BOD5 REMOVALS VIA BIOLOGICAL CONTACT AND BALLASTED CLARIFICATION FOR WET WEATHER

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Bench-scale testing was conducted to quantify the effectiveness of BOD5 removal utilizing an aerobic biological contact reactor and ballasted flocculation/settling. Tests were conducted at activated sludge plants. Samples were collected and mixed with Return Activated Sludge RAS targeting an MLSS concentration of 1 g/L. This mixture was aerated and true soluble and total soluble CBOD5 concentrations were measured over 25 minutes. Results demonstrated that a majority of the true soluble CBOD5 is removed immediately upon contact with RAS. This removal was assumed to be sorption by biomass. True soluble CBOD5 continued to decline over the remaining test period. This was attributed to utilization by biomass for growth under first-order kinetics. Following aeration, samples were jar tested to simulate coagulation/ballasted flocculation/settling. This removed 90 % of suspended solids resulting in removal of the majority of the particulate CBOD5, sorbed soluble CBOD5, and a large fraction of colloidal CBOD5. Effluent Total CBOD5 concentrations were between 6-29 mg/L, demonstrating this treatment configuration can meet CBOD5 limits during wet weather events.
Pilots in Knoxville, TN and Akron, OH confirm that contact tank aeration with ballasted high rate clarification will achieve 85% removal of CBOD5. Effluent values of 20 mg/L Total CBOD5 are typical. Results have demonstrated higher CBOD5 removals with a higher contact tank MLSS concentration. A full scale facility in Wilson Creek, TX has produced results that validate the process' ability to achieve Total BOD removals equivalent to secondary treatment

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Ballasted clarification has long been accepted as a viable treatment method for the removal of solids (TSS) from wet weather wastewater flows. However, as there is no biological mechanism in a typical system, removal of Soluble BOD5 is minimal and total BOD5 removal is therefore a function of the Total BOD5 present as particulate. The addition of an aerated contact tank upstream of the ballasted clarification unit, where wet weather wastewater and Return Activated Sludge (RAS) are combined, has been proposed as a means to accomplish Soluble BOD5 (SBOD5) uptake and meet the EPA’s requirement of 85% Total BOD5 removal for secondary treatment.

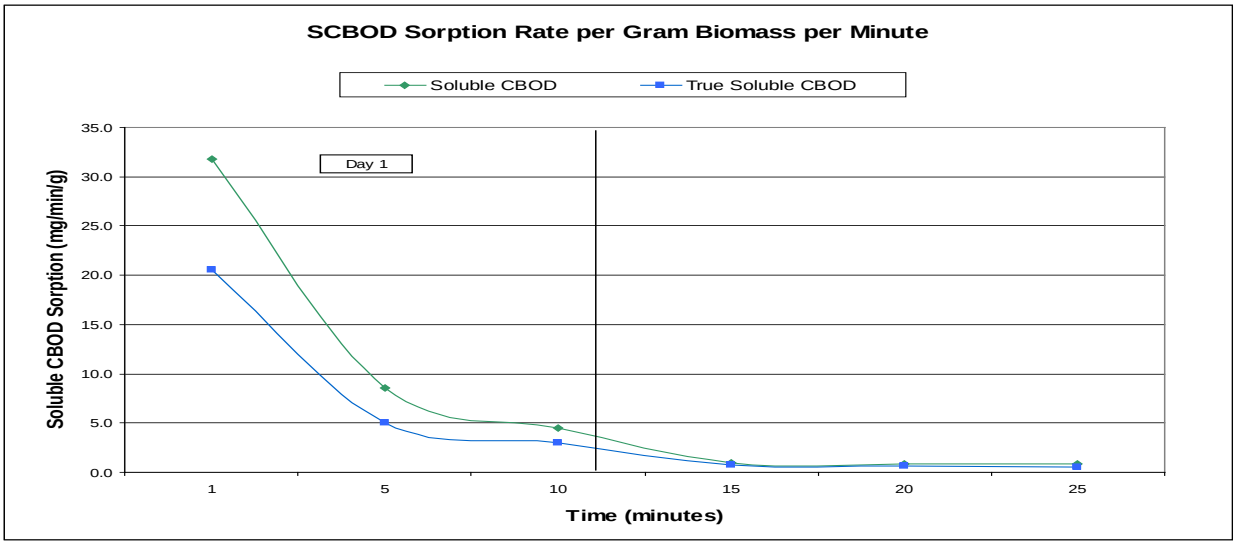
Materials and Methods - Bench Scale Testing

The initial step in investigating this method of treatment was to conduct bench scale testing. Trials were conducted at two wastewater plants in North Carolina with different sludge ages to determine the impact of sludge age on SBOD5 uptake. The test procedure was as follows:

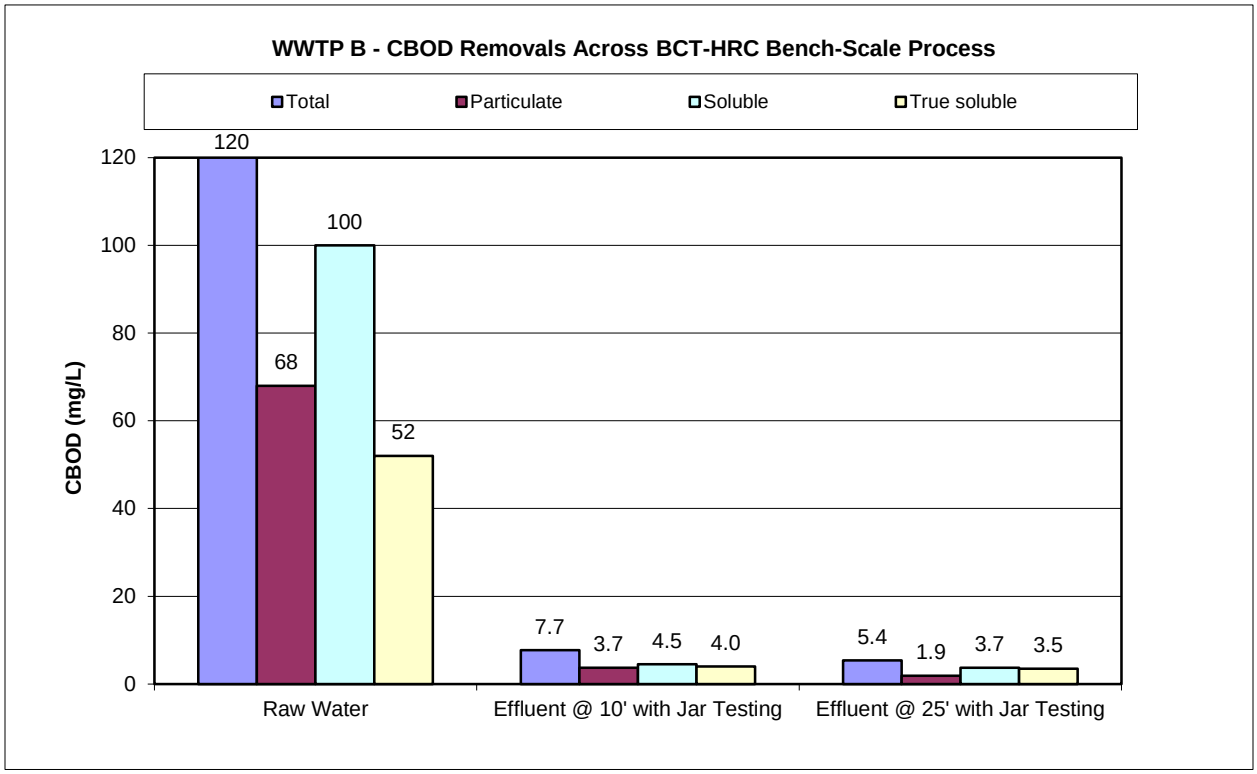
1. Sample ~30 L of Raw Wastewater.
2. Sample ~15 L (vol. varied with plant) of RAS and allow to settle/thicken.
3. Add Raw Water to Bio-contact tank.
4. Start aeration and timer.
5. Add RAS to contact tank to achieve set MLSS.
6. Immediately sample, filter and floc filter for SCBOD, TSCBOD and TSS analyses (t=1 minute).
7. At time t = 5, 10, 15 minutes, etc… sample and filter (SCBOD) or floc filter (TSCBOD).
8. Conduct Ballasted jar testing on aerated samples (e.g. 10' and 25' samples) and analyze for Total CBOD, SCBOD and TSCBOD.
9. Ballasted Floc Jar Test Procedure:
    - Add metal salt coagulant & ballast (sand) to raw sample
    - Mix at 300 rpm, 2 min
    - Add polymer
    - Mix at 200 rpm, 45 sec
    - Settle for 2 min
10. Filter a portion of the jar test effluent for SCBOD analyses.
11. Flocculate and filter (0.45 uM) a portion of the jar test effluent for TSCBOD analysis.
12. Floc/Filtering for TSCBOD:
    - ZnSO4 addition
    - Caustic addition (to 10.5 pH)
    - Settle/Filter = Colloid-free

Results and Discussion

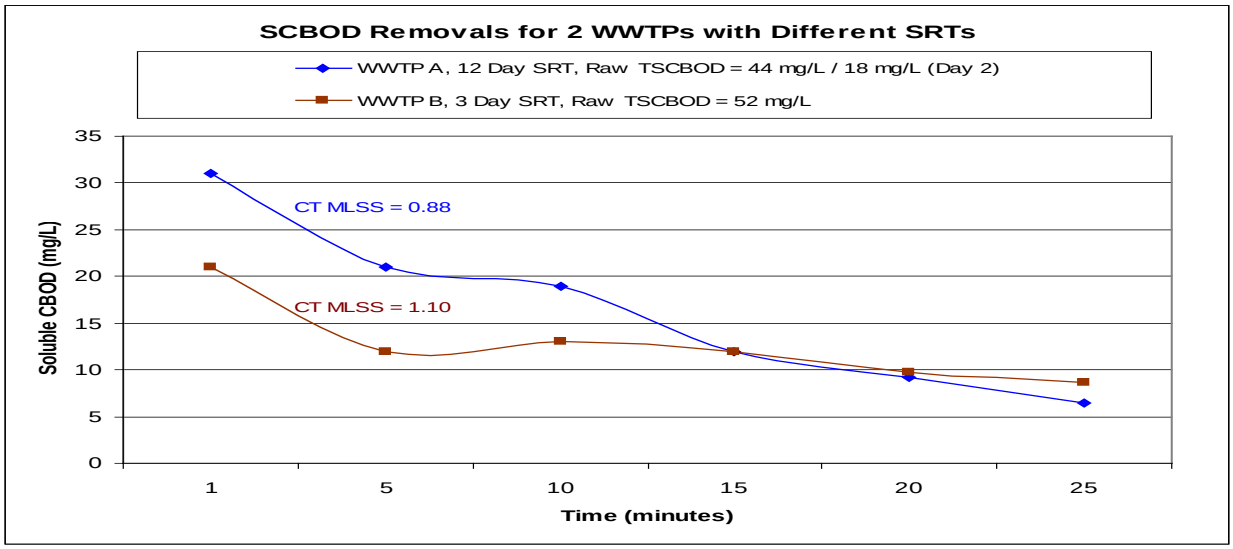
Initial test results demonstrated dramatic reduction in soluble and true soluble BOD5 within the first 5 minutes of aeration, indicating that the majority of SBOD5 removal is due to sorption alone. The more gradual decrease over the remaining time can be seen as due to respiration.



When Ballasted Clarification jar tests were conducted following aeration for 10 and 25 minutes the resulting Total CBOD5 and Soluble CBOD5 removals were > 90%.



SCBOD5 removals were compared between two plants with different sludge ages (3 days vs. 12 days). The plant with the shorter sludge age (i.e. more active sludge) showed better SCBOD5 removals over the same time period when compared to the longer sludge age.



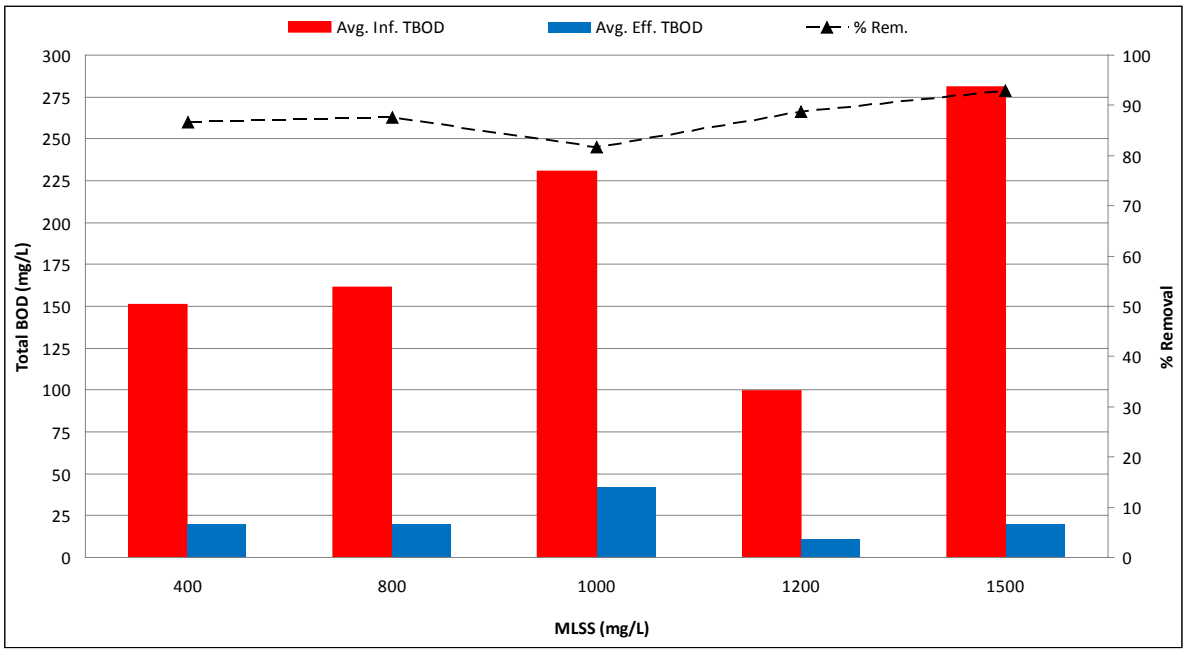
Based on the bench scale testing we can conclude that the aerated contact tank in combination with ballasted flocculation will accomplish 85% removal of Total BOD5. The initial rapid reduction in Soluble BOD5 during the aeration step can be attributed to sorption while the subsequent more gradual reduction is mainly due to respiration. The ballasted flocculation step accomplishes the removal of Particulate BOD5 resulting in Total BOD5 removals of > 90%.

Knoxville, TN - Pilot Testing

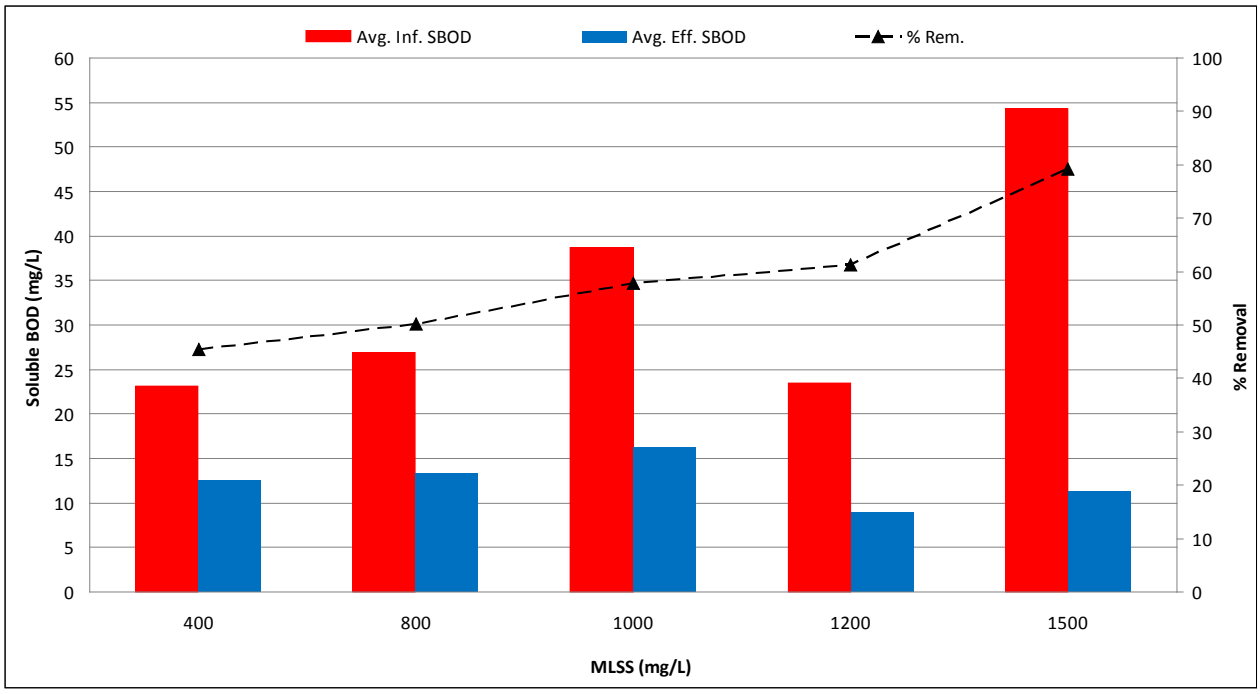
Pilot testing was conducted in Knoxville, TN at both the Kuwahee and 4th Creek WWTPs in early 2010. The Kuwahee plant is an activated sludge plant with a rated capacity of 44 MGD located near the University of Tennessee. The Fourth Creek plant is an activated sludge plant with a rated capacity of 10.8 MGD and is located in the suburbs of Knoxville. Pilot test goals were to remove BOD5, CBOD5, and TSS. Wet weather flows were simulated using a blend of raw wastewater and secondary effluent, with RAS introduced into the blended feed ahead of the contact tank.

Dissolved Oxygen (DO) was monitored in the contact tank, with a value of 2.0 mg/L targeted. TSS was also monitored in the contact tank. As flow exited the contact tank Ferric Chloride was fed at a dose of 80-130 mg/L. An anionic dry polymer was fed in the ballasted flocculation pilot at a dose of 2.5-4.0 mg/L. Settled water turbidity was maintained at < 2 NTU throughout the testing while operating at overflow rates of 30-40 gpm/ft2.

Contact tank Mixed Liquor Suspended Solids (MLSS) levels from 400 – 1500 mg/L were tested to determine the impact of MLSS concentration on BOD5 removals. The influent wastewater at the Kuwahee plant contained a higher industrial component and therefore a higher portion of the Total BOD5 was present as Soluble BOD5. Initial testing at Kuwahee showed that a higher MLSS concentration in the contact tank was required to meet the 85% removal for Total BOD5.



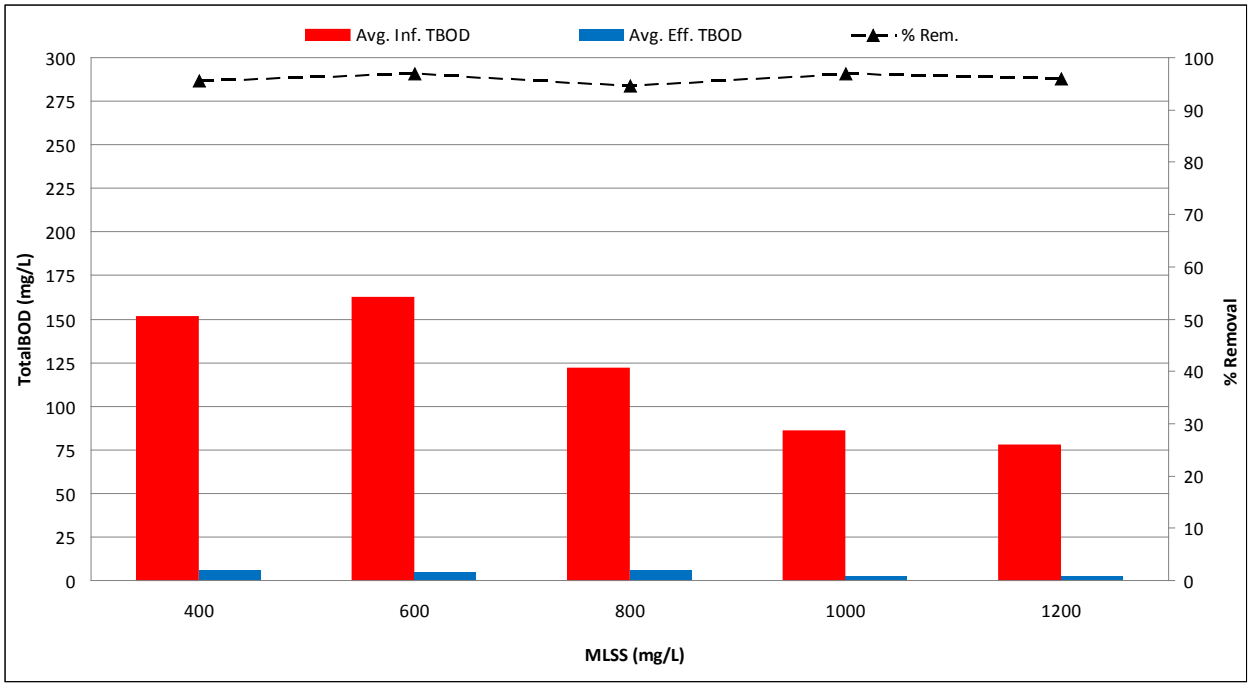
During the Kuwahee study it was demonstrated that higher MLSS concentrations resulted in improved SBOD5 removals.



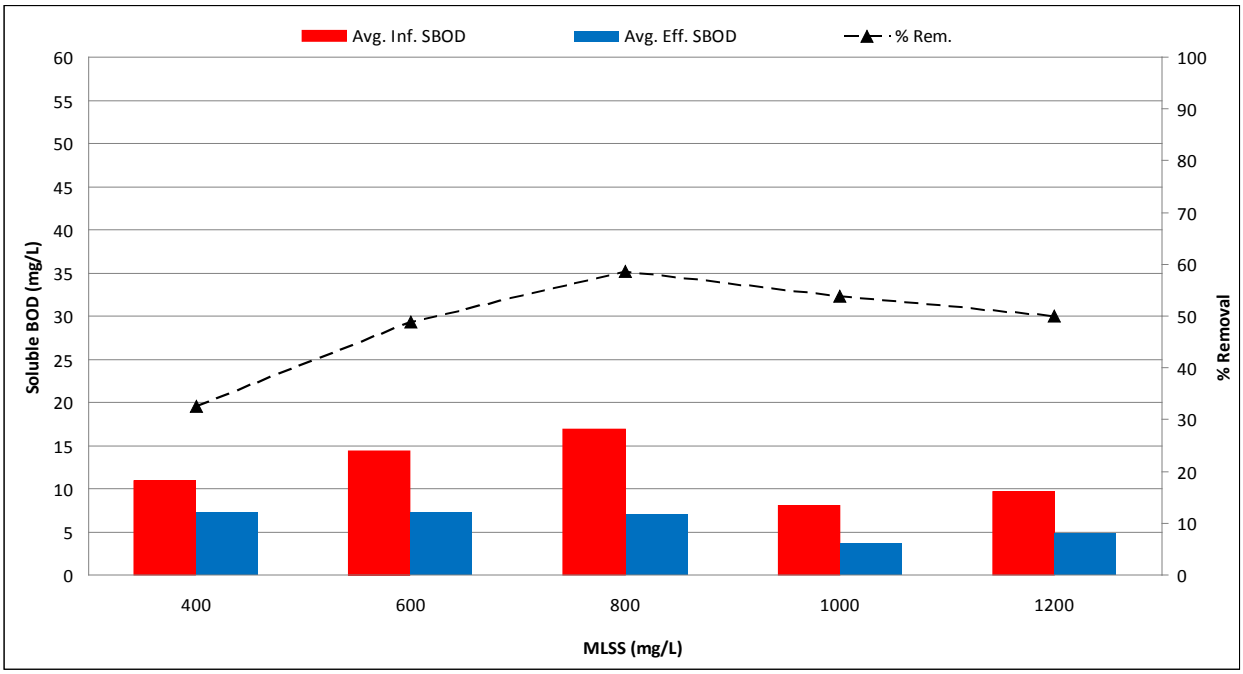
The Kuwahee portion of the study showed that MLSS values of greater than 1000 mg/L were required to consistently meet the required 85% removal of Total BOD5. SBOD5 removals improved as MLSS levels were increased. An average effluent Total BOD5 of 20 mg/L was achieved throughout the pilot.

The second portion of the Knoxville study was conducted at the 4th Creek WWTP, located in a more residential area. The soluble portion of the Total BOD5 was much lower at this plant which resulted in a higher RAS flow requirement to meet the selected MLSS levels. MLSS values from 400 to 1500 mg/L were again targeted during the study. Ferric Chloride was fed at 65-85 mg/L, with a cationic dry polymer dosed at 2.5-4.5 mg/L.

4th Creek results showed excellent Total BOD5 removals over all MLSS levels tested. This can be seen as mainly due to the lower SBOD5 levels present. Since most of the Total BOD5 was present as particulate BOD5, this allowed the system to achieve > 90% Total BOD5 removals.



Soluble BOD5 removals showed improvement as MLSS levels were increased to 1000 mg/L, but no additional benefit was observed at higher MLSS levels.



Excellent Total BOD5 removals were observed during the 4th Creek study primarily due to the low Soluble BOD5 levels present in the wet weather blend. Removals of > 90% were observed over all MLSS ranges tested, and TSS removals of > 90% were also experienced. The 4th Creek and Kuwahee studies further validated the concept of biological contact in combination with ballasted flocculation for wet weather wastewater treatment.

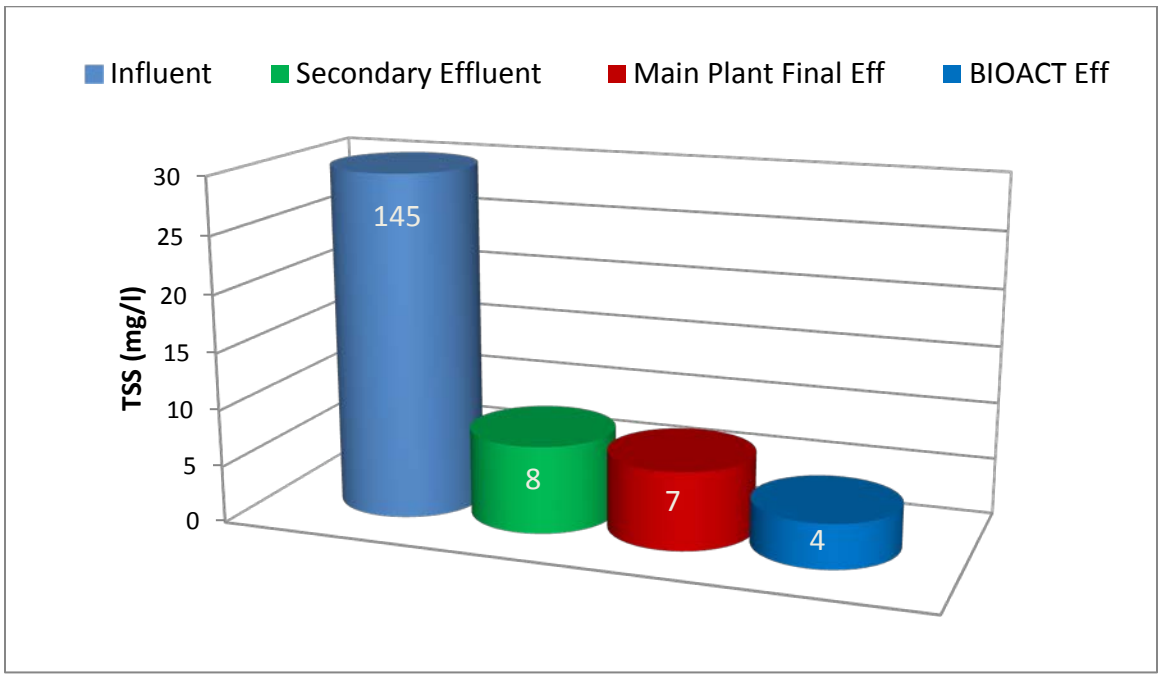
Akron, OH - Pilot Testing

The enhanced ballasted clarification unit was piloted in Akron, OK from March – December 2012. The City is under a consent decree with the US EPA and State of Ohio regarding their combined sewer system and the EPA approved of the pilot study plan. The system was operated over a predetermined number of actual wet weather events with the following two objectives:

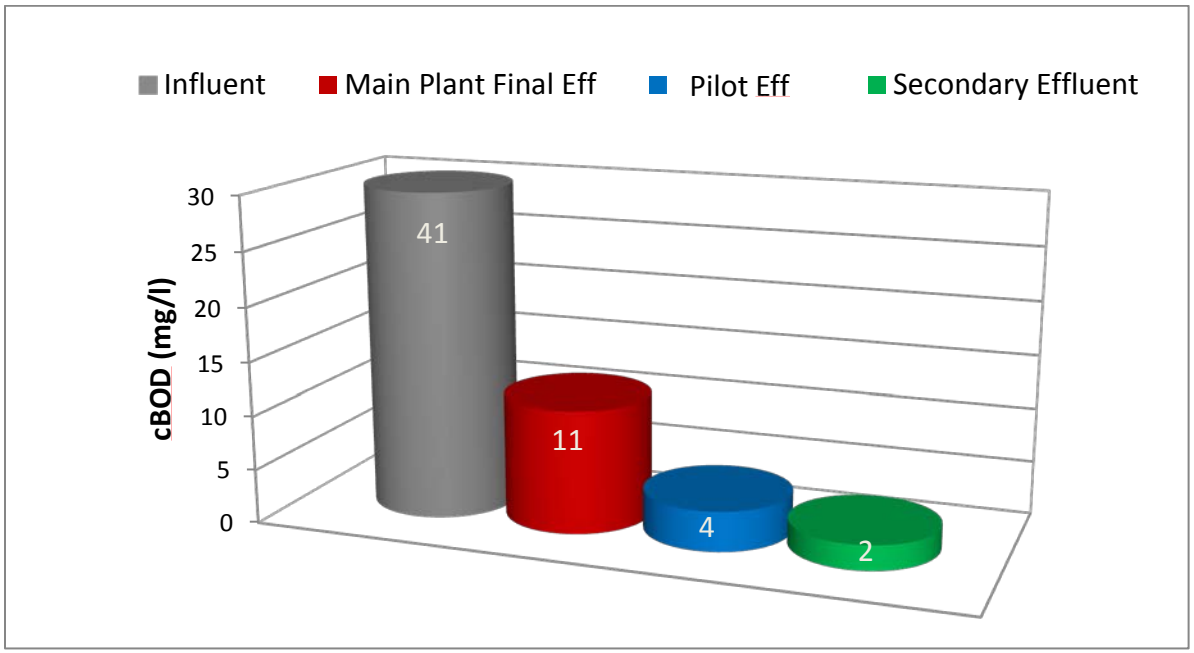
1. Meet the plant 30-day average effluent limitations which were listed as 30 mg/L Total Suspended Solids (TSS) and 25 mg/L Carbonaceous Biochemical Oxygen Demand (cBOD).
2. Demonstrate that the process could achieve > 85% Total cBOD removal.

During the wet weather events the pilot unit was operated with a 21 minute retention time in the contact tank. An MLSS concentration between 900 – 1200 mg/L was targeted. The settling tank overflow rate was 40 gpm/ft2, which is considerably greater than the conventional plant. A dose of 105 mg/L Aluminum Sulfate and 2.8 mg/L anionic polymer was fed to the system during each event.

The TSS results confirm that the pilot system achieved lower final TSS concentrations than the conventional plant secondary or final effluent.



The pilot effluent Total CBOD5 concentrations were almost identical to the plant secondary effluent.



Conclusion

The combination of an aerated biological contact tank and ballasted clarification has been approved for full scale implementation by several EPA regions (3, 4, and 6) as equivalent to secondary treatment for TSS and BOD5 removal. Bench scale testing demonstrated the viability of the process, and numerous pilot studies have confirmed its effectiveness in achieving excellent TSS and BOD5 removals. Full scale plants in Wilson Creek, TX and Cox Creek, MD have recently been commissioned which will provide further validation of the process as a solution to wet weather wastewater treatment issues.