement	m <sup>3</sup> /10 <sup>3</sup> m <sup>3</sup> .min	19
Air flow rate (SOTE)	m <sup>3</sup> /h	1,997.5
Discharge pressure	psig	10.12
Total blower power (BHP)	HP	85.6

### Sludge production

Sludge production rate	Kg TSS/kgBOD <sub>removed</sub>	0.410
Sludge production	kgTSS/d	248.6
Waste activated concentration	mg/l	7,500
Waste activated sludge flow rate (Qw)	m <sup>3</sup> /d	33.15

Return activated sludge ratio (Qr/Q)	-	1.14
<b>Return sludge flow rate (Qr)</b>	m <sup>3</sup> /d	373.9

<b>System Performance</b>	<b>COD/ppm, 2012 2013</b>		<b>TSS/ppm, 2012 2013</b>	
EQ tank after centrifuges	7,000	13,800	800	2,400
GEM effluent/ppm	4,500	7,900	102	135
UASB effluent/ppm	280	1,350	N/A	N/A
Aerobic clarifier	44	55	18	22
Effluent/ppm				

Secondary clarifier effluents also have less than 1 ppm of total phosphorous and 1 ppm of TKN. Most of the time, FOG's are nondetectable. Calcium concentrations are high up to 400 ppm. Water softener will be installed to prevent irrigation nozzles fouling. Also we may install filters to reduce TSS to close to zero to prevent irrigation nozzles fouling.



**Figure 7. UASB anaerobic bioreactor tanks**



**Figure 8. Extended aeration aerobic bioreactor tanks**



**Figure 9. Top view of the aeration tank**



**Figure 10. High performance clarifier installed after extended aeration tanks**

## **CONCLUSIONS**

The treatment System consisting of solid separation (centrifuges and flocculation -flotation), biodegradation (anaerobic UASB followed by aerobic extended aeration bioreactors) and clarification was installed to treat high strength tortilla manufacturing wastewater. Multistep treatment with solids removal prior to biodegradation is very effective. Solids removal significantly reduced BOD and COD and enhances the performance of the System. Final effluents TSS and COD/BOD are very low. This gives the manufacturer the flexibility to either discharge water to the City, into the local waterways or reuse water for irrigation.