Blue Frog™ System White Paper: Oxygen Transfer Rate

Oxygen Transfer in the Blue Frog System

Oxygen transfer in a traditional aeration basin is directly proportional to the running horsepower when the DO is held at a constant set point. When the bio-load increases, more horsepower is used.

Oxygen transfer in a Blue Frog System is directly proportional to the BOD concentration of the influent. When the bio-load increases, the apparent oxygen transfer increases proportionately with no increase in horsepower.

This explains why.

Background

Metcalf & Eddy (M&E) define the overall oxygen mass transfer coefficient (K_La):

$$r_C = K_La * (C_s - C)$$

where r_C is the change in concentration
K_La is the overall mass transfer coefficient
C_s is the saturation concentration of oxygen in solution
C is the concentration of oxygen in solution

Thus the rate of oxygen uptake is reduced if the oxygen is not immediately consumed.

M&E goes on to say: "Typically, oxygen is maintained at a level of 1 to 3 mg/l, and the oxygen is used by the microorganisms as rapidly as it is supplied." But in fact multiple factors are used to adjust clean-water-performance to dirty-water-performance and to allow for handling common cause process upsets.

When aerobic organisms oxidize BOD, sludge is formed. This sludge is only partially oxidized. Sludge handling costs are a major cost to a waste treatment plant.

Blue Frog System

The Blue Frog System (BFS) does not work like a well-mixed M&E aeration basin. Microbubbles are formed which reduce the specific gravity of the upper 3ft of a lagoon to ρ= .97. Insoluble BOD and partially oxidized soluble BOD sludge sink rapidly into the anaerobic zone below the induced-at-3ft-"thermocline". Thus most of the bio-load transfers from the aeration zone to the anaerobic zone. The lagoon is intentionally stratified, not mixed.

The BFS increases the anaerobe/facultative count and selects for different indigenous anaerobes than an M&E aeration basin system. Sludge is digested in situ, producing methane, carbon dioxide, ammonia and water. The following results are observed:

1. Sludge is digested in situ (old inventory & newly produced)
2. There is no malodor (sulfur reducing bacteria and pathogens (E. coli reduced 99%) are consumed by other faster-growing, selected-for, indigenous anaerobes)
3. There is very little algae growth (aerobic CO_2 production is curtailed in favor of anaerobic methane production)
4. BOD reduction performance improves when an upset occurs (because BOD is physically transferred to the anaerobic zone)
5. Methane production occurs only over the flat bottom of the lagoon (the angle of repose is lowered to 5° by the anaerobe selection process and sludge slides off the berm and down to the flat)
6. Ammonia increases as the nitrogen in sludge is released (as ammonia)
7. Energy is reduced by at least 50%.

Tulare, CA

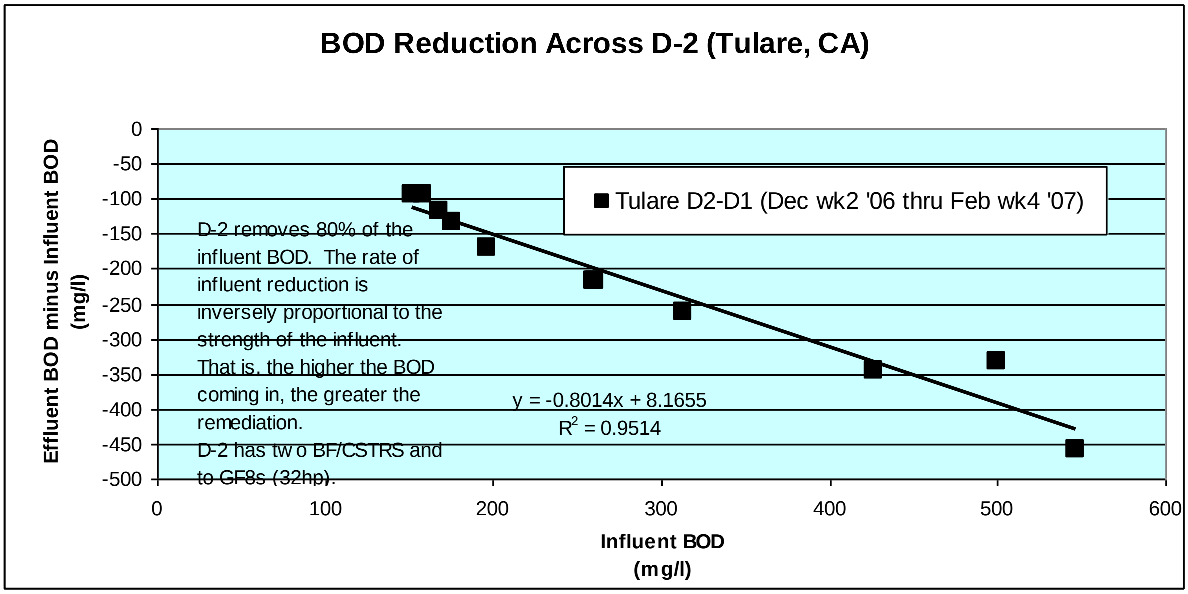
Tulare is a 7MGD waste treatment plant with a large industrial load (primarily cheese and dairy bottling). The incoming BOD is 800-1,200mg/l. Tulare pre-treats the waste in an anaerobic digester, then in an M&E-type complete mix aeration basin and thereafter in three lagoons. There are 5 nearly-identical lagoon trains, A-E. D&E have somewhat higher loads because of influent piping layout.

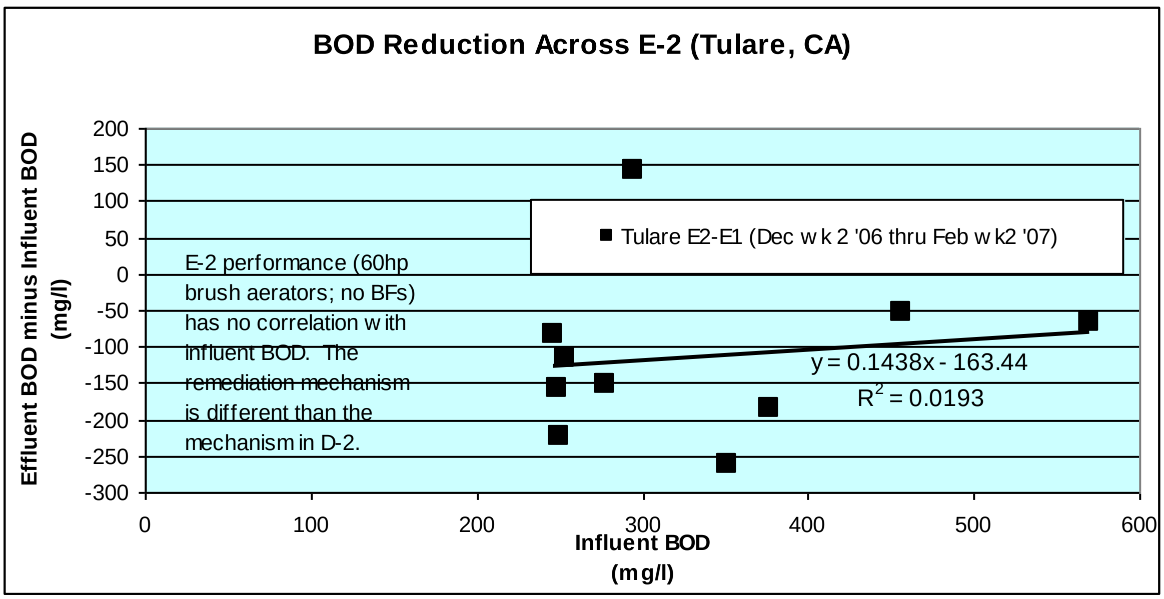
The Tulare system is prone to upset as the upstream anaerobic system delivers influent BOD from 150 – 550mg/l to Lagoon 2.

Train D has been modified to use the BFS. The largest share of the BOD remediation load takes place in D-2 (80%). Data is taken by the plant weekly at each lagoon. Train E is the control Train for Train D.

In the first Chart, the drop in BOD going through D-2 is correlated with the D-2 influent BOD. The drop in BOD is inversely proportional to the influent BOD (R^2=.95). When the load increases to D-2, the work done by D-2 increases.

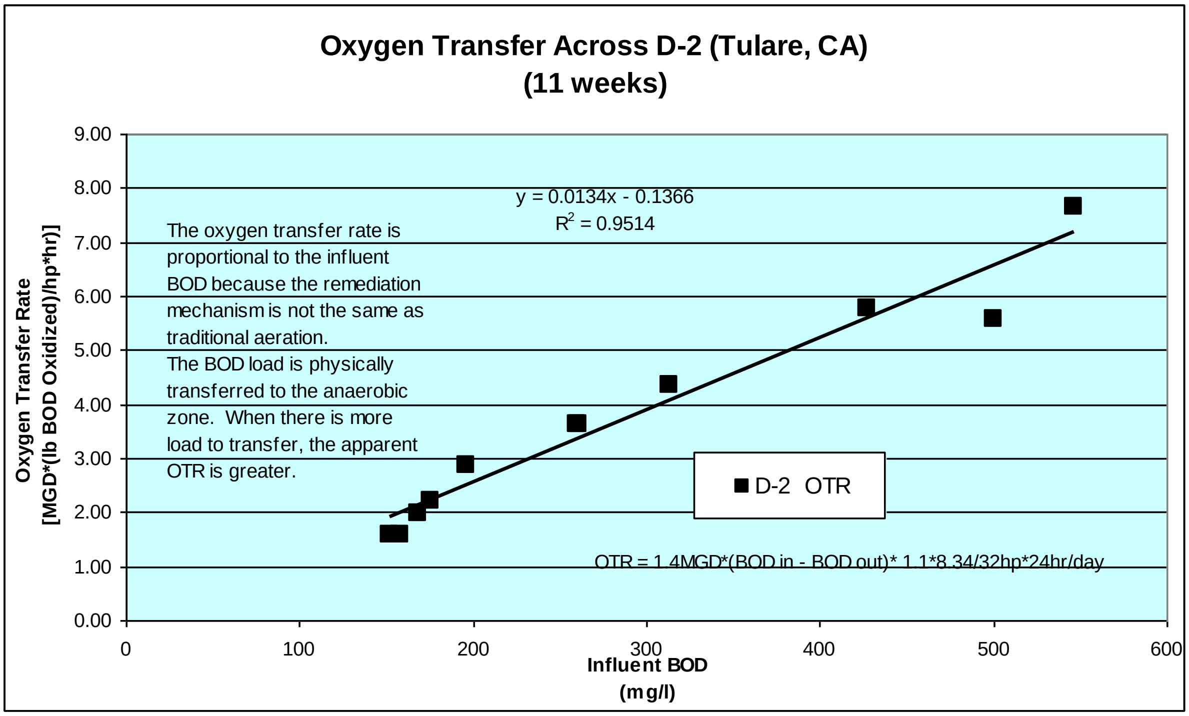
In the second Chart, the same data are plotted for E-2, the control lagoon. The response in E-2 is random (R^2=.02), suggesting that the remediation mechanisms in E-2 and D-2 are different.





During the 11week reporting period, the horsepower in D-2 was constant @ 32hp. Since the drop in BOD is a variable in calculating oxygen transfer, these same data can be used to determine the actual oxygen transfer rate (OTR). [The math is shown on the Chart.]

The OTR is directly proportional to the incoming BOD load (R^2=.95). This apparent anomaly is readily explained when the difference between a well-mixed lagoon and a stratified lagoon is considered.



The OTR is determined by measuring the loss of BOD times the flow divided by the horsepower (in consistent units) while passing through an aeration basin. The explicit assumption is that all the BOD loss took place in the aeration zone. This is a sound assumption in a well-mixed basin, whether vertically mixed or completely mixed. It is however, an unsound assumption if the basin is stratified. It is a particularly poor assumption if the basin is stratified and there is a material difference in specific gravity between the light and heavy zones.

The BFS adds just enough air (first as oxygen-containing microbubbles, then as nitrogen-only residual microbubbles) to allow any solids to physically transfer to the anaerobic zone. The physical transfer of solids is not affected by load, only density and viscosity. Thus when the load increases, the load is absorbed by anaerobes and facultative organisms.

The stratification strategy only has value if the anaerobes can keep up with the load. M&E teaches that the bio-system will "select" for rapid settling organisms if allowed to first digest the soluble fraction of the total BOD. The BFS does exactly this by clever circulation of the influent in a very small volume of the lagoon (the CSTR). When the selected organisms leave the CSTR, they inoculate the downstream lagoon with Inoculated Activated Sludge (IAS). [There can be no Returned Activated Sludge (RAS) as there is no accumulated sludge to return.]

Thus the microbiology of the entire lagoon is changed in a fundamental way. These differences change the utility, predictability and economics of lagoons in a material way.

This new technology has several implications:

1. Methane production increases because both the traditionally-digested-sludge and the traditionally-aerated BOD make methane.

2. Hydrogen sulfide in bio-gas is virtually eliminated by eliminating the biological root cause of its formation.

3. Ash is contained in the lagoon, not spread on fields or land-filled.

4. Pathogens are reduced by 99%; animal health in confined feeding operations is measurably improved and the fact they are not thrown into the atmosphere is beneficial in urban areas or where humans might have contact with the mist.

5. Energy is reduced, not only because the normal bio-load is transferred to the anaerobic zone, but the safety factor typically designed into aeration systems is not needed as the stratification strategy inherently increases efficiency as the load increases.

6. When discharged water is land applied, the nutrient value (ammonia) is increased instead of being left behind in the sludge; when ammonia must be controlled, additional BFS strategies are employed to remove ammonia (nitrification/de-nitrification similar to an oxidation ditch is done vertically (not horizontally) in a downstream CSTR).