United States
Environmental Protection
Agency

# Wastewater Technology Fact Sheet

## Ballasted Flocculation

### DESCRIPTION

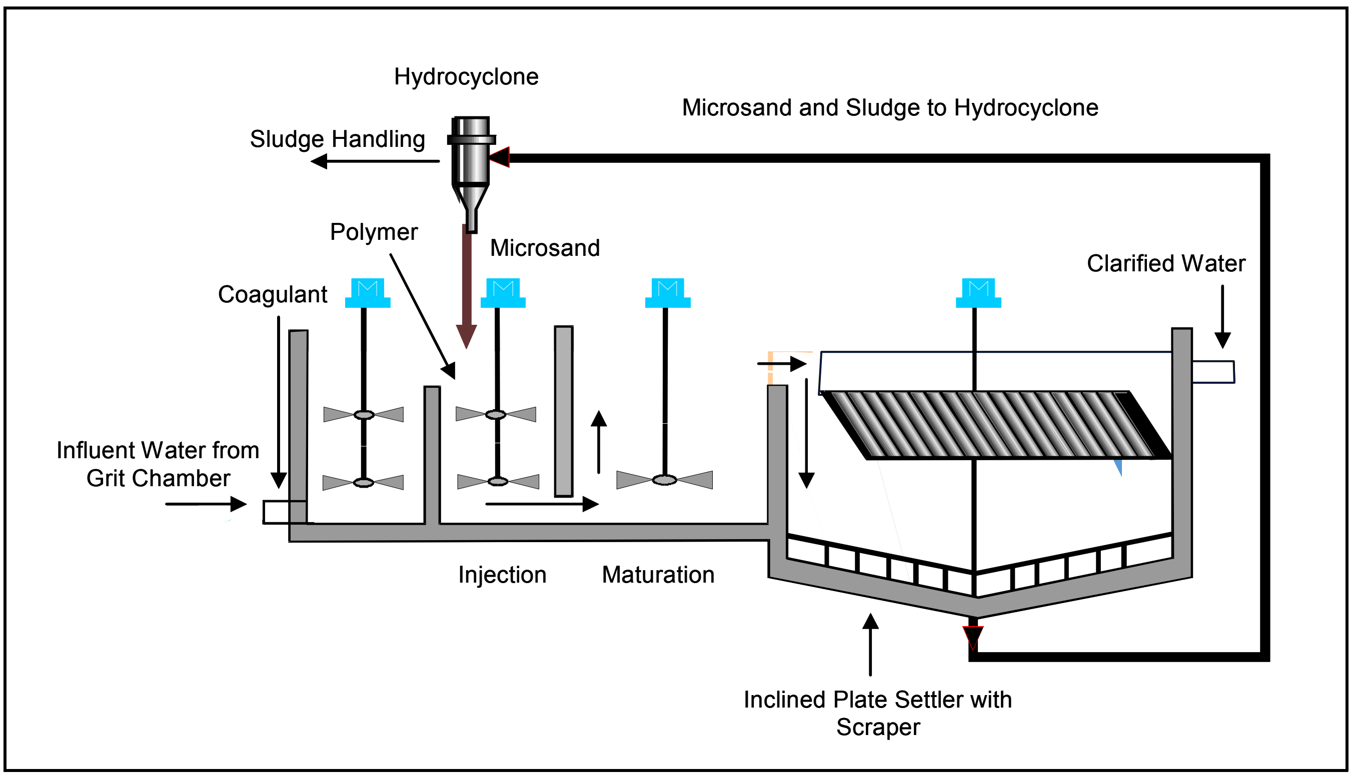
Ballasted flocculation, also known as high rate clarification, is a physical-chemical treatment process that uses continuously recycled media and a variety of additives to improve the settling properties of suspended solids through improved floc bridging. The objective of this process is to form microfloc particles with a specific gravity of greater than two. Faster floc formation and decreased particle settling time allow clarification to occur up to ten times faster than with conventional clarification, allowing treatment of flows at a significantly higher rate than allowed by traditional unit processes.

Ballasted flocculation units function through the addition of a coagulant, such as ferric sulfate; an anionic polymer; and a ballast material such as microsand, a microcarrier, or chemically enhanced sludge. When coupled with chemical addition, this ballast material has been shown to be effective in reducing coagulation-sedimentation time (Liao, et al., 1999). For instance, ballasted flocculation units have operated with overflow rates of 815 to 3,260 $L/m^2 \cdot min$ (20 to 80 $gal/ft^2 \cdot min$) while achieving total suspended solids removal of 80 to 95 percent (Tarallo, et al., 1998).

The compact size of ballasted flocculation units makes them particularly attractive for retrofit and high rate applications. This technology has been applied both within traditional treatment trains and as overflow treatment for peak wet weather flows.

Several different ballasted flocculation systems are discussed in more detail below:

The Actiflo® process (Figure 1), manufactured by US Filter Kruger (US operations) has been used in




Source: Modified from US Filter Kruger, 2002.

**FIGURE 1 ACTIFLO® PROCESS DIAGRAM**

Europe since 1991 for drinking water, wastewater, and wet weather applications. This three-stage process uses microsand particles (45-100 $\mu$m in diameter) to enhance the flocculation process.

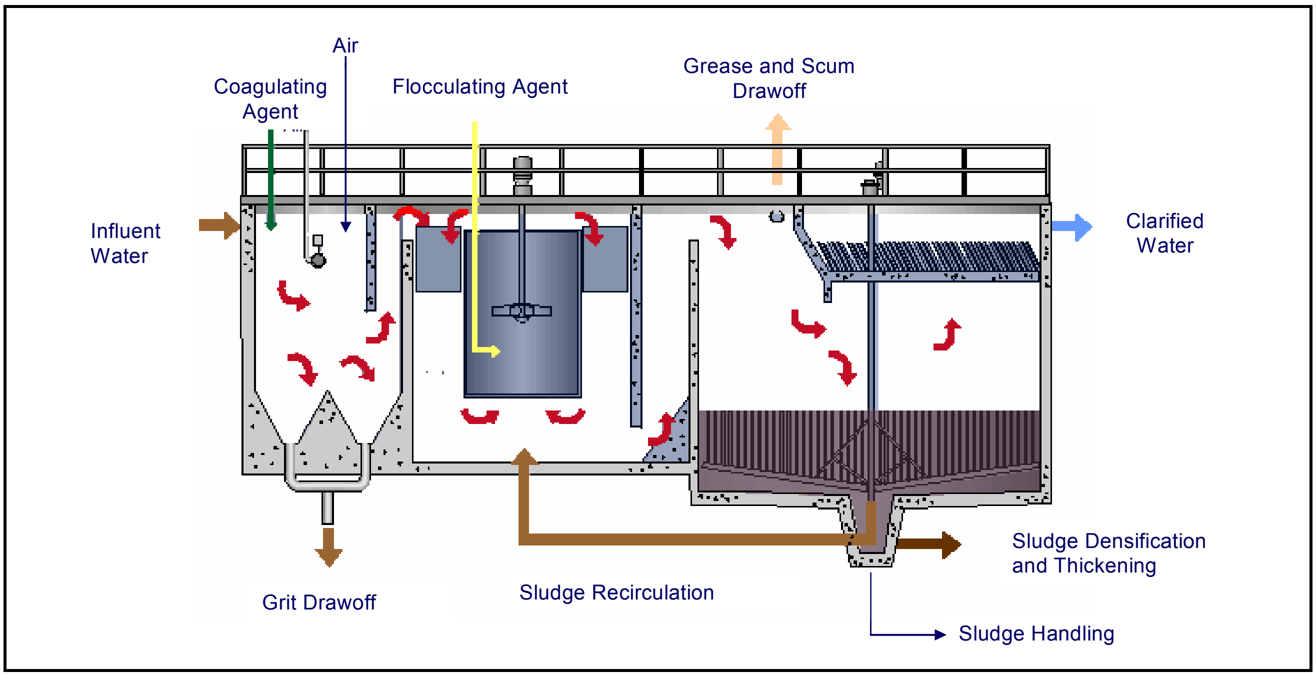
Prior to entering the first stage of the Actiflo® process, the influent wastewater is usually screened and passed through a grit chamber to remove large particulates. The next step is the addition of a traditional metal coagulant in a flash mixer. Iron or aluminum coagulants are used to reduce phosphorus levels, typically to below 2 mg/L. Within this first stage, a polymer and microsand (the ballast materials) are also added.

The second stage of the Actiflo® process is maturation, where the ballast material serves to enhance floc formation, resulting in a much faster settling rate relative to traditional coagulants. The influent wastewater then flows to a second tank where it is gently mixed with chemical flocculants and ballast to enhance the flocculation process.

The third stage of the Actiflo® process is clarification. During this stage, the mixed influent and the floc flow downward through the unit. The floc settle by gravity to the bottom of the unit where they are collected, typically in a cone-shaped chamber. A baffle is used to direct the flow to the top of the tank for further settling. Inclined tube settlers further enhance the settling process by providing a greater surface area over which settling can occur and by reducing settling depth. Clarified effluent is then directed to the next process treatment or to discharge. Ballast from the bottom of the chamber is separated from the sludge and re-introduced into the contact chamber. A hydrocyclone uses centrifugal force to separate the sludge from the ballast and re-introduces it into the contact chamber. The sludge is taken to an appropriate handling facility.

Marketed by Infilco Degremont, Inc., of Richmond, Virginia, and first installed in 1984, the DensaDeg® process, shown in Figure 2, is a high-rate clarifier designed for grit removal, grease removal, settling, and thickening. The DensaDeg® reuses recirculated sludge in combination with a flocculating agent to achieve rapid settling. Like the Actiflo® system, the first step in the DensaDeg® process involves the injection of a traditional coagulant into the system. However, unlike the Actiflo® system, the DensaDeg® process uses injected air rather than flash mixing to disperse the coagulant. The DensaDeg® 4D uses the same technology and processes as the DensaDeg® but can handle flows with the rapid start-up and shut-down time frame typically required for stormwater, combined sewer overflow (CSO), and sanitary sewer overflow (SSO) applications.

In the coagulation zone of the DensaDeg®, air is




Source: Modified from ONDEO-Degremont, Inc., 2002.

**FIGURE 2 DENSADEG 4D PROCESS DIAGRAM**

simultaneously injected with the coagulant to separate grit particles from organic matter and to provide fluid motion for coagulant dispersion and mixing. Coagulated wastewater enters the reactor where a polymer flocculating agent is added with recycled settled sludge to help the flocculation process. In the reaction zone, wastewater enters a clarifer where grease and scum are drawn off the top. In the final step of the process, inclined tube settling is used to remove residual floc particles. Settled sludge from the clarifier is thickened, and part of this sludge is recirculated and added to the flocculate. Because this system uses entirely recycled sludge as a coagulant aid, it does not require separation techniques (hydrocyclone) to recover microsand from the sludge.

The Lamella® plate clarification system, which is manufactured by the Parkson Corporation of Ft. Lauderdale, Florida, is usually used in conjunction with non-proprietary coagulation and flocculation units rather than as a single flocculation and clarification process. The Lamella® system does not include a microcarrier, but enhanced coagulation aids (ballast materials) can be used with this system to achieve enhanced high-rate clarification. This system uses a series of inclined plates to increase the surface area over which particles can settle out. Because the plates are stacked at an incline, the depth from which they must settle is significantly less than those of traditional clarifiers. This decreases settling time compared to that of traditional clarifiers, allowing much higher flow rates to be treated. A thickener can be added to the Lamella® unit to increase the concentration of solids in the resulting sludge. Like the DensaDeg® system, underflow sludge can be routed back to the flocculation unit for use as a ballast material.

Like other ballasted processes, the Lamella® system can be used in either new designs or retrofits to achieve high rate clarification. The advantages of other systems incorporating the use of a microcarrier are also applicable to the Lamella® system. Figure 3 shows a typical Lamella® system.

## APPLICABILITY

Ballasted flocculation can be used as part of a traditional treatment train or as a parallel treatment train in new or existing wastewater facilities. Applications of ballasted flocculation include:

1. Enhanced primary clarification.

2. Enhanced secondary clarification following fixed and suspended growth media biological processes.

3. Peak flow reduction for CSO and SSO treatment. This process has been applied to a variety of wastewater facilities ranging from less than 0.1 MGD to more than 1,000 MGD, both as a parallel train and as a means of optimizing existing unit processes (Infilco Degremont, 2000).

## ADVANTAGES AND DISADVANTAGES

### Advantages

Major advantages for both new and upgraded treatment operations include:

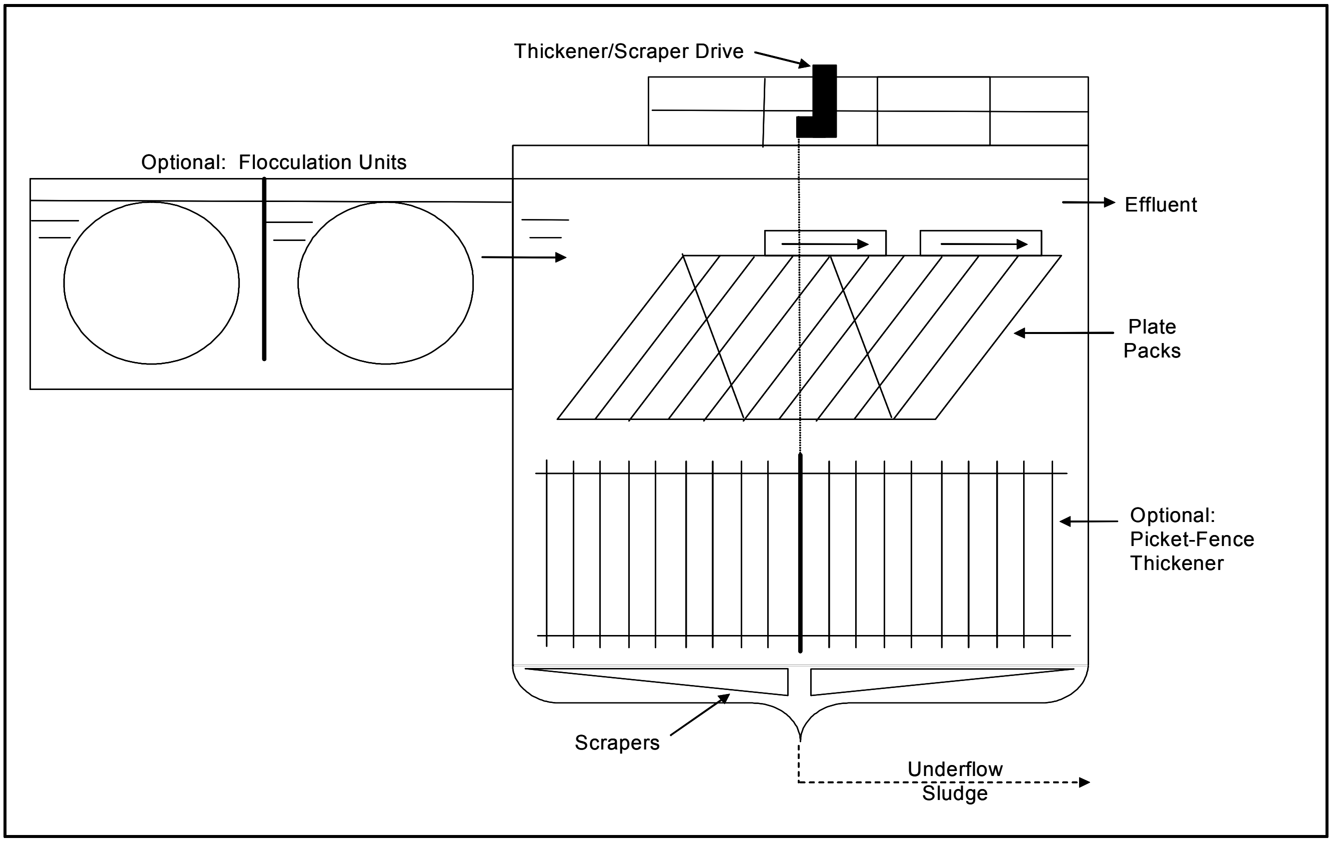
- The reduced surface area of the clarifiers minimizes short-circuiting and flow patterns caused by wind and freezing (a problem only in extremely cold climates).

- Systems using ballasted flocculation can treat a wider range of flows without reducing removal efficiencies.

- Ballasted flocculation systems reduce the amount of coagulant used, or improve settling vs. traditional systems for comparable chemical usage.

In CSO and SSO applications:

- Ballasted flocculation requires less land than a storage tank of comparable capacity. The compact size of the clarifier can significantly reduce land acquisition and construction costs.




Source: Parsons, Inc., from Parkson Corporation, 2000.

**FIGURE 3 LAMELLA® PLATE SETTLERS**

- Operational costs are incurred only during use.
- These systems do not require conveyance of flow to wastewater treatment plants following wet-weather events (if secondary treatment requirements do not apply).
- Ballasted flocculation systems can be used as primary treatment facilities for primary rehabilitation or replacement projects.

**Disadvantages**

Some disadvantages of ballasted flocculation systems include:

- They require more operator judgment and more complex instrumentation and controls than traditional processes.
- Pumps may be adversely affected by ballast material recycle. Lost microsand or microcarrier must be occasionally replaced (except where settled sludge is recycled for use as a microcarrier/ballast).

For CSO and SSO applications:

- Systems require significantly more operation and chemical feed than a comparable storage tank of similar capacity.
- Use of ballasted flocculation systems results in low removal rates during the start-up period (typically 15 to 20 minutes after a wet weather event).
- The process may take several hours to achieve the optimal chemical dose and hence, the desired pollutant removal.
- This is a relatively new technology for CSO/SSO abatement without a history of long-term performance.

## DESIGN CRITERIA

The Actiflo® can process flows between 10 and 100 percent of its nominal design capacity, allowing systems to provide wet weather treatment for a range of design storm events. Typical start-up to steady-state time is about 30 minutes. Table 1 shows additional design parameters for the Actiflo® system.

The DensaDeg® unit has been successfully applied to treat hydraulic loads of 20 to 40 $m^3/m^2 \cdot h$ (11,800 to 23,600 $gal/ft^2 \cdot d$). Start-up to steady state times range from 15 to 30 minutes. Within the grit removal coagulation reactor, a high solids concentration (>500 mg/L) is maintained. Settling rates within the clarifier are as high as 2,450 $L/m^2 \cdot min.$ (60 $gal/ft^2 \cdot min.$). The solids removed from the clarifier/thickener are typically 3 to 8 percent dry solids. Additional thickening is not required in most cases. Table 1 provides additional design parameters for the DensaDeg®.

Loading rates used in conventional settlers can typically be applied directly to sizing Lamella® settlers by substituting the projected area for the surface provided by a conventional clarifier (Parkson, 2000). The surface area depends upon the angle of plate inclination, with typical applications at about 55 degrees. Lamella® plate packs are proportioned to the clarification and thickening area by adjusting the plate feed point.

The ratio of clarification to the thickening area is determined from representative wastewater samples (Parkson, 2000).

## PERFORMANCE

Pilot studies were conducted for both the Actiflo® and DensaDeg® 4D processes to evaluate their pollutant removal abilities.

The Actiflo® process was evaluated at the Airport Wastewater Treatment Plant in Galveston, Texas, under both wastewater and CSO simulated conditions. Table 2 summarizes removal rates for both influent conditions.

The DensaDeg® 4D process was evaluated by the Village Creek WWTP in Birmingham, Alabama, as a method of treating peak flows. Pilot studies were conducted to determine optimum operating parameters. During testing, primary effluent was selected to best represent SSO influent (with the assumption that a surge tank with a detention time of two hours would collect SSO volume before being discharged to the DensaDeg® for treatment). Table 3 lists removal efficiencies achieved under optimum steady-state operating parameters.

The city of Fort Worth, Texas, conducted pilot tests of several ballasted flocculation treatment processes during the design of a new treatment facility for peak flow treatment. Results indicated that every tested process achieved a higher degree of pollutant removal when compared to conventional preliminary treatment. Table 4 shows the removal efficiencies of different

**TABLE 1 DESIGN PARAMETERS FOR BALLASTED FLOCCULATION SYSTEMS**

| Parameter | Actiflo® | DensaDeg® | DensaDeg® 4D |
|---|---|---|---|
| Microsand (percent of peak raw water flow) or Ballasted Sludge | 45-150 $\mu$m | 0.5-4.0% | 0.5-4.0% |
| Overflow Rate | 2,450 $L/m^2 \cdot min.$ | up to 450 $L/m^2 \cdot min.$ | up to2,040 $L/m^2 \cdot min.$ |
| Reactor Retention Time | 3-5 minutes | 6 minutes | 4-6 minutes |
| Total Retention Time | 4-7 minutes | 22 minutes | 15 minutes |
| Minimum Single Train Capacity | 0.2 MGD | 0.8 MGD | 8 MGD |
| Maximum Multiple Train Capacity | Unlimited | Unlimited | Unlimited |
| Maximum Single Train Capacity | 90 MGD | 24 MGD | 100 MGD |

Source: US Filter, 2000 and Infilco Degremont, 2000.

## TABLE 2 PERFORMANCE OF ACTIFLO® PROCESS AT GALVESTON, TEXAS

| | TSS Removal | COD % Removal | BOD % Removal |
|---|---|---|---|
| Raw Wastewater | 71-95% | 66-87% | 55-88% |
| CSO Simulated | 80-94% | 65-83% | 48-75% |

Source: US Filter Kruger, 2000.

treatment technologies during this pilot study.

## OPERATION AND MAINTENANCE

In general, proper operation of a ballasted coagulation and flocculation system requires greater operator expertise than does operation of conventional coagulant systems because the addition of ballast requires close monitoring of the recycle. The short retention time also requires prompt operator response to maintain design conditions and to provide optimum coagulant dosages.

For wet weather applications, maintenance requirements for ballasted flocculation units are greater than for traditional storage tanks, which retain wet weather volume for subsequent treatment. Wet weather suspended solids concentrations vary, and require monitoring and adjustment of the microsand concentration and overflow rate. As with non-wet weather applications, the polymer dose, coagulant doses, and pH of coagulation should be closely monitored to ensure design conditions are met.

Most systems recover and recycle the ballast material using a hydrocyclone. It is important to ensure proper operation and maintenance of the hydrocyclone to avoid accumulation of organic material on the sand particles. This does not occur in systems that use only sludge recycle.

### TABLE 3 REMOVAL EFFICIENCIES OF THE DENSADEG® 4D PROCESS AT BIRMINGHAM, AL WWTP

| Parameter | Influent Range (mg/L) | Effluent Range (mg/L) | Removal Efficiency |
|---|---|---|---|
| COD | 112-260 | 44-168 | 45-60% |
| TSS | 47-86 | 3-11 | 80-95% |

Source: Tarallo, et al., 1998.

## COSTS

The compact design of ballasted flocculation units reduces land acquisition costs when compared to conventional treatment trains, reducing capital costs, especially where land acquisition is expensive or prohibitive. However, operational costs can be higher than for comparable conventional processes. For wet weather applications, operational costs are incurred only during peak flow conditions. Capital and operating costs vary depending on the specific treatment application. In Fort Worth, Texas, capital costs for ballasted flocculation were $0.05/L treated ($0.20/gal) with operating costs of $24/million L treated ($90.85/million gal) (Camp, Dresser & McKee, 1999).

## REFERENCES

### Other Related Fact Sheets

Chemical Precipitation
EPA 832-F-00-018
September 2000

Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owm/mtb/mtbfact.htm


1. Camp, Dresser & McKee, Inc., 1999. *High Rate Clarification Saves Fort Worth $34 Million*. Internet site at http://www.cdm.com/Svcs/wastewtr/balfloc.htm, accessed 2000.

**TABLE 4 REMOVAL EFFICIENCIES OF TREATMENT TECHNOLOGIES AS PILOT TESTED FOR THE CITY OF FORT WORTH, TEXAS**

| Unit/Manufacturer | BOD Removal | TSS Removal | TKN Removal | Phosphorus Removal |
|---|---|---|---|---|
| Actiflo® | 36-62% | 74-92% | 25-30% | 92-96% |
| DensaDeg® | 37-63% | 81-90% | 28-40% | 88-95% |
| Lamella® | 41-57% | 53-73% | 19-34% | 69-76% |

Source: Crumb and West, 2000.
*Note: A fourth system, Microsep®, was evaluated but is no longer manufactured.*


2. Crumb, F.S. and R. West, 2000. *After the Rain*, Water Environment and Technology, April 2000.

3. Infilco Degremont, 2000. Design information on the DensaDeg system.

4. Liao, S.-L., Y. Ding, C.-Y. Fan, R. Field, P.C. Chan, and R. Dresnack, 1999. *High Rate Microcarrier-Weighted Coagulation for Treating Wet Weather Flow*. Water Environment and Technology Poster Symposium, New Orleans, LA.

5. Parkson Corporation, 2000. Principle of Lamella Gravity Settler.

6. Tarallo, S., M. W. Bowen, A. J. Riddick, and S. Sathyamoorthy, 1998. *High Rate Treatment of CSO/SSO Flows Using a High Density Solids Contact Clarifier/Thickener-Results from a Pilot Study.*

7. US Filter Kruger, 2000. Design information on the Actiflo® process for wastewater.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