

SYNERGISTIC APPLICATION OF ADVANCED PRIMARY AND SECONDARY WASTEWATER TREATMENT SYSTEMS

**Published in Water and Waste Digest membrane issue,
November 2008**

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To be published in Water and Waste Digest later this year

The increased regulatory pressures and demand for reused water stimulated development of several new wastewater technologies in the last decade. Advanced treatment systems are characterized by small footprint, high contaminant removal efficiency, flexibility, resilience to changes in wastewater quality and high level of automation.

To recycle/reuse wastewater, most contaminants have to be removed. Primary systems are used to remove suspended and dispersed solids, free and emulsified oils, fats and grease. Secondary systems (biological treatment) are used to reduce organic contaminants (BOD's, TOC). Tertiary systems such as filtration and membrane filtration are used to remove what is left after secondary treatment (ions, small non - biodegradable molecules, very fine solids etc.)

Several hybrid systems, combining two or three different technologies have recently been developed and applied. For instance, membrane bioreactors (MBR) are composed of biological unit (aeration and microbial growth) responsible for the biodegradation of the waste compounds and a membrane filtration module for the separation of produced biosolids. Membranes can be immersed in the aeration unit, or used externally. Cleaning of the membranes is achieved through frequent permeate back pulsing and occasional chemical washing. Membrane bioreactors have been pilot tested and used in industrial and municipal wastewater treatment. Another configuration under development is using fixed film bioreactors such as moving bed biofilm reactors (MBBR) followed by external membrane ultrafiltration.

Moving bed biofilm reactors (MBBR) are a hybrid of activated sludge and biofilter processes. Contrary to most fixed film bioreactors, MBBR utilizes the whole tank volume for biomass. However, contrary to activated sludge reactors, 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 easy to separate and dewater.

Finally, anaerobic mobile film technology (MFT) bioreactors can be used with ultrafiltration replacing sedimentation for biosolids removal. While all of the aforementioned bioreactors do perform as advanced treatment systems (criteria described before), using membranes for biosolids separation still presents some challenges. Backpulsing to clean membranes requires lot of energy, and membranes are more expensive than clarifiers or flotation systems for biosolids removal. Membrane cleaning solutions also add to the cost of treatment.

To reduce backpulsing energy needs and cleaning solutions cost, suspended solids and fats, oils and grease (FOG) should be removed prior to bioreactor or membrane treatment. FOG's are highly hydrophobic and deposit very strongly on membrane surfaces. FOG's also have a tendency to float on top of bioreactors reducing aeration efficiency or coating fixed film bioreactors media. Removing FOG's significantly reduces BOD's that are difficult for microorganisms to remove in any bioreactors. Removing FOG's reduces foaming potential. Pretreatment systems can be used to neutralize pH and remove any biocides that would interfere with microorganisms performance.

Pretreatment systems to be used ahead of advanced secondary and tertiary technologies should have small footprint, high contaminants removal efficiency, flexibility and design that is easy to automate and incorporate with downstream technologies.

FOG's have density lower than water and are consequently removed with flotation technologies. In flotation systems, fine air bubbles are introduced and carry particles and FOG's to the surface where they are skimmed and separated from wastewater. To remove small particles present in the wastewater small bubbles perform best. Dissolved air flotation units produce smallest bubbles that rise to the surface very slowly. Therefore, DAF's have large footprint (tank size). Induced air systems produce larger bubbles with faster raise time, but also lower performance in fine TSS removal.

We developed a hybrid centrifugal –dissolved air flotation system (the GEM System) that combines benefits of small bubbles and fast rise time. At the hearth of the System is liquid – liquid hydrocyclone column with heads that permit adjustments of treatment chemicals – particles – bubbles mixing energy. Coagulants and flocculants are

introduced on the top of the column at the same time with air and wastewater particles. Therefore, flocs and bubbles nucleate at the same time, producing porous sludge filled with air. Large flocs (often 1 inch diameter) are produced. Solid/liquid separation occurs inside the hydrocyclone column. Tanks are only used for sludge skimming. Such design results in footprint that is only 15-40% of that of DAF systems. Efficient mixing of treatment chemicals and particles results in very low residual amounts of chemicals such as flocculants in wastewater. This is particularly important to protect membranes and microorganisms from damage that can happen when cationic reagents adsorb. Schematic presentation of the GEM System is shown in Figure 1.

Successful primary treatment is a combination of the best system and best treatment chemicals for the system. We tested the efficiency of hundreds of coagulants and flocculants before choosing a handful that perform best, allowing the GEM System to achieve the most efficient primary treatment. Dual flocculant approach results in production of best sludge with very high solids loading (10-30% by weight), low TSS and FOG in effluent, fast response and absence of cationic flocculant overdose in the effluent. High molecular weight high charge cationic flocculants are used to neutralize charge and overcharge particles lightly. Medium charge, ultrahigh molecular weight anionic flocculants are then added to grow large stable flocs and precipitate any excess cationic flocculant present. Figure 2 shows schematic presentation of the dual flocculant approach. If coagulants are used to lower cost of treatment, low molecular weight epi-amine or polyaluminum chloride coagulants produce best treatment results with lowest possible danger to microorganisms or membranes downstream.

In conclusion, no matter how efficient secondary (bioreactors) or tertiary treatments are, it does make sense to remove suspended solids and FOG's before other treatment steps. When using new generation of advanced secondary and tertiary treatment systems, it is a good idea to try novel systems developed recently for primary treatment. Stepwise approach (screens – coagulation – flocculation – flotation – secondary treatment – tertiary treatment) delivers the most reliable treatment results with minimum cost. All – in - one systems are still the technology of the future, in spite of great promise of membrane bioreactors and moving bed biofilm membrane reactors.

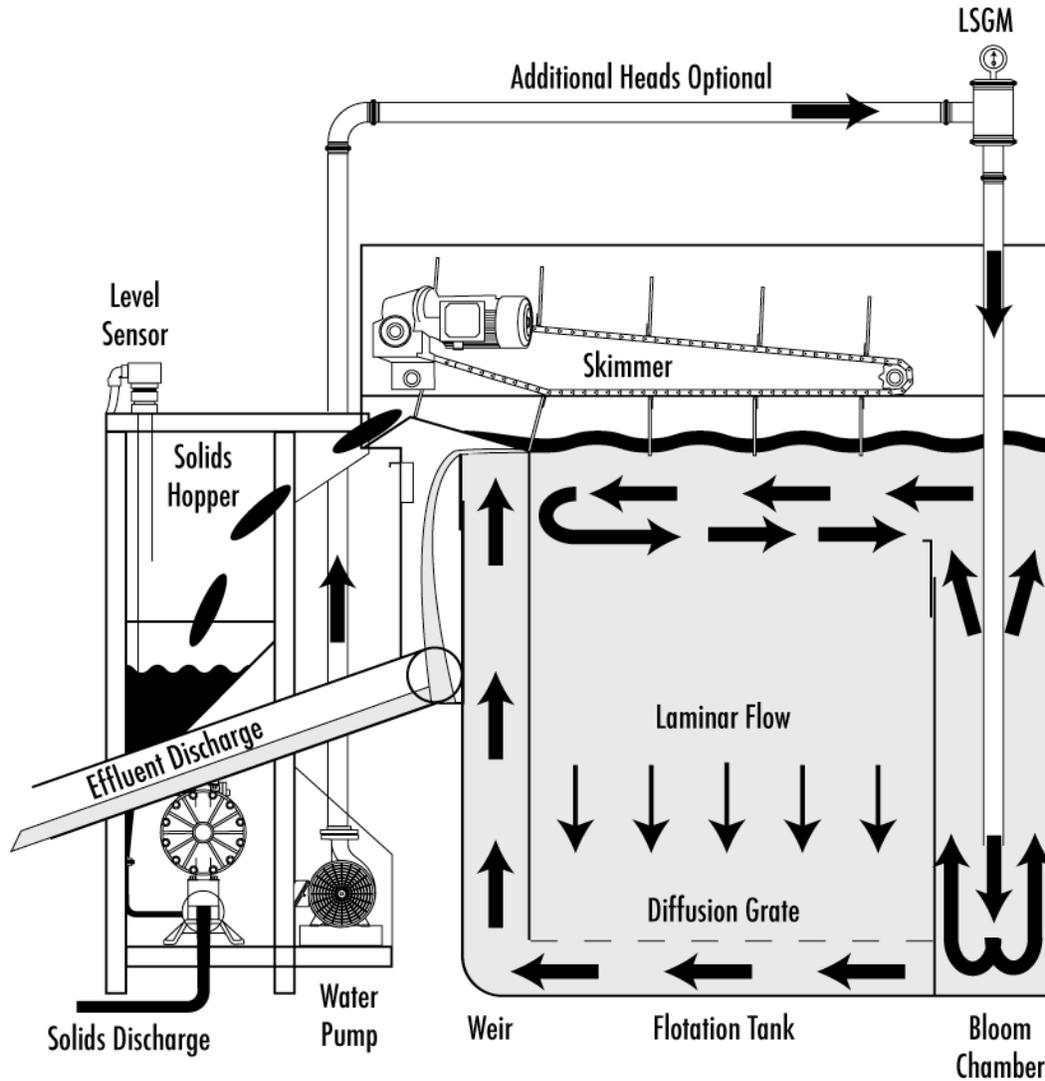


Figure 1. Schematic Presentation of the Hybrid Centrifugal – Dissolved Air Flotation System.

DUAL POLYMER FLOCCULATION

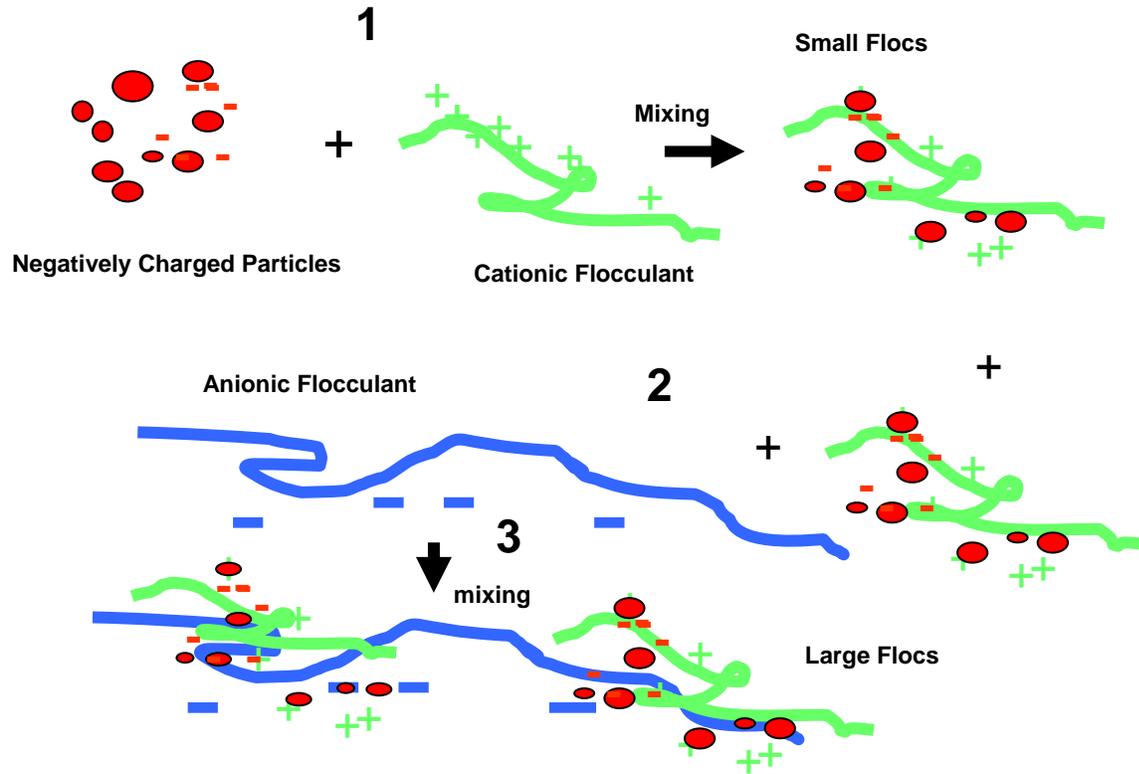


Figure 2. Dual high molecular weight polymeric flocculant approach.