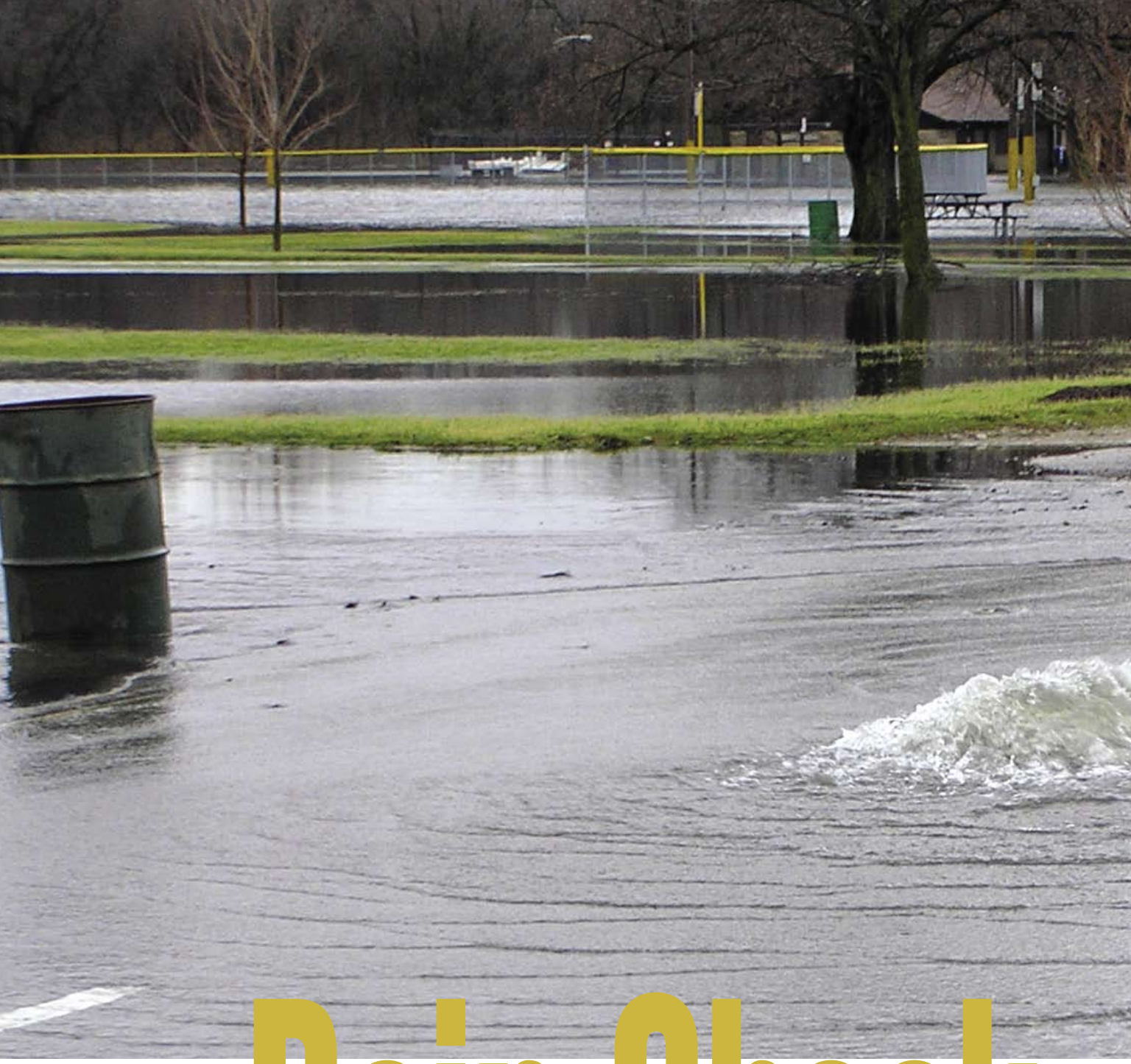


Rain Check

Columbus, Ohio, considers ballasted flocculation to treat its wet weather flows

Susan Landon, Colleen Donahue, Sam Jeyanayagam, and Donald Cruden

© 2006 Water Environment Federation All rights reserved

Columbus, Ohio, found that an effective high-rate clarification system can help minimize sanitary and combined sewer overflows.

Under a consent order to minimize untreated wastewater discharges during wet weather events, the Columbus, Ohio, Division of Sewerage and Drainage evaluated treatment processes that could handle intermittent high-volume, low-strength flows. After reviewing several alternatives, the city decided to pilot-test two promising high-rate clarification systems. Both use ballasted flocculation to treat wet weather flows.

© 2006 Water Environment Federation All rights reserved

The city's project team compared the two systems for

- site-specific performance;
- the most effective combination of chemicals and doses required to remove 85% of total suspended solids (TSS) from influent;
- effluent quality, given variable influent characteristics; and
- potential operating issues for full-scale implementation.

Ballasted Flocculation

A ballasted flocculation system uses coagulants and flocculation aids to maximize solids removal. It also includes a dense ballast material to promote floc formation and increase particle settling velocities by fiftyfold to one-hundredfold, so it requires less space than a conventional sedimentation process.

The Actiflo® system, licensed by Krüger Inc. (Cary, N.C.), and the DensaDeg® system, licensed by Infilco Degremont (Richmond, Va.), both include the following stages after wastewater screening:

- addition of coagulant, which is rapidly mixed into the wastewater;
- addition of ballast material;
- addition of polymer;
- flocculation;
- particle settling; and
- ballast recirculation.

The Actiflo system uses microsand for the ballast material, while the Densadeg system uses thickened recirculated sludge.

Pilot-Testing

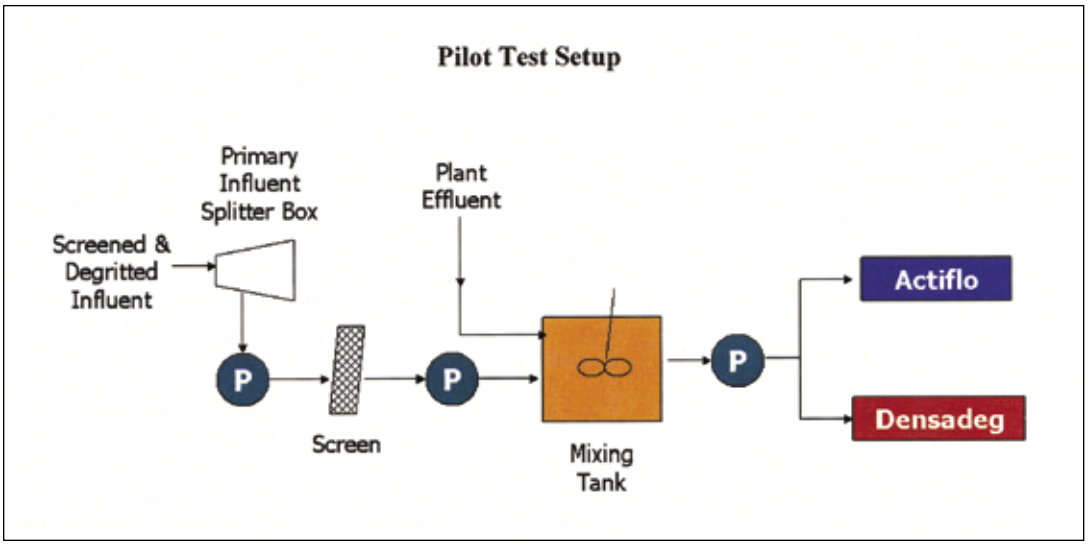
The project team pilot-tested the two systems at the Southerly Wastewater Treatment Plant from May through August 2004. The pilot plants were trailer-mounted units that included all the necessary components, including chemical feed equipment, process controls, pumps, and instrumentation (see figure, below). To simulate wet weather flows and ensure testing consistency, a blending tank diluted primary influent with unchlorinated plant effluent. Influent feed rates ranged from 0.53 to 1.32 m^3/min (140 to 350 gal/min) for the Actiflo unit and 0.49 to 0.81 m^3/min (129 to 215 gal/min) for the DensaDeg unit. Surface overflow rates ranged from 1.2 to 3.1 m^3/min•m^2 (30 to 75 gal/min•ft^2) for the Actiflo unit and 1.2 to 2.0 m^3/min•m^2 (30 to 50 gal/min•ft^2) for the DensaDeg unit.

The two systems were subjected to a range of operating conditions, as well as performance tests for

- chemical optimization,
- surface overflow rate,
- extended runs, and
- wet and dry startups.

Altogether, the team conducted more than 170 runs of the Actiflo system and 102 runs of the DensaDeg system during the 3-month study. (The Actiflo unit's typical hydraulic detention time — about 5 to 7 minutes — was about half that of the DensaDeg unit, so more Actiflo runs were completed.)

The project team typically operated each pilot system for two hydraulic detention times to reach steady state before taking samples. During startup testing, however, team members collected three influent and effluent grab samples during the first and second hydraulic detention times. During chemical optimization and surface overflow rate testing, they collected the samples during the third hydraulic detention time.



© 2006 Water Environment Federation All rights reserved

During extended run testing, they collected samples during the third and subsequent hydraulic detention times.

All samples were analyzed for TSS, biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Samples collected during chemical optimization also were analyzed for alkalinity.

Chemical Optimization

The project team conducted chemical optimization tests to determine the most effective doses of ferric chloride, aluminum sulfate (alum), and polyaluminum hydroxychloride (PACl) to meet the treatment goal of 85% solids removal. These tests also were used to determine whether pH adjustment was necessary, since metal salts can lower pH if influent alkalinity is low.

Actiflo. The tests were performed at surface overflow rates of 2.0 to 2.4 $m^3/min \bullet m^2$ (50 and 60 $gal/min \bullet ft^2$) and coagulant doses ranging from 15 to 150 mg/L. The team also tested four anionic polymers (doses ranging from 0.6 to 1.8 mg/L) with each coagulant. These tests provided the first approximation of the coagulant and polymer dose needed to remove 85% of TSS.

The team found that all three coagulants were effective; ferric chloride consumed the most alkalinity. Alkalinity levels dropped by as much as 160 mg/L (as calcium carbonate), although effluent alkalinity typically remained above 140 mg/L (as calcium carbonate). PACl consumed the least alkalinity (typically less than 20 mg/L [as calcium carbonate]). Overall, the influent contained enough alkalinity to accommodate the drop without affecting effluent pH.

DensaDeg. The tests were performed at surface overflow rates of 1.2 $m^3/min \bullet m^2$ (30 $gal/min \bullet ft^2$) and coagulant doses ranging from 20 to 120 mg/L. They provided the first approximation of the coagulant and polymer doses needed to remove 85% of TSS.

The team found that ferric chloride and alum were effective, but PACl could not remove 85% of TSS — even at doses up to 60 mg/L — so the team decided not to test this coagulant any further. The coagulant doses that did remove 85% of TSS were used in subsequent DensaDeg pilot testing.

As for alkalinity, the team found that ferric chloride consumed the most alkalinity, and PACl consumed the least. In any case, the influent contained enough alkalinity to make supplemental addition unnecessary.

The project team pilot-tested the two systems for 3 months.

Surface Overflow Rate

The project team operated the systems over a range of influent flow rates to assess performance at both typical design surface overflow rates and at higher loads. These tests involved both primary influent and simulated wet weather flows.

Actiflo. The team tested six surface overflow rates ranging from 1.2 to 3.3 $m^3/min \bullet m^2$ (30 to 80 $gal/min \bullet ft^2$) for the three coagulants. Polymer dose ranged from 1.3 to 1.4 mg/L.

Results showed that ferric chloride was most effective, consistently providing more than 95% TSS removal up to a surface overflow rate of 2.9 $m^3/min \bullet m^2$ (70 $gal/min \bullet ft^2$). PACl consistently provided more than 87% TSS removal at surface overflow rates of 2.0 to 2.9 $m^3/min \bullet m^2$ (50 to 70 $gal/min \bullet ft^2$). The minimum alum dose, on the other hand, was less effective — although higher doses during subsequent extended run tests achieved TSS removals between 80% and 90%.

DensaDeg. The team conducted seven tests at surface overflow rates ranging from 1.2 to 2.4 $m^3/min \bullet m^2$ (30 to 60 $gal/min \bullet ft^2$) for ferric chloride and alum doses. Polymer dose ranged from 1.5 to 3.0 mg/L.

Results showed that TSS removal varied, even at identical coagulant doses and overflow rates. Overall system performance generally dropped as the surface overflow rate exceeded 1.8 $m^3/min \bullet m^2$ (45 $gal/min \bullet ft^2$).

Although the data were inconclusive, the project team was able to determine that this unit could meet performance goals if operated at a surface overflow rate of 1.6 $m^3/min \bullet m^2$ (40 $gal/min \bullet ft^2$) or less.

Extended Runs

The project team conducted extended wet weather runs to confirm that the systems would

© 2006 Water Environment Federation All rights reserved

provide 85% TSS removal under various operating conditions. These tests involved both primary influent and simulated wet weather flows.

Actiflo. The tests generally ranged from about 1 to 6 hours and primarily involved simulated wet weather flows, surface overflow rates of 2.0 to 3.1 $m^3/min \bullet m^2$ (50 to 75 $gal/min \bullet ft^2$), and coagulant dosages that ranged from below the minimum to above the maximum effective doses. Polymer doses ranged from 1.1 to 1.4 mg/L.

Sampling frequency varied between 6 and 20 minutes. Early samples were used for the startup testing evaluation, while those taken after two hydraulic detention times were used in the extended run evaluation.

The team found that all three coagulants could meet the 85% TSS removal target. Effluent TSS levels were consistently below 30 mg/L.

The team observed that higher coagulant doses did not necessarily increase COD and BOD removal rates, perhaps because of the change in COD and BOD fractionation. High-rate treatment systems are best at removing particulates, so they would be less effective treating an influent with a higher fraction of dissolved COD and BOD.

DensaDeg. The project team conducted 28 tests primarily involving a surface overflow rate of 1.6 $m^3/min \bullet m^2$ (40 $gal/min \bullet ft^2$). The ferric chloride dose was between 60 and 70 mg/L, alum was 120 mg/L, and polymer was 2.5 mg/L.

Effluent TSS levels were generally below 30 mg/L, but results indicated that alum, which consistently met the 85% TSS removal target, was more effective than ferric chloride, which averaged 77% TSS removal.

A sanitary sewer overflow. The project team found that both of the pilot-tested ballasted flocculation technologies could remove 85% of total suspended solids.

Wet and Dry Startups

The project team performed startup testing (as part of the extended run testing) to assess the time needed to achieve stable performance. Both wet and dry startup conditions were tested. Under wet conditions, both systems were started up with their tanks filled with liquid, and the Actiflo unit also contained microsand. Under dry conditions, both systems were started up empty (not counting the microsand in the Actiflo tanks).

Actiflo. The team conducted five runs to evaluate wet startup performance and three runs to evaluate dry startup performance. Startup tests generally were completed at surface overflow rates of 2.0 to 3.1 $m^3/min \bullet m^2$ (50 to 75 $gal/min \bullet ft^2$).

Results showed that initial TSS removals varied less during wet startups than during dry ones. TSS removals initially varied during wet startups but were generally 80% or more. After two hydraulic detention times (about 12 to 18 minutes), the system usually reached the 85% TSS removal target — except during one PACl run that was at less than the minimum dose. Initial TSS removals during dry startups varied over a wide range of TSS removals and required more than two hydraulic detention times to achieve 85% TSS removal consistently.

DensaDeg. The team conducted wet and dry startup runs at surface overflow rates of 1.4 to 1.6 $m^3/min \bullet m^2$ (35 to 40 $gal/min \bullet ft^2$) using chemical doses of 60 mg/L ferric chloride, 120 mg/L alum, and 2.5 mg/L polymer. Initial TSS removals showed a wide range of performance during both wet and dry startups, although the wet startup had better initial performance. Nevertheless, TSS removal stabilized over time under both conditions, generally reaching 85% in about three to four hydraulic detention times.

Full-Scale Operating Issues

The project team identified four issues to be addressed when implementing a full-scale ballasted flocculation system: startup time, screening and grit removal, odors, and sludge.

Both systems need startup time to reach optimum performance — especially the DensaDeg process, which uses recirculated sludge as ballast and therefore needs more startup time to accumulate an ad-

© 2006 Water Environment Federation All rights reserved

Pilot-Test Conditions for 85% Total Suspended Solids Removal					
System	Chemical dose (mg/L)				Surface overflow rate [$m^3/min/m^2$ (gal/min/ ft^2)]
	Ferric chloride	Alum	PACl	Polymer	
Actiflo	45 to 60	40 to 65	17 to 25	1.4	≤ 2.4 (60)
DensaDeg	60 to 70	80 to 120	—	2.0 – 2.5	≤ 1.6 (40)

PACl = polyaluminum hydroxychloride.

equate sludge blanket. A management strategy will be needed during startup to avoid discharging inadequately treated wastewater.

Both systems require screening to remove wastewater solids that could damage equipment, but the Actiflo system requires finer screening to avoid clogging its hydrocyclone, which is used to separate microsand from waste sludge. Grit removal also should be considered for both processes. Grit generally will be wasted with the DensaDeg waste sludge, but it could recirculate and accumulate in the Actiflo system, depending on wastewater characteristics and operating frequency. If excessive grit accumulates, the microsand would have to be wasted to remove the grit and keep the system functioning properly.

Odors could be a problem for both systems if residual wastewater and sludge are not flushed out of the tanks. The project team found that the Actiflo microsand generated odors even after being flushed with clean water and had to be covered with clean water to minimize odor. A full-scale system may require odor control, depending on the system's location and frequency of operation.

The two systems produce different types and volumes of sludge that will have to be managed. DensaDeg sludge is expected to contain between 2% and 5% solids, and Actiflo sludge is expected to contain less than 0.5% solids.

Another factor that may require further investigation is effluent foaming, which has been reported in full-scale ballasted flocculation systems.

In Summary

Overall, the project team found that both ballasted flocculation technologies can be optimized to remove 85% TSS or more from wet weather flows at the Southerly Wastewater Treatment Plant (see table, above). The team also found that

- wet startup provided better performance and initial effluent quality than dry startup;
- at least two hydraulic detention times were needed to achieve target performance;
- the Actiflo system needed less coagulant and polymer than the DensaDeg system to achieve 85% TSS removals, and it could handle a wider range of influent and operating conditions (possibly because of the microsand); and
- effluent COD and BOD concentrations varied more than TSS levels, which was attributed to variable COD and BOD fractionation (high-rate treatment processes generally do not capture the soluble fraction).

***Susan Landon**, P.E., BCEE, is an associate in the Wakefield, Mass., office of Malcolm Pirnie Inc. (White Plains, N.Y.). **Colleen Donahue**, P.E., is president of Donahue IDEAS LLC (Columbus, Ohio). **Sam Jeyanayagam**, Ph.D., P.E., BCEE, is a senior associate in the Columbus, Ohio, office of Malcolm Pirnie. **Donald Cruden**, P.E., is a project engineer for the City of Columbus, Ohio.*

This study would have been impossible without the cooperation of the Southerly Wastewater Treatment Plant (Columbus, Ohio) staff. The authors thank them for their dedication and hard work.

For More Information

Fitzpatrick, J., C. Wallis–Lage, A. Bhandari, and M. Palomo (2005). "Bubble Trouble," *Water Environment & Technology* (December), pp. 58–63.

Jolis, D and M. Ahmad (2001). "Pilot Testing of High Rate Clarification Technology in San Francisco," WEFTEC 2001.

Keller, J. and M. Schultze (2004). "Rain Yes, Foam No," *Water Environment & Technology* (March), pp. 31–35.

Radick, K.A. and M.A. Morgan (2002) "Brace for the Storm," *Water Environment & Technology* (August), pp. 60–64.

Scruggs, C. and C. Wallis–Lage (2001). "Ballasted Flocculation: A Wet-Weather Treatment Solution?" WEFTEC 2001.

© 2006 Water Environment Federation All rights reserved