REUSE OF CALIFORNIA BRINE OLIVE OIL PROCESSING WASTEWATER TO MEET ZERO DISCHARGE GOAL

Miroslav Colic*, Wade Morse**, Jason Hicks**
*Clean Water Technology, Inc.
6860 Cortona Dr., Building A
Goleta, CA 93117
mcolic@cleanwatertech.com

**Clean Water Technology, Inc.

ABSTRACT

Reuse of low strength municipal wastewater is becoming quite common and many technologies are available for that purpose. However, treatment and reuse/recycling of high strength industrial wastewater is still a challenge. In this paper we present some case studies with implemented integrated systems to achieve zero discharge goal.

We will concentrate on the description of a wastewater recycling/reuse system that was implemented at an olive processor plant in California. Olive processing produces large amounts of high strength wastewater with significant amounts of suspended solids, oil and grease, dissolved organics and salts (brine and caustic). The integrated wastewater treatment system was installed to achieve a zero discharge goal. The integrated system included solid screens, chemical flocculation, centrifugal flotation, ultrafiltration, reverse osmosis, ozonization, carbon filters, chlorine dioxide disinfection and evaporation.

The integrated system achieved the zero discharge goal. However, concentration ratios of ultrafiltration and reverse osmosis devices and maximum flows were lower than predicted from pilot studies. The cost of treatment was high ($20 per 1000 gallons of treated water). The reverse osmosis system required cleaning with chemicals several times a day and energy costs of running the system were high.

In more recent installations, it is shown that more efficient integrated systems can be implemented to achieve zero discharge goals at similar food processing plants. A system that includes flocculation/flotation, anaerobic and aerobic bioreactors and, if needed, low pressure fouling resistant reverse osmosis for salt removal can achieve similar goals at much lower cost of treatment. However, initial installation costs of bioreactors are higher, particularly for high flow applications (100 gallons per minute or more).

KEYWORDS

Industrial wastewater reuse, brine, zero discharge, integrated treatment system

INTRODUCTION

Wastewater treatment plants are designed to meet different challenges. Municipal wastewater treatment plants treat large amounts of low strength, diluted wastewater with relatively low amounts of suspended and dissolved contaminants. In recent years more emphasis has been placed at pretreatment of more concentrated high strength industrial or agricultural wastewater at the point of origin. Such an approach can significantly lower pressure at cash strapped municipal facilities everywhere.

Wastewater recycle/reuse is the ultimate goal of any treatment plant. Modern membrane treatment and membrane bioreactor technologies enable the reuse/recycle of wastewater at some municipal plants. In addition to more common irrigation reuse, replenishing of local groundwater or surface reservoirs is becoming a reality.

In an industrial wastewater plant the ultimate goal is a zero discharge facility with all water feeding back directly into the plant for reuse. Such an approach not only helps preserve the environment but also saves on potable water use. Needles to say, if water is to be reused in the plant processes, it has to be cleaned from almost all contaminants and microorganisms. This intended goal has to be achieved at an economically feasible cost of total treatment.

Integrated wastewater treatment systems have to be implemented to achieve zero discharge goals. Industrial high strength wastewater often contains high amounts of suspended solids, free and emulsified fats, oil and grease, dissolved organic materials and dissolved salts. It is particularly common to encounter wastewater that contains a mixture of suspended particles and stable oil emulsions. It is difficult to remove oily contaminants from wastewater and other natural and industrial systems containing oil. Oil can be present as a non - dispersed surface layer, usually floating at the air/water interface. Such layers can easily be removed. On the other hand, if oil is present as a dispersed phase in the form of fine droplets (oil in water emulsions), separation is much more difficult. Many emulsions are stabilized with surfactants or other emulsifying agents. Modern emulsions often contain droplets, which are very small (size range of less than 10 microns) and stabilized with powerful emulsifying agents. De-emulsification and oil extraction from such systems present huge challenges. Moreover, such processes have to be economically feasible to be accepted by industry.

Screens usually have to be used to remove large particles. Coagulation, flocculation and flotation are commonly used to remove suspended solids and fats oil and grease. Numerous options exist to remove fine colloidal solids, macromolecules and dissolved small organic molecules. Integrated membrane technologies such as ultrafiltration followed by reverse osmosis can be used to achieve this goal. Alternatively, biodegradation can be used to remove finely suspended and dissolved organic biodegradable materials. If salts are present, reverse osmosis or ion exchange are implemented at the end of process. Disinfection is commonly applied at the end of the treatment process. Careful analysis including pilot studies should be performed before designing and building any integrated wastewater treatment system. We will describe one particular case study below.

CASE STUDY: INTEGRATED SYSTEM FOR WORLD'S FIRST ZERO DISCHARGE OLIVE PROCESSOR WASTEWATER TREATMENT FACILITY

Overview

In 1997 Tri Valley Growers (TVG) completed installation of an $8.4 million dollar integrated membrane based wastewater treatment system to achieve the goal of zero discharge at the Oberti Olive Plant in Madera, California. Historically, the plant used clay-lined evaporation ponds to hold the brine and evaporate the liquid with solar energy. Over the years, the plant added evaporation ponds, as needed to handle production expansion needs. However, clay's porous nature allowed slow seepage of salts into the local groundwater. Stricter regulations implemented by the Regional Water Quality Control Board (RWQCB) required installation of double lining plastic evaporation pond to avoid seepage. Additionally RWQCB required the installation of a leachate collection system. Complete cost of the double plastic lining and leachate collection facility was estimated to over $40 million. Cheaper alternatives had to be considered.

Oberti Olive Plant processed about 20,000 tons of black ripe olives per year. Roughly 360 million cans were shipped each year. A secondary product was olive oil, with about 40,000 to 80,000 gallons shipped annually in 55-gallon drums.

Olive processing involves a three - step process: receiving, curing and canning. In step one the crop is cleaned, preprocessed and stored in large tanks. In step two raw olives are processed in a caustic solution (curing). In a step three the olives are pitted, sliced and canned. Olive pits are processed to recover saleable olive oil and processed pits are sold to a bio-waste burner. Fresh water was pumped from private wells at a rate of about 1.3 million gallons per day. Improvements in olive curing process reduced this need to 800,000 gallons a day.

Zero Discharge Plant Design Overview

Plant operation personnel identified six wastewater streams that would be handled by the new integrated treatment system designed to replace brine evaporation ponds: olive oil processing water, cannery processing water, low-to-neutral pH vat room (curing) processing waters, high pH-vat room processing waters, olive storage water and storm water runoff.

Several options have been considered to treat these wastewater streams. Double-lined ponds are not environmentally sound and had the largest capital cost of installations. Bioreactors with filtration, evaporation and drying had lower capital cost, but for such high flows (800,000 gallons per day) and contaminant loads in wastewater, the cost of installing and running an aerobic bioreactor for polishing were still considered too high. Plant operators were also worried that seasonal and daily variations in contaminant loads could upset microorganisms in bioreactors too often.

Membrane filtration with integrated ultrafiltration and reverse osmosis membranes at the center of the process was identified as the most feasible solution. The TVG team worked together with the California Institute of Food and Agricultural Research (CIFAR) at the University of

California Davis, the Electric Power Research Institute (EPRI), the RWQCB, and membrane vendors such as GEA/Niro and Osmonics/Desal to develop a solution tailored to Oberti plants needs. Our team at CWT was involved in the design and implementation of flocculation/flotation systems to pre-treat water ahead of UF membranes and remove as much as possible of suspended solids and oils and grease. After 13 pilot plant studies with mathematical models used to design scale up systems, the following process was designed (see Figure 1 and reference Moore et al. 2000):

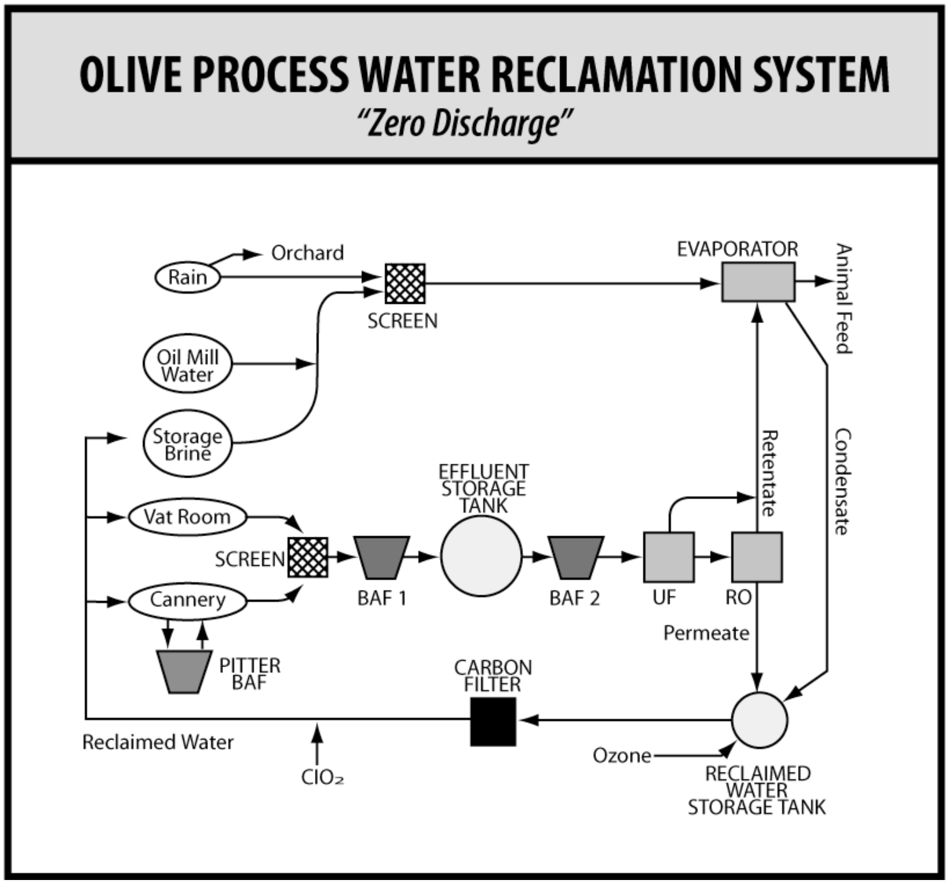


Figure 1 **Schematic Presentation of the Zero Discharge Olive Processing Wastewater Treatment System**

Olive wastewater from the brine storage tanks and the oil mill was prescreened and pumped directly to the evaporators. Wastewater from the vat room (i.e. olive curing area) and cannery was pre screened and treated with flocculation/flotation before pumping to a million gallon effluent storage tank. Mixed effluent was further treated with more stringent flocculation and flotation to remove as much solids and oil and grease as possible. After flotation, the effluent was treated with the spiral wound ultrafiltration (UF) membranes, which filter out the remaining fine solids, oil and grease, macromolecules and colloidal materials. Permeate containing salts, and dissolved organic materials, were pumped to a spiral wound reverse osmosis (RO) system.

Retentate/concentrate from UF and RO systems were pumped to evaporator. After evaporation, the solids from the system were sold as animal feed. Permeate was stored in clean water storage tanks and reused in the plant. To further remove trace organic impurities and microorganisms from treated water, ozonization, carbon filtration and chlorine dioxide disinfection were added to the system. The integrated water reclamation system is schematically presented in Figures 1 and 2. The performance of various components of the system is illustrated in the Figure 3.

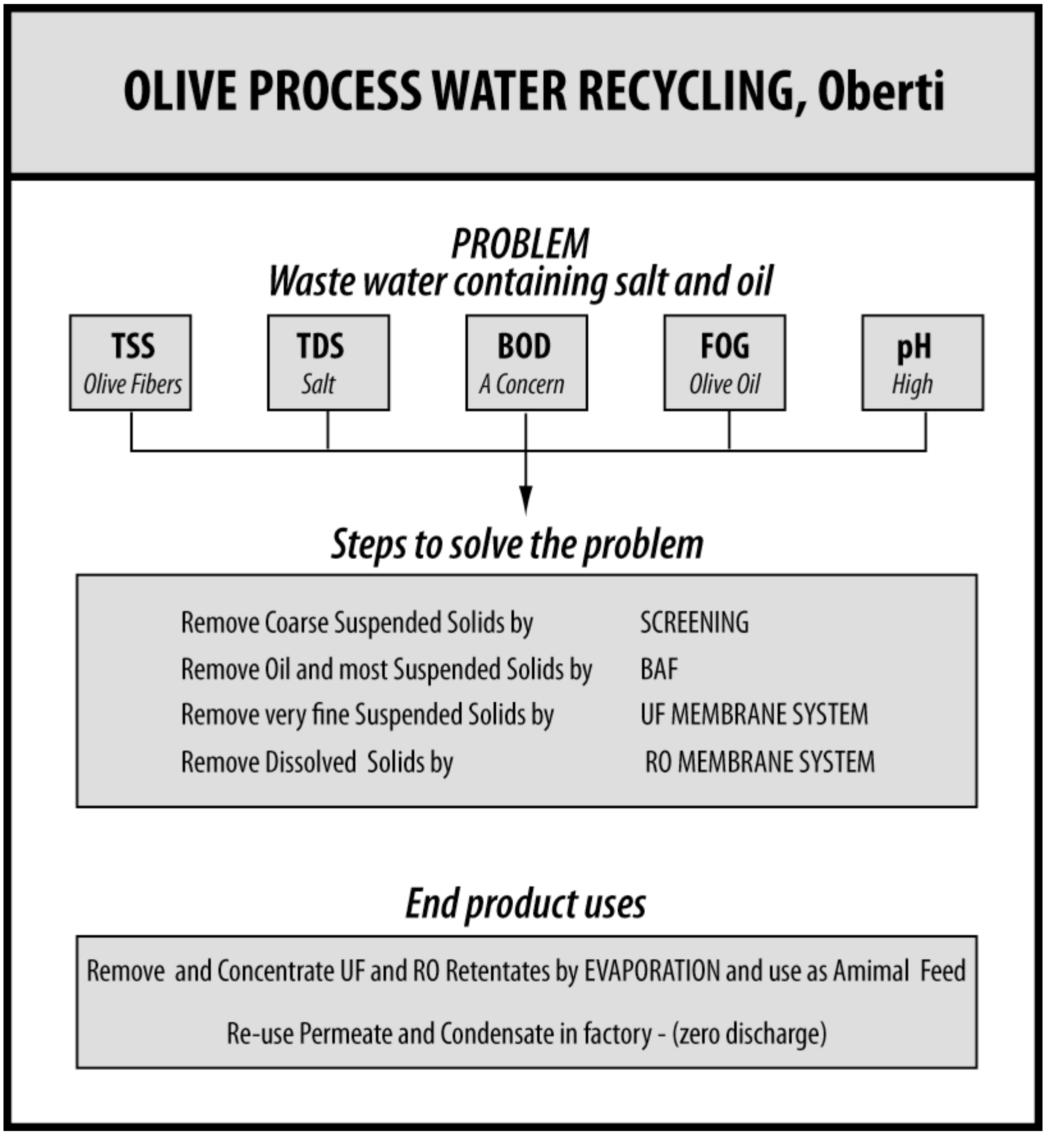
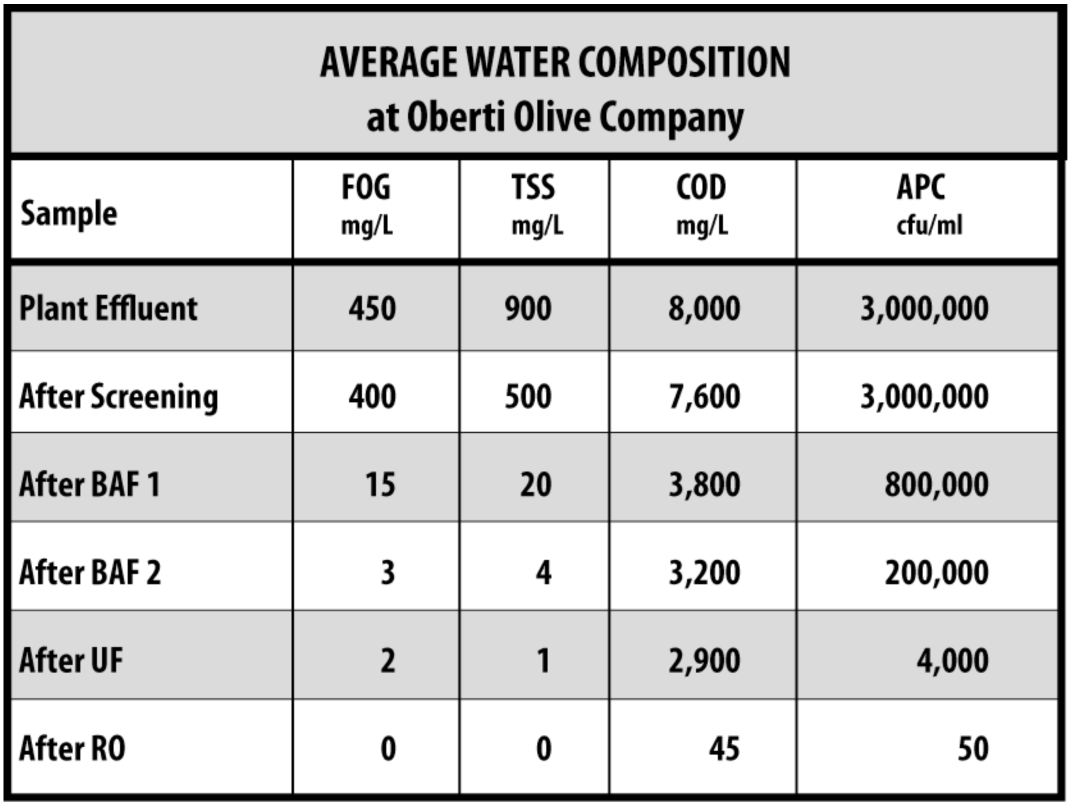


Figure 2 **Schematic Presentation of the Goals – Steps in Zero Discharge Olive Processing Wastewater Treatment System**



AVERAGE WATER COMPOSITION
at Oberti Olive Company

Sample	FOG mg/L	TSS mg/L	COD mg/L	APC cfu/ml
Plant Effluent	450	900	8,000	3,000,000
After Screening	400	500	7,600	3,000,000
After BAF 1	15	20	3,800	800,000
After BAF 2	3	4	3,200	200,000
After UF	2	1	2,900	4,000
After RO	0	0	45	50

Figure 3 Schematic Presentation of the Performance of the Zero Discharge System for the Treatment of Olive Processing Wastewater

The evaporator - a triple effect, falling – film unit supplied by GEA Industries removed up to 60,000 lbs/hour (7200 gallons/hour) of water at a thermal efficiency of 4.5:1.   This unit increased the slurry concentration from 1.5% to 60% solids. The resulting concentrated slurry was stored in a tank unit until it is hauled to Foster Farms, an animal feed manufacturer.

Condensate from the evaporator was pumped to a one million gallon permeate storage tank. Permeate from the RO membrane was also piped to this tank. Following chlorination and ozonization, this purified water was pumped back to the plant for use in the cannery, vat room and oil mill.

The UF and RO systems were installed by GEA – Niro, and used Osmonics/DESAL spiral wound ultrafiltration polysulfone and RO composite membranes. The UF and RO reclaimed approximately 80% of the 700,000 gallons per day (gpd) of wastewater produced. The remaining 20% was evaporated into animal feed slurry. Variable frequency drives (VFD’s) modulated flows through all the UF loop pumps and the high - pressure RO pumps to maintain constant loop pressure. The VFDs also reduced operating costs compared to throttling valves, the traditional method of providing flow and/or pressure to control. The RO pump motors had a “soft – start” feature to reduce electric demand charges and protect system elements, especially the membranes from excessive pressure shock. The starting ramp was 30 seconds, providing a smooth pressure rise.

The UF and RO units achieved 15X and 6X concentration ratios, respectively, below the design levels of 20X and 10X. Membranes had to be cleaned 5 times a day with cleaning costs close to $1,600 dollars a day. Cleaning frequency and costs ($900 dollars a day) were significantly reduced by addition of the flocculation/flotation system prior to the UF system. The UF and RO systems were designed to treat 750 gpm (up to 900,000 gallons a day) but actual operational flow never exceeded 650 gpm. The energy costs of running the system were $15.54 per 1,000 gallons (340% more than expected). Membrane cleaning costs were 400% of those expected after pilot studies. Related cleaning water usage was 300% higher than expected from pilot studies 150,000 gpd as opposed to 50,000 gpd).

Our team was involved in the designing of efficient flocculation/flotation systems for removal of most TSS and FOG's without fouling membranes with polymer residues. The goal was to significantly reduce cleaning costs and increase the flow of UF membranes. Below, we will describe the system that was developed and applied for that purpose. The detailed report on installation and operation of the Oberti plant wastewater treatment system can be found in the reference (Moore at el., 2000).

Physico-chemical Separations Ahead of Membrane Systems

The integrated membrane system at Oberti plant was designed to remove oils and grease with UF spiral wound polysulfone membranes ahead of RO membranes. However spiral wound membranes cannot be back flushed. The operation of UF membranes required frequent chemical cleaning, up to 8 times a day. This resulted in significant loss of performance and increase in the cost of operating a system. Actual operational flows on days with the heavy loads of oil and grease were as low as 300 gpm, in a system designed to treat 750 gpm flow. On an average day wastewater from 1 million gallon effluent collection tank contained around 450 ppm of FOG's, but FOG's could be as high as 3,500 ppm. The decision was made to design a flotation system to efficiently remove as much FOG and TSS as possible before the UF treatment.

Sedimentation is one of the favorite gravity-separation methods to remove contaminants in water treatment. However, most oils have low density and cannot be separated by sedimentation from water streams. Thus, flotation is a much more suitable technique to remove oil and particles with low density from water during or after de-emulsification. Flotation is a process in which one or more specific particulate constituents of a slurry or suspension of finely dispersed particles or droplets become attached to gas bubbles so that they can be separated from water and/or other constituents. Gas/particle aggregates float to the top of the flotation vessel where they are separated from water and other non - floatable constituents.

Flotation processes in water and wastewater treatment are designed to remove all suspended particles, colloids, emulsions, and even some ions or soluble organics that can be precipitated or adsorbed on suspended solids. In this case, the process is optimized by the maximum recovery of cleaned water with the lowest concentration of contaminants. It is also often desired that the recovered sludge contain a high percentage of solids. Such solids can sometimes be recycled and reused. The design features and operating conditions of flotation equipment used for this purpose must be modified accordingly. It is evident that the processes causing water loss to the froth phase or migration of solids to the water phase must be minimized and appropriate conditions established for complete particle recovery. A recent review summarizes new developments in flotation as a wastewater treatment technique (Rubio et al. 2002).

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 water by blowing air through canvas or other porous material. In some impeller-based machines, air could be introduced from the atmosphere without compressors or blowers. This type of flotation, in which impeller action is used to provide bubbles, is known as induced-air flotation (IAF) and also produces fairly coarse bubbles. Such flotation methods are not suitable for wastewater treatment and oil extraction. Jameson (see description in Rubio et al., 2002) developed an improved version of induced-air flotation, which was more successful in the removal of fats, oil, and grease from the wastewater. Another flotation method, called dissolved-air flotation (DAF), is much more 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 psig). 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. There is a price to pay for having such small bubbles (up to 20 microns): Such bubbles rise very slowly to the surface of the tank. This is the main driver of the large dimensions for DAF tanks. Final solubility of gas in water, even at high pressures, also results in fairly low air-to-water ratios. Air-to-water ratios of 0.15:1 by volume are common in DAF systems, and it is very difficult to achieve higher ratios. Therefore, classical DAF systems are not efficient in treating wastewater with more than 1% of suspended solids.

The flotation system that was implemented was at that time, just developed, bubble accelerated flotation (BAF), a particular type of centrifugal flotation. This system will be described next.

Centrifugal Flotation Systems

As mentioned earlier, dissolved air flotation -- DAF systems commonly used in wastewater treatment have some serious limitations. While small bubbles used in such systems yield better contaminant removal efficiencies than induced air flotation or other flotation techniques, the rise time of particles attached to bubbles is minutes, which results in long water residence time inside flotation tanks and a large tank footprint. The solubility of air in water and a necessity of recycling instead of full flow treatment limit the number of bubbles that can be produced in such systems. Until recently, these matters limited the use of DAF systems for applications in which high strength industrial wastewater was treated. Coagulation and flocculation are performed ahead of bubble nucleation. Therefore bubble attachment is the only mechanism of particle removal. If gases could nucleate inside simultaneously nucleated flocs, more efficient processes can be developed. To address these and other limitations of DAF systems the following flotation techniques have been developed and applied in industrial wastewater pretreatment.

Air Sparged Hydrocyclone Flotation (ASH): the First Centrifugal Flotation Systems

One of the recent developments in flotation technology circumvented some of these problems. In particular, the air-sparged hydrocyclone (ASH) couples a porous cylindrical membrane with the design features of a hydrocyclone (Miller 1981). Gas is introduced through the porous membrane while wastewater is pumped through the hydrocyclone. Such a device is not dependent on the gas solubility and can introduce air-to-water ratios as high as 100:1. Because the bubbles are sheared off the wall of the porous membrane due to the high velocity and centrifugal forces of the water inside the hydrocyclone, they are broken up into very small sizes compared to those observed in the DAF. Thus, even though the ASH is essentially a mechanically sparged device similar to the induced air flotation (IAF) or early flotation devices, it does not suffer from similar problems. The ASH is one of the first centrifugal flotation techniques that was developed and applied in the treatment of wastewater. The ASH and bubble accelerated flotation (BAF) systems will be described below.

Because the ASH is essentially a modified hydrocyclone device, it has similar restrictions. Removed particulates in such devices are forced through an overflow device known as the vortex finder. In the ASH, the creation of an overflow results in a separate stream of contaminated water with a low concentration of solids. This deficiency results in sludge with low particulate concentrations and a larger volume of waste.

Below, we discuss modifications to the ASH device. Bubble-accelerated flotation (BAF) evolved from ASH technology to address operational limitations resulting from the traditional stream-splitting characteristics of hydrocyclones. The BAF removes the cleaned-water underflow restriction device that forces the froth and contaminants to be ejected through a vortex finder. Removing the underflow restriction in the BAF improves the consistency and ease of operation. The point at which the stream exits the BAF hydrocyclone, the bubble/particle aggregates have already formed, and coagulation and flocculation are complete before the froth particles are ejected with the cleaned water through the underflow. The requirement to separate this froth in the receiving tank from the treated water results in the new system described below.

Bubble Accelerated Flotation (BAF)

Description and Principles of Operation

The BAF system consists of a bubble chamber and a BAF tank. The bubble chamber can be operated with sparged air, induced air, vacuum, electro-flotation and even dissolved air. We will describe the air-sparged bubble chamber and BAF system. Such systems are commercially installed and successfully operated in over twenty locations within the U.S. see (Morse et al., 2000, 2001, Owen et al., 1999) for detailed descriptions of this system. Figure 4 contains an illustration of the air-sparged bubble chamber. Wastewater is introduced through a liquid/liquid hydrocyclone head (tangential injection) at the top of the unit. The tangential inlet creates a swirl flow and causes centrifugal acceleration as the water is forced into a swirl layer against the inner wall of an inert porous tube. A gas plenum, which encloses the porous tube, is pressurized commonly with low-pressure air from a blower. The air pressure must slightly exceed the water pressure due to the centrifugal acceleration and the resistance of the tube itself. Gas forced through the porous tube generates bubbles on the inside surface due to high shear. These bubbles are extremely buoyant in the centrifugal field because of the effective radial pressure gradient in the swirl layer generated by the hydrocyclone action. The bubbles accelerate toward the inner surface of the swirl layer. In addition to creating the radial acceleration of the bubbles, the centrifugal field also aids in the classification of particles with densities different from that of water. The acceleration across the swirl layer usually ranges from 25 to 1,000 Gs during routine operation. Even though the residence time of the liquid stream in the bubble chamber is only a fraction of a second, due to their rapid acceleration, the bubbles traverse the short distance across the swirl layer (typically 1 cm for a 15-cm diameter unit) in milliseconds. During this time, the bubbles collide with particles moving toward the porous tube and form bubble/particle aggregates. Another advantage of the sparging gas is that it cleans and protects the porous tube from scaling and fouling.

Given the small bubble size, large bubble flux, and the kinetic paths of the bubbles through the swirl layer, gas transfer rates are very high. This results in the ability to remove volatile organic species or to aerate the water if desired.

The flotation process is completed outside the bubble chamber in the BAF tank. In a DAF system, the tank is designed to allow sufficient residence time for the bubbles and particles to collide and for the resulting aggregates to rise to the surface. This results in low hydraulic flow rates in order to permit bubble/particle aggregates to form and to float to the surface without being swept out of the system. In DAF systems, the low hydraulic flow rate is accomplished by increasing the cross-sectional area of the flow and consequently enlarging the tanks. Consequently, for the DAF there is a trade-off between footprint and residence time.

The design needs for BAF separation tanks are completely different. The bubble chamber has already created bubble/particle/polymer aggregates before they enter the tank. The tank is simply used as a separator and not to achieve bubble/particle contact. Unlike other flotation tanks, the effluent from the bubble chamber can enter the tank near the top of the water, resulting in a shorter distance for the froth to reach the surface. This feature, combined with the fact that the aggregates are already formed, permits much higher hydraulic flow rates through the flotation tank. Figure 5 illustrates the BAF tank with the bubble chamber attached.

Figure 4 - Schematic Presentation of the Bubble Chamber (BC)

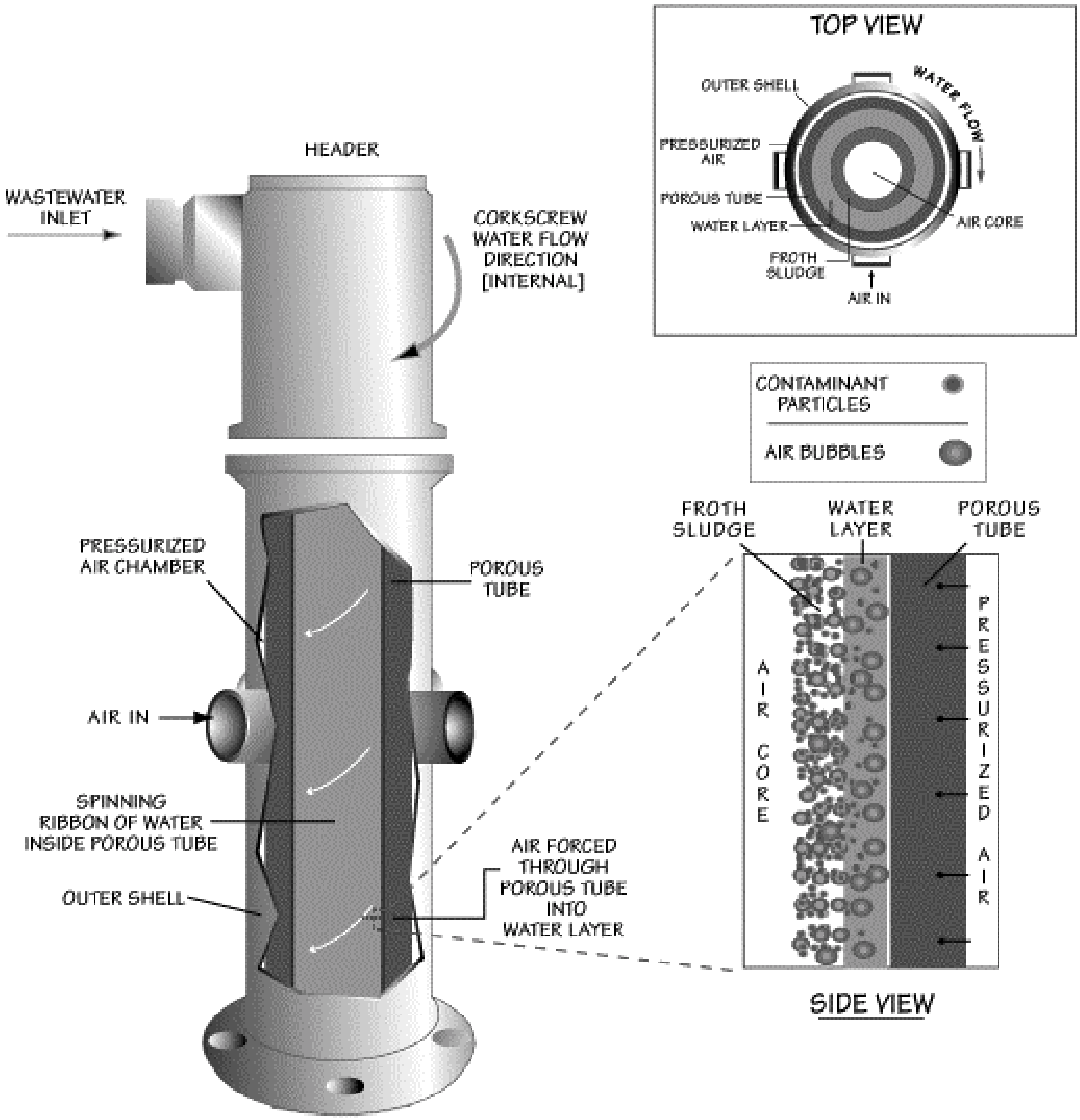
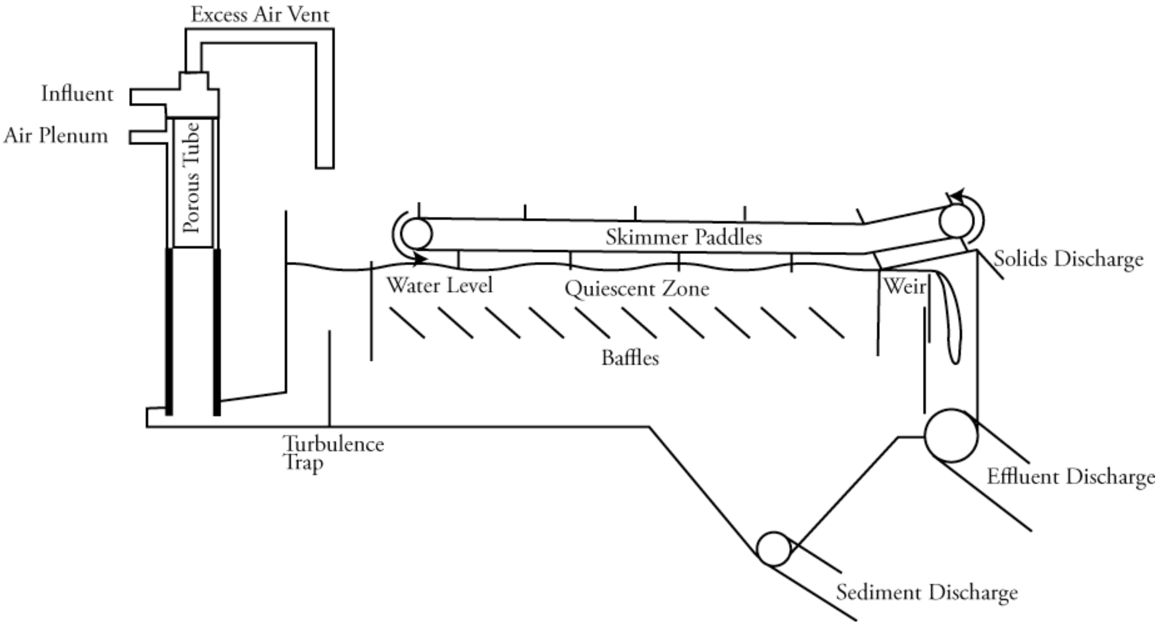


Figure 5 - Schematic Presentation of the BAF System



Detailed Description of the Flocculation/Flotation Process at the Oberti Plant

Numerous approaches were used to coagulate and flocculate particulates in wastewater prior to the BAF treatment. The pH of the suspension is usually adjusted close to the pH of the isoelectric point to reduce consumption of coagulants (charge neutralizing agents). The isoelectric point of contaminants in Oberti wastewater was around 4.3, so the pH was adjusted to 5.5. The residual charge is then partially neutralized with either inorganic coagulants or low-molecular-weight cationic polymers (polyamines, polyDADMACs etc.). Dual-polymer flocculation with high-molecular-weight (HMW) cationic and anionic polyacrylamide flocculants (PAMs) is then performed. Dual-polymer flocculation with HMW PAMs yield large, stable flocs, which float very efficiently inside the BAF tank. We also observed that if the main portion of the charge is neutralized with low-molecular-weight cationic coagulants, the BAF performance is not as good. Among the most efficient polymeric flocculants used were Cytec's (Cytec water treatment has recently been acquired by KEMIRA) C-498 HMW cationic polyacrylamide with ultrahigh-molecular-weight (>5,000,000 D) and 0.55 charge density, and Cytec's anionic polyacrylamide A-130 HMW with-molecular-weight estimated to be over 7,000,000 D. When animal feed applications of the collected sludge are desired, Cytec's "GRAS" (generally regarded as safe) polymers, such as 234 GDH cationic moderate-molecular-weight polyacryalamide, were used. When necessary, emulsion polymers were also used with the BAF system.

Dual-polymer flocculation with granular flocculants also results in very low residual polymer concentration in the effluent. This is particularly important, when flotation is used as a pretreatment ahead of UF membrane separation processes. Membranes are particularly sensitive to fouling with cationic polymers. Pilot studies and years of operation of UF membranes at Oberti plant were performed without ever observing irreversible membrane fouling with flocculants. Spectroscopic studies of autopsied membranes identified absence of adsorbed polymers. However, plant operators did perform jar tests to optimize the dosage of cationic granular flocculants. It was shown in laboratory scale UF tests that significant overdosing of cationic polyacrylamide flocculants did cause irreversible fouling of membranes (overdose of 20 mg/l of C-498 HMW flocculant over the period of 48 hours could irreversibly foul UF membranes).

In average, the dosage of cationic flocculant was around 20 mg/l, while dosage of anionic flocculant was kept constant at 10 mg/l (A-130 HMW from Cytec). Two BAF systems were installed, one treating water ahead of the million-gallon effluent tank, another one after. After the second BAF unit wastewater in average contained less than 10 mg/l of TSS and less than 5 mg/l of FOG. However dissolved organics were still present, as expected. In average COD's after the BAF treatment were 3,000 mg/l. Organic materials present in the BAF effluent still caused some fouling of UF membranes, even though membranes chemical cleaning was reduced by 75%. Wastewater pretreatment with the BAF system reduced cost of UF membrane cleaning from around 1000 dollars per day to 250 dollars per day. The average flow through the UF membranes was also increased from 80 gallons per minute to 450 and later 650 gallons per minute.

It was also observed that high-molecular-weight polymeric flocculants could be added directly into the bubble chamber head. Large batch mixing tanks or floc tubes can therefore be avoided. Powerful vortex mixing and wall effects inside the bubble chamber tube result in better uncoiling of polymers with minimum polymer and floc breakage. HMW flocculants can therefore achieve superb flocculation inside the bubble chamber. This often results in the formation of large flocs with diameters of up to 10 cm. The flocs are very stable, with high solids loading of between 10 and 30% upon short drainage. The best flocs are usually produced when using a combination of HMW cationic and anionic flocculants. (Fan et al. 2000) show that dual-polymer flocculation actually results in more efficient uncoiling of the HMW polymeric flocculants. The uncoiled flocculant chains then act as better bridging agents. Vortex mixing inside the centrifugal field within the bubble chamber seems to enhance this process. Additional research should be performed to investigate these processes.

DISCUSSION AND CONCLUSIONS

The recycle of high strength industrial wastewater for zero discharge goal is possible in theory and practice. The Oberti case showed that this could actually be quite expensive, with the total cost of wastewater treatment of slightly over 20 dollars per 1000 gallons. Ultrafiltration membranes can indeed be used to remove fine colloidal solids and fats oil and grease. Cost of membrane cleaning is quite high. Pretreatment to remove some suspended solids and fats oil and grease can significantly improve the performance of the UF membranes and lower the cost of operation. After UF filtration, significant amount of dissolved organics still remain in wastewater. This results in significant cost of cleaning of RO membranes downstream. Energy to run RO process of such wastewater purification is also quite high.

Deciding which integrated technologies to use to achieve zero discharge goal with high strength industrial wastewater treatment is not an easy task. However, after careful analysis, we now believe that it is more economically feasible to remove colloidal and dissolved organic materials with anaerobic and aerobic bioreactors or membrane bioreactors. If salt is present in wastewater, the RO membranes can be used to remove it after the organics have been removed. Low pressure fouling resistant RO membranes should be used whenever possible.

Other plant design specialists seem to agree with this approach. For instance, a large vibrating nanofiltration membrane system installed at Hilmar cheese plant in California never achieved its goal. A significant investment involving tens of millions of dollars was lost on vibrating nanofiltration membranes that were initially installed without proper pre-treatment ahead of membranes. The new design implements a process that includes, screens, flocculation, flotation, anaerobic reactor, aerobic reactor and RO membranes. This new system is achieving its goals. The treated water is cleaner than the local well water. We are aware of several other multimillion-dollar UF or microfiltration membrane systems in Mexico and the US that have been abandoned, and replaced with bioreactors ahead of RO membranes. Needles to say, for large flows of high strength wastewater, the initial capital costs of installing a bioreactor are very high but in the long run are worth the investment.

In short, the Oberti case showed that total recycle of high strength industrial wastewater to achieve zero discharge goal and reuse water and solids is possible, but can be quite expensive. Other cases such as recently installed system at Hilmar cheese factory in California further strengthen such data. It is not probable that the cost of flocculation chemicals, flotation equipment, membranes or bioreactors will become much lower. Unfortunately most of the mentioned systems and chemicals are more expensive due to increases in oil prices. The future will show just how economical these fully integrated wastewater systems will be to treat high strength industrial wastewater.

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