Blue Frog™ System
White Paper: Sludge Reduction

The Blue Frog System for In-Situ Sludge Digestion

The patented and patents pending Blue Frog System is a low energy system which naturally selects for indigenous, fast-settling microbes (by creating a low density, soluble-BOD upper zone) and rapid-digesting, low angle-of-repose microbes (by creating a high density, insoluble-BOD-rich lower zone). The two zones are created in a hydraulically-contained environment at the inlet to a waste treatment lagoon. The low density, soluble-BOD zone and the high density, insoluble BOD zone leave the contained area as a stratified stream at the sludge/water interface. The low density fraction migrates to the surface above the thermocline; the high density stream stays below the thermocline. [The thermocline is artificially created by the density differences.]

Aerators, which mix microbubbles and water, circulate low density (ρ=.97) water horizontally in a shallow, well mixed, short-HRT zone. Residual nitrogen microbubbles are continually re-mixed into the surface water column by induced eddies, keeping the density of the entire circulating surface flow below $\rho = 1$. Produced sludge sinks rapidly to a secondary sludge blanket separating the well-mixed zone from the plug flow zone. Aerators are sized to oxidize only the soluble BOD.

The high density, high viscosity stream moves laterally across the lagoon in extended-HRT, plug flow.

Sludge is completely digested in situ such that there is no sludge to waste or return [1.4MGD train (Tulare, CA, Train D) lost 17 inches of sludge in 82days; control Trains (A, B, C & E) all accumulated sludge. A poultry processing lagoon lost 41% of its sludge at a rate of -.16in/week over 56 weeks (R^2 = .99).]

When sludge is digested in situ and not wasted or accumulated, several things change:

1. Malodor is eliminated because the selector tank selects against malodor-producing bacteria, such as sulfur-reducing-bacteria. This eliminates one of the root causes of malodor formation.
2. Produced sludge is concentrated over the flat part of the lagoon. The low angle of repose lets sludge slide off the angled berms to fill in any short-circuit channels and even out the sludge depth across the entire lagoon. As-designed hydraulics is maintained.

3. Methane production increases because available carbon partitions away from CO_2 and towards methane. [Municipal waste is typically 35% soluble BOD]. The size of the lagoon cover to capture the methane is reduced because the angled berm area does not produce methane.
4. Algae growth is curtailed because there is less CO_2 available to feed them.
5. Energy costs are cut in half as only the soluble fraction (35%) of the BOD is oxidized.
6. Since there is no sludge to return or waste, sludge handling costs are eliminated. Sludge for upstream inoculation comes from the bottom sludge in the contained zone at the lagoon inlet.
7. When sludge is digested in situ it forms methane (65-70%), CO_2 (25-30%), water and ammonia. Effluent ammonia increases, particularly after start-up when pre-existing sludge inventory is being wasted.
8. An important measure of the reproducible, predictable capacity of a treatment lagoon is the rate of BOD reduction ($(BOD_{effluent} - BOD_{influent})/ BOD_{influent}$). Traditional lagoon performance is not predictable and the correlation of ($BOD_{effluent} - BOD_{influent}$) versus $BOD_{influent}$ is random (R^2=.16). Blue Frog lagoon BOD performance is predictable (R^2=.89). [Basis: Tulare Train D before and after Blue Frog installation.]

The Blue Frog System minimally entails an influent Blue Frog Continuously Stirred Reactor (BF/CSTR) and a Gold Frog Aerator. As shown in the attached sketch, the BF/CSTR creates a surface zone and a sub surface zone using entrained microbubbles to significantly change the density of the two zones. Some oxygen is added, but the amount is trivial.

The GF aerator has a BF circulator combined with an impingement aerator. [When you impinge two gas/liquid streams at a velocity greater than a defined minimum, the bubbles fractionate and are small enough to reflect light. The individual bubble drag coefficient is such that the microbubbles are continually re-entrained in the water column by induced eddies.] The oxygen is rapidly consumed by the soluble BOD, but the 79% residual nitrogen continues to perform the density difference function needed to sink produced solids. The circulator moves microbubbles horizontally up to 250' from the center.

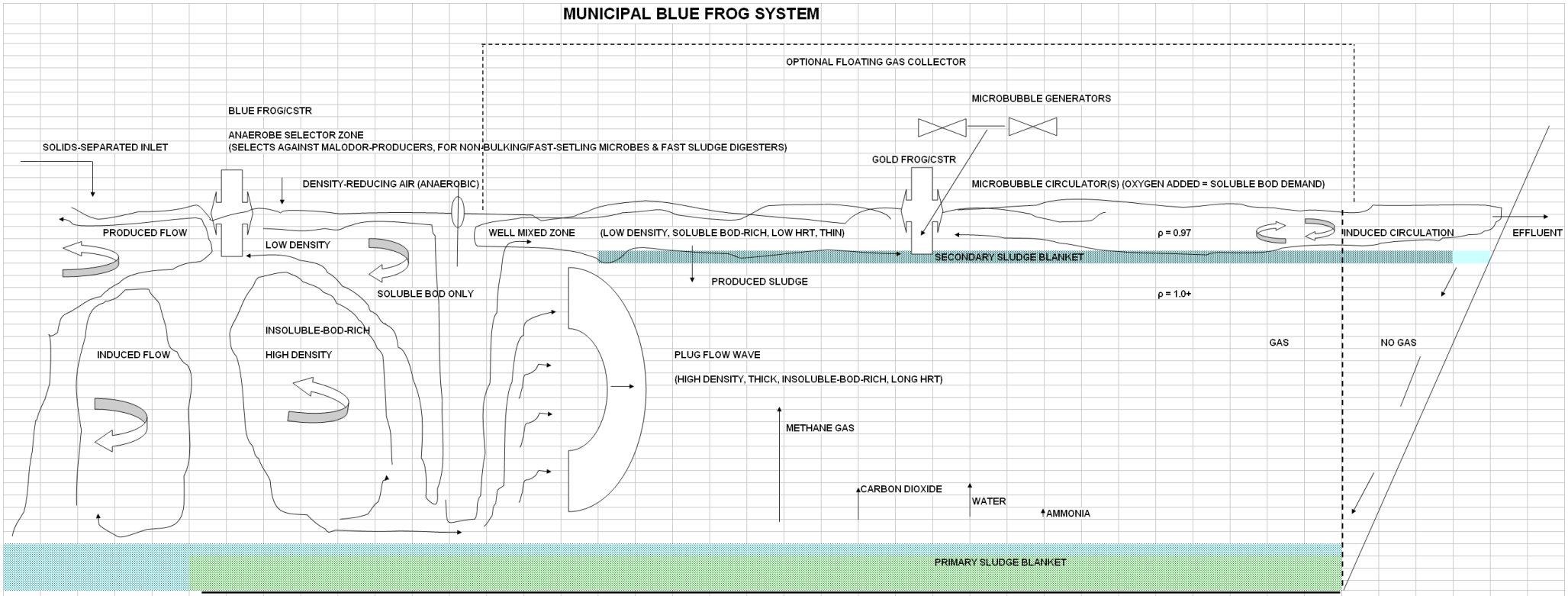
Depending on flows and loads, the basic system is repeated as needed to oxidize the soluble BOD. Surface-to-floor curtains are used to divide the lagoon into channels. These curtains are also used to re-engineer lagoons whose original flow patterns invite short-circuiting.

The BF/CSTR is created with a 3hp water circulator which accepts recycled water horizontally at the 3' level and distributes ~7MGD radially from the circulator. A floating 3' deep boom is placed circumferentially around the circulator. Out-flowing surface water piles up at the boom until the vertical hydraulic force is sufficient to drive the radial flow straight down to the floor. There is no force to alter the course of the produced-waterfall until it ricochets off the floor and returns to the circulator inlet. The waterfall creates a small resistance to cross-flow, so entry and egress from the CSTR is at the sludge/water interface. The returning low density flow induces a high density

counter-flow. Together a low density produced surface zone is stacked vertically above a high density induced sub surface zone. Each brings microbes and food into intimate contact, encouraging growth.

Metcalf & Eddy teach that such a selector tank preferentially selects for fast settling sludge.

The attached sketch illustrates the flow patterns and describes the effects of each stage in the process.



BENEFITS

1. MICROBIAL ROOT CAUSE OF MALODOR ELIMINATED
2. ANAEROBE SELECTOR PREFERENTIALLY SELECTS FOR RAPID SETTLING/FAST DIGESTING/LOW ANGLE-OF-REPOSE MICROBES BY ISOLATING SOLUBLE BOD
3. INCREASES METHANE PRODUCTION BY TRANSFERRING INSOLUBLE BOD INTO ANAEROBIC ZONE
4. LOW ANGLE OF REPOSE PRODUCED-SOLIDS SLIDE DOWN BERM TO FLAT. GAS ONLY PRODUCED OVER FLAT. REDUCES/SIMPLIFIES AREA FOR GAS COLLECTION
5. SLUDGE ALL DIGESTED IN SITU
6. ALGAE GROWTH BIOLOGICALLY CONTROLLED BY PARTIONING CARBON TO METHANE AND AWAY FROM CO_2
7. ENERGY COSTS CUT IN HALF BY ADDING OXYGEN ONLY FOR SMALL FRACTION OF BOD (SOLUBLE BOD)