

Blue Frog™ System

White Paper: Gold Frog/CSTR

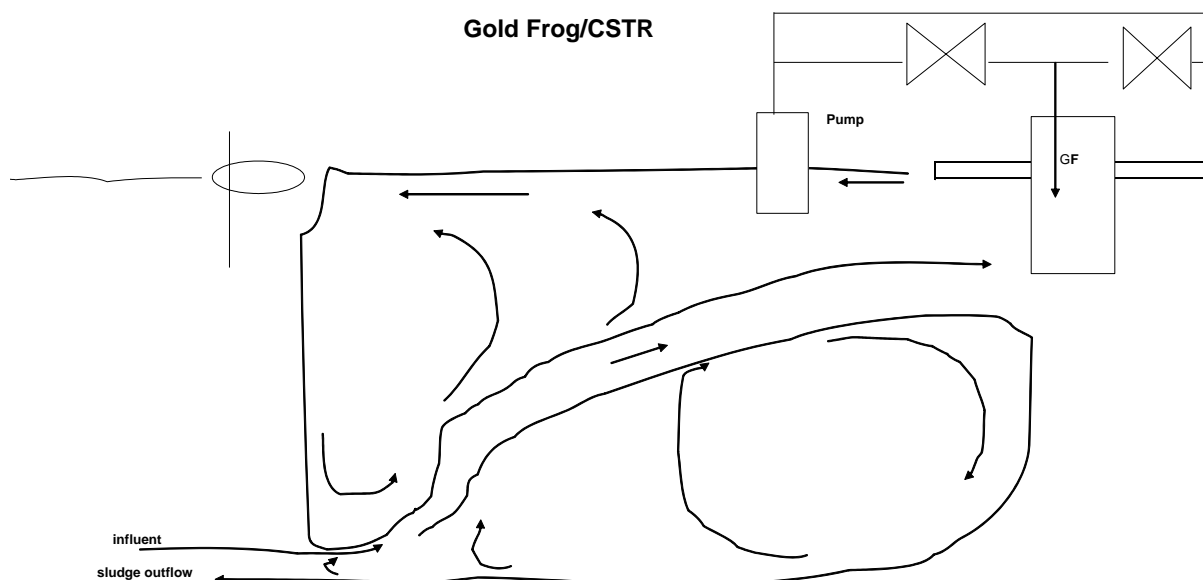
Gold Frog/CSTR – Soluble-BOD Selector/Converter

The patented Gold Frog/CSTR selects for soluble BOD, converts soluble BOD into insoluble BOD and then sinks the produced insoluble solids. This strategy delivers many changes:

1. Much of the bio-load is transferred from the expensive aerobic zone to the inexpensive anaerobic zone.
2. Energy consumption to aerate and move water is cut at least in half (depending on the per cent soluble BOD in the influent).
3. A low density, aerated surface zone caps a high density anaerobic sub-surface zone.
 - a. There is no malodor.
 - b. As produced sludge sinks rapidly in low density surface water, the surface-zone-process naturally selects for soluble BOD in the surface zone (from the physical transfer of insoluble BOD to the sub-surface zone). The sub-surface zone naturally selects for organisms acclimated to insoluble BOD digestion.
 - i. Metcalf & Eddy teach that a short detention time "selector" tank, targeting soluble BOD before the aeration basin, "selects" for desirable organisms such as fast settling sludge.
4. The specific gravity difference is so large in the GF/CSTR, that the produced-stratification into insoluble-poor and insoluble-rich zones is maintained as the two zones exit the contained volume.
 - a. Outboard Gold Frogs are often installed to maintain the low density surface zone and the high density lower zone throughout the lagoon. In these installations, most of the soluble BOD is converted into insoluble BOD early enough in the process that anaerobic mechanisms predominate over aerobic mechanisms. The total oxygen requirement of the system is reduced.

- i. An artifact of producing rapid-settling sludge in a continuous aerobic cap is the clarifying effect that fast settling floc has on sub-surface slow-settling floc. Insoluble BOD is disproportionately concentrated in the sludge blanket deep within the lagoon.
5. Soluble BOD oxidizes faster than insoluble BOD.
 - a. The surface zone is lower viscosity, lower density and low in slow-to-react-insoluble BOD. The inherent fluid dynamic of light, thin water reduces the detention time in the surface zone... but little is required for soluble BOD (with available DO).
 - b. Conversely, thick, heavy anaerobic fluid dynamics increase the detention time in the sub-surface zone... exactly where it is needed.
6. Sludge, both new and old, is digested in situ in the long-detention time, sub-surface zone.
 - a. Return activated sludge (RAS) is eliminated; sludge wasting is eliminated; measurable accumulation of sludge ash is not (yet) observed.
 - b. The sludge contained within the CSTR comes from microbes acclimated to the rapidly-oxidizing soluble BOD. This is an Incubated Activated Sludge (IAS) substantially different from traditional RAS which is rich in aerobes and sludge-bulking anaerobes.
 - c. The observed characteristics of IAS include:
 - i. Rapid sludge settling
 - ii. Low angle of repose sludge
 - iii. Rapid methane production
 - iv. Reduced algae growth
 - v. Reduced pathogens and reduced malodor formers (e.g. E. coli and sulfur reducing bacteria)
 - vi. In situ digestion of solids
7. Algae growth is reduced because the carbon load exits the system mostly as methane, not carbon dioxide or sludge solids. The carbon source for alga growth is carbon dioxide; reduce carbon dioxide... reduce algae growth.
 - a. Methane can be captured with a cover over only the flat-bottomed portion of the lagoon (because the low angle of repose concentrates the sludge over the flat). Recovered low-hydrogen-sulfide-methane (because the H₂S-forming bacteria were eliminated) can be used beneficially with pre-

existing technology. Methane is produced year-round even in Northern climates.

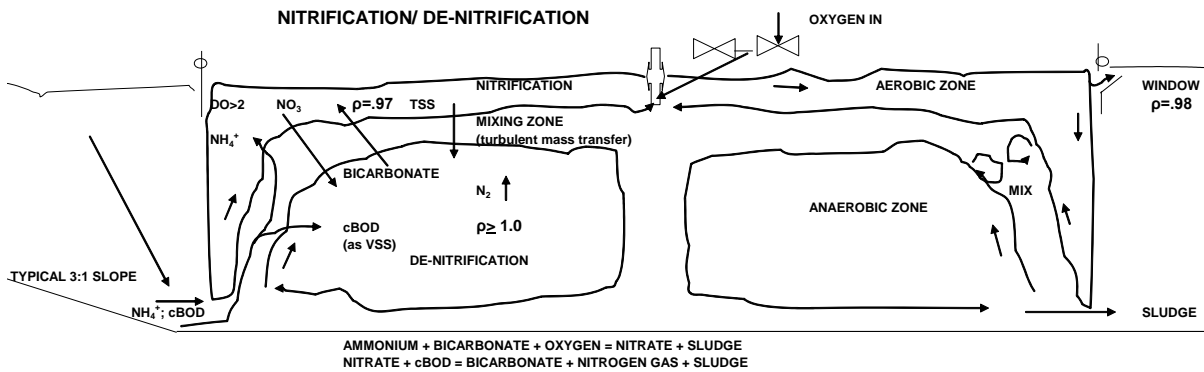


8. A by-product of in situ sludge digestion is ammonia production.
 - a. Sludge (when completely digested) = ash, CO₂, CH₄, water and ammonia.
 - b. Ammonia accumulates when the GF/CSTR is first installed as old sludge is digested. When the inventory is eliminated, ammonia production declines, but is still more than when sludge was accumulating and temporarily capturing ammonia.

9. Ammonia is oxidized-then-reduced by installing a GF/CSTR late in the process when most of the cBOD has been eliminated.
 - a. The GF/CSTR creates a produced upper zone and an induced lower zone around the circulator ("stacked donuts"). Between the two donuts is a turbulent transition "washer" which aids in mass transfer between the donuts. Entry into the GF/CSTR is at the sludge/water interface along the bottom of the lagoon at the inlet end. New water enters along the "washer".
 - b. The biochemistry requirements for nitrification/de-nitrification are well known. Nitrification proceeds in two steps to nitrite-then-nitrate. The carbon source is bicarbonate (dissolved CO₂); the DO must be ≥ 2 . De-nitrification is an anoxic reaction where produced-nitrate reacts with cBOD to make nitrogen gas, bicarbonate and sludge. Thus the reactions are interdependent and interactive.
 - c. The two zones, separated by a mixing layer, work well to effect transfer of nitrate from top to bottom, bicarbonate from bottom to top. The difference

in density directs incoming cBOD to the bottom heavy layer (where it is needed) and away from the light top layer (where it would otherwise "steal" oxygen from the nitrifiers). [See sketch.]

- d. The surrounding boom has cut out "windows" to allow low density upper zone fluid to exit at the top and high density, anaerobic lower zone fluid to exit out the bottom. This strategy retains the critical separation of the nitrification and de-nitrification zones.
 - i. Skilled artisans will recognize that this strategy mimics the well known oxidation ditch strategy; except the GF/CSTR is a vertical embodiment and the ditch strategy is horizontal.



It is easiest to understand the strategy by reviewing examples of wastewater with high, low and in-between soluble BOD concentration.

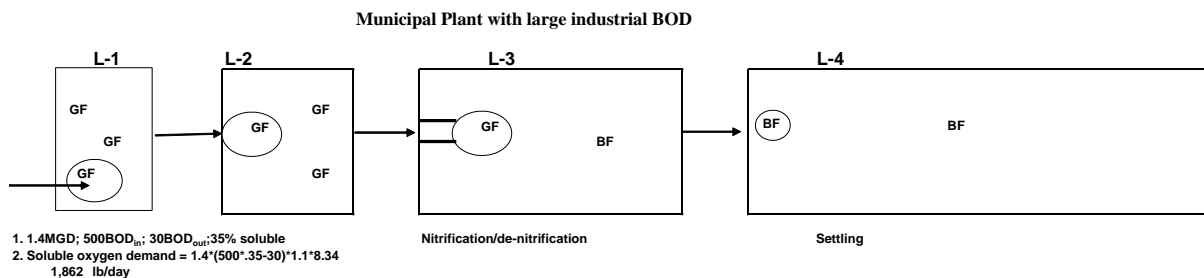
Municipal Waste

Municipal waste is typically about 35% soluble BOD and 65% insoluble. Most plants physically remove as much of the BOD as possible (e.g. grit removal and primary clarifiers) before aeration. Aeration is used to mix water and air bubbles together. RAS is used to inoculate the aeration tank. It is natural for aerated wastewater to produce bulking (hard to settle) sludge. Much clever work is done to minimize sludge bulking. After aeration, the water is clarified (e.g. secondary clarifier). Clear water is discharged; part of the settled sludge is returned to inoculate the process (RAS); the remainder is wasted.

Wasted sludge is accumulated and digested. Digestion is never complete, so a solid stream (~70% bound moisture) is land applied, land-filled or lagoon-stored. Waste disposal costs are a major portion of the waste treatment budget.

The GF/CSTR is used at the beginning of the municipal waste treatment to effect physical separation of the soluble from the insoluble BOD. Typically the oxygen demand is so great that both GF/CSTR zones are anaerobic. [Malodor is not an issue because the sulfur reducing bacteria are consumed in situ in the CSTR and thus one root cause of the malodor is eliminated.]

Effluent is released at both the top and bottom of the water column. Downstream GFs continue to aerate the surface water and sink any produced solids. Eventually the soluble BOD is oxidized and the surface becomes aerobic. Meanwhile the sunken insoluble BOD passes along the base of the lagoon in slow, plug flow towards the outfall. The sunken insolubles are digested in situ. Methane is released above the flat. The embedded sketch illustrates the process.



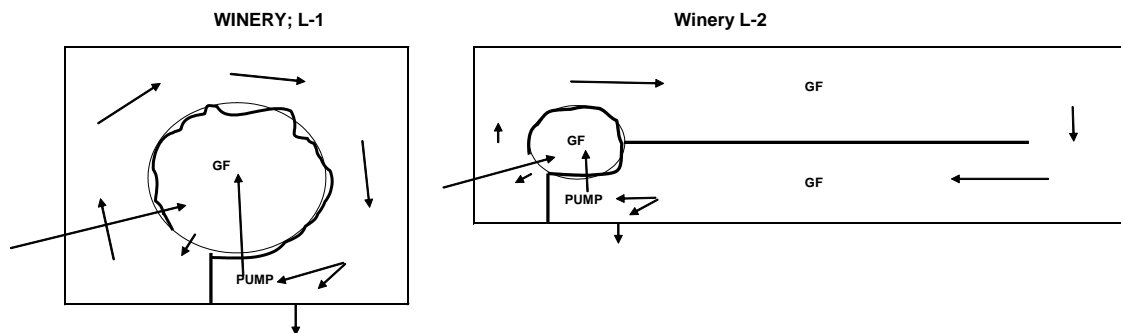
Winery (also: food plant, dairy bottling plant, juice plant etc.)

Wineries are a special case because their waste is 90% soluble and the soluble waste (e.g. sugar, ethanol, starch, milk etc.) is extremely easy to oxidize. As a result, there is almost no practical way to keep the system aerobic; all added oxygen is consumed faster than it can be dissolved. The GF/CSTR converts the soluble BOD into insoluble BOD and sinks it for subsequent slow anaerobic digestion.

Wineries also have a seasonal distinction which adds enormous bio-loads to the system for 8 weeks or so during the crush. A functional system must have utility during the crush and be economic after the crush.

The GF/CSTR is used to incubate IAS, to create a light upper zone and provide just enough oxygen to convert soluble into insoluble BOD. The system is not aerobic during the crush, but there is no smell because the malodor formers were eliminated by tilting the competitive microbial "field" to eliminate undesirable organisms.

As shown in the sketch, the lagoons are made to recirculate by moving the GF pump outside the CSTR. When the crush is over, this recirculation keeps the surface light and brings incubated anaerobes in contact with sunken nutrients.



1. Inlet is directly into CSTR
2. .055MGD; 12,000BOD_{in} (90% soluble); 200BOD_{out}
3. Oxygen demand = .055*(12,000-200)*1.1*8.34= 5,954 lb/day
4. Outlet of CSTR is through a "window" boom
5. Pump induces circulation around CSTR

During the off season, the downstream GF pumps are shut down. This saves energy and the GF becomes a circulator, not an aerator.

Tannery

Tanneries have only about 6% soluble BOD and 94% insoluble BOD. Traditional strategies work only when excessive horsepower is installed to suspend aerobic solids during the very-slow-to-react time required of a high dose of insolubles.

The GF/CSTR is used to sink insoluble BOD. The soluble BOD load is not as low as one would assume because the BOD concentration is up to four times a typical municipal load. Thus additional GFs are located downstream to match the pounds of oxygen required by the tannery soluble BOD load and to sink insoluble BOD. The number of GFs to maintain low density surface water may exceed the soluble BOD demand.

The energy savings are as much as 75% because the mixing energy is not required in a totally stratified lagoon. GF-added air is equal to the total soluble BOD load. The largest part of the load is digested anaerobically in situ.

