Removal of Biochemical Oxygen Demand via Biological Contact and Ballasted Clarification for Wet Weather

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Ballasted clarification has long been accepted as a viable treatment method for the removal of total suspended solids (TSS) from wet weather wastewater flows. However, as there is no biological mechanism in a typical system, removal of soluble biochemical oxygen demand after five days (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 U.S Environmental Protection Agency (EPA) requirement of 85 percent 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 their impact on SBOD5 uptake (Figure 1). 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 biocontact tank.
4. Start aeration and timer.
5. Add RAS to contact tank to achieve set mixed liquor suspended solids (MLSS).
6. Immediately sample, filter, and floc filter for soluble carbonaceous biochemical oxygen demand (SCBOD), total carbonaceous biochemical oxygen demand (TCBOD) and TSS analyses (t=1 minute).
7. At time t = 5, 10, 15 minutes, etc., sample

and filter (SCBOD) or floc filter (TCBOD).

8. Conduct ballasted jar testing on aerated samples (e.g., 10-minute and 25-minute samples) and analyze for total carbonaceous biochemical oxygen demand (CBOD), SCBOD, and TCBOD.
9. Ballasted floc jar test procedure:
   - Add metal salt coagulant and ballast (sand) to raw sample.
   - Mix at 300 rpm, two minutes.
   - Add polymer.
   - Mix at 200 rpm, 45 seconds.
   - Settle for two minutes.
10. Filter portion of jar test effluent for SCBOD analyses.
11. Flocculate and filter (0.45 uM) portion of jar test effluent for TCBOD analysis.
12. Floc/filtering for TCBOD:
    - 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 five minutes of aeration, indicating that the majority of SBOD5 removal is due to sorption alone (see Figure 1). 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 percent.

The SCBOD5 removals were compared between two plants with different sludge ages: three days versus12 days (Figure 3). 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, it can be concluded that the aerated contact tank, in combination with ballasted flocculation, will accomplish 85 percent 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 percent.

Knoxville, Tenn.: Pilot Testing

Pilot testing was conducted in Knoxville, Tenn., at both the Kuwahee and Fourth Creek Wastewater Treatment Plants (WWTPs) in early 2010. The Kuwahee plant is an activated sludge plant with a rated capacity of 44 mil gal

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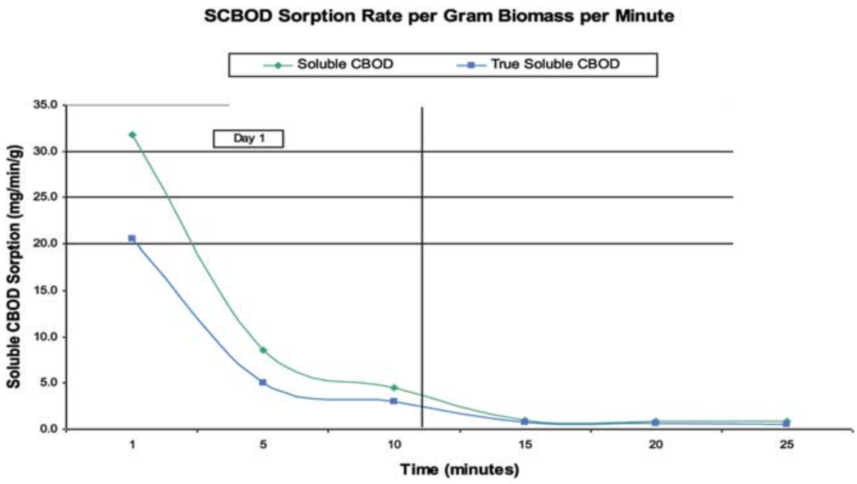
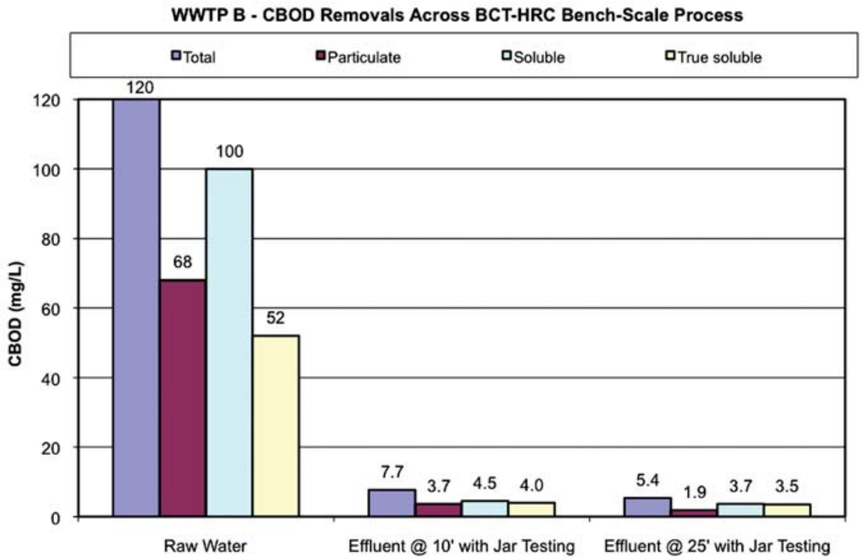


Figure 1.



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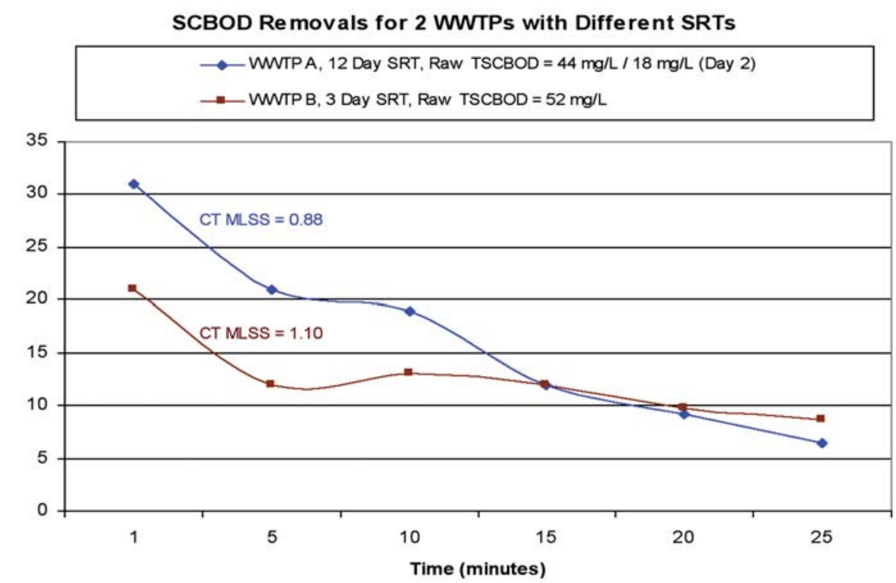

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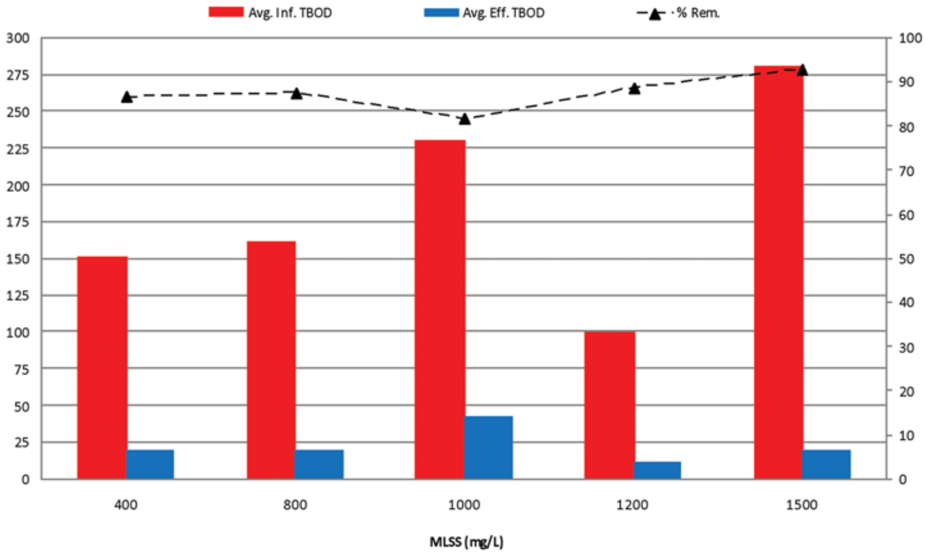

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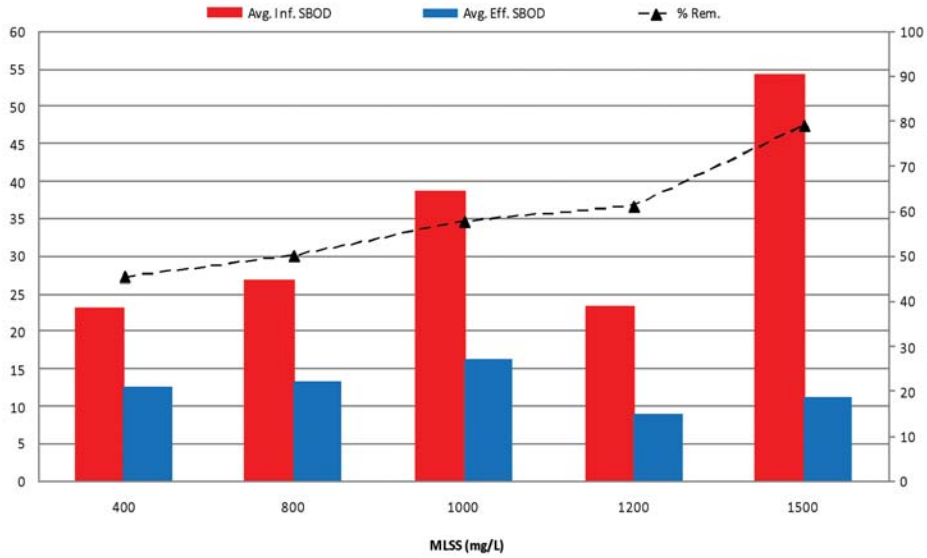

Figure 5.

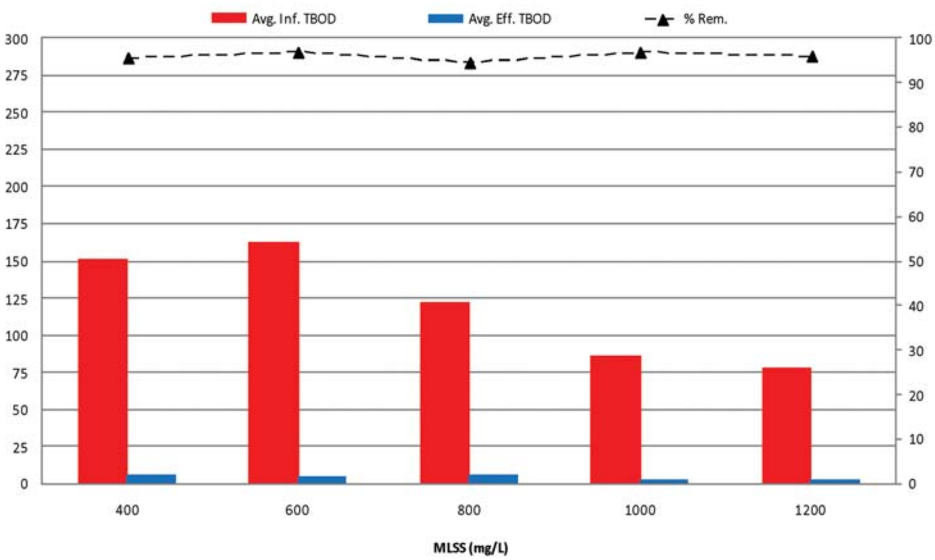

Figure 6.

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per day (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; the 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 nephelometric turbidity units (NTUs) throughout the testing, while operating at overflow rates of 30-40 gpm/ft^2.

Contact tank MLSS levels from 400 to 1500 mg/L were tested to determine the impact of MLSS concentration on BOD5 removals (Figure 4). 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 percent removal for total BOD5.

During the Kuwahee study it was demonstrated that higher MLSS concentrations resulted in improved SBOD5 removals (Figure 5).

The Kuwahee portion of the study showed that MLSS values of greater than 1000 mg/L were required to consistently meet the required 85 percent removal of total BOD5. The 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 Fourth 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. The 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.

The Fourth Creek results showed excellent total BOD5 removals over all MLSS levels tested (Figure 6). 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 percent total BOD5 removals.

Soluble BOD5 removals that showed improvement as MLSS levels were increased to