Blue Frog™ System White Paper: Mimics a Municipal WWTP

The patented and patents pending Blue Frog Technology seeks to mimic best municipal treatment plant practices in a lagoon.

Publicly owned treatment works (POTW) are capital intensive, individually-designed, microbiological processes which break the mitigation problem into component parts, then design a process to maximize the microbial kinetics for each component part while keeping operating costs to a minimum.

Although no two POTWs are alike, the best ones all have these similarities:

1. Raw water is mixed and surged (EQ tank) to truncate peaks and valleys and send a more uniform nutrient/pH flow forward. Microbes do not respond well to process upsets.
2. A microbial stream, conditioned to the individual plant (activated sludge), is recycled to inoculate raw water with an appropriate microbial package.
3. cBOD oxidation is kinetically faster than nitrogen oxidation and functions well at DO $\leq$ 2. A byproduct of cBOD oxidation is alkalinity formation and sludge.
4. Nitrification (ammonia-to-nitrite-to-nitrate) requires a higher DO (DO>4), alkalinity, the presence of nitrification bacteria and an alkalinity-buffered pH (7.8 – 8.2). In high cBOD environments, nitrification bacteria are out-competed by carbon-oxidizing bacteria for available oxygen.
5. De-nitrification bacteria require an anoxic environment. A byproduct is dinitrogen gas bubbles. These rising bubbles inhibit clarification.
6. Solids are separated at the beginning and end of the process and then treated in a separate process. The kinetics of solids digestion is orders of magnitude slower than supernatant clean-up. Odor control is an issue with sludge digestion. Sludge management is usually the highest operating cost in the POTW.

Traditional lagoons are characterized by:

1. Little horizontal mixing. Nutrient peaks and valleys travel through the lagoon, particularly in industrial food processing lagoons where operating and clean-up loads differ widely.
2. Slow kinetics. Air is typically added in the front end of a lagoon system to oxidize cBOD, but existing aeration systems are notoriously inefficient because most aerobic lagoons are shallow [e.g. diffuser oxygen transfer efficiency is directly proportional to water depth.]
3. Long hydraulic retention time. Lagoon systems are large to offset the slow kinetics.
4. Lagoons have a natural anaerobic zone where sludge accumulates. Low temperature water is denser than warm water. A thermocline exists in lagoons

deeper than 5-7' separating the high density water from the low density water. There is little mixing between these zones.

5. Seasonal odor release. Lagoons typically turnover twice per year (temperature change causes the aerobic top layer to change density and displace the anaerobic bottom layer), releasing malodor.
6. Little nitrification. Lagoons have high DO only at the surface (during the day from photosynthesis or during windy conditions (waves increase surface area)) so nitrification bacteria kinetics are typically slow.
7. Lagoons become less efficient over time. BOD oxidation generates sludge; as sludge build-up increases, hydraulic retention time decreases. The inherently slow kinetics is no longer fast enough to clean the supernatant in the available declining retention time.
8. Lagoon operating cost is low until sludge removal is required. Sludge removal is problematic for many reasons.

An ideal lagoon system would:

1. Equalize the influent flow to reduce downstream upsets.
2. Preferentially incubate anaerobic bacteria for continuous in situ sludge digestion below the thermocline.
3. Oxidize cBOD with DO<2, generating alkalinity and sludge.
4. Oxidize ammonia with DO>4.
5. Denitrify nitrate/digest sludge in an anoxic zone.
6. Repeat steps 2 – 5 as needed to meet BOD and nitrogen discharge limits.
7. Settle the water to reduce turbidity and lower TSS to meet discharge limits.
8. Distribute anaerobic bacteria in the settling zone to continue in situ digestion. [TSS is a balance between effective settling (reduces TSS) and in situ sludge digesting (increases TSS)].

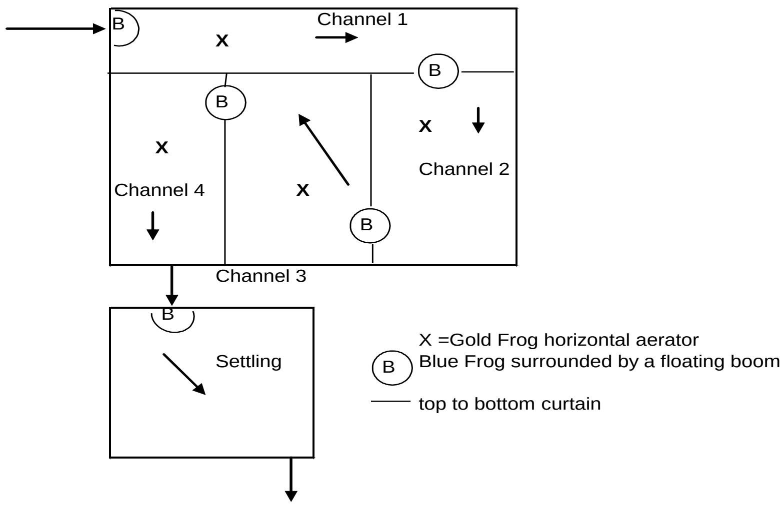
The Blue Frog Technology approaches the ideal lagoon system with low energy systems to gently mix/gently aerate lagoons to maximize the kinetics of the indigenous microbial community.

The Sketch helps explain the process. The upper part is an idealized actual lagoon; the bottom part is a block flow diagram with four mitigation channels and a settling zone.

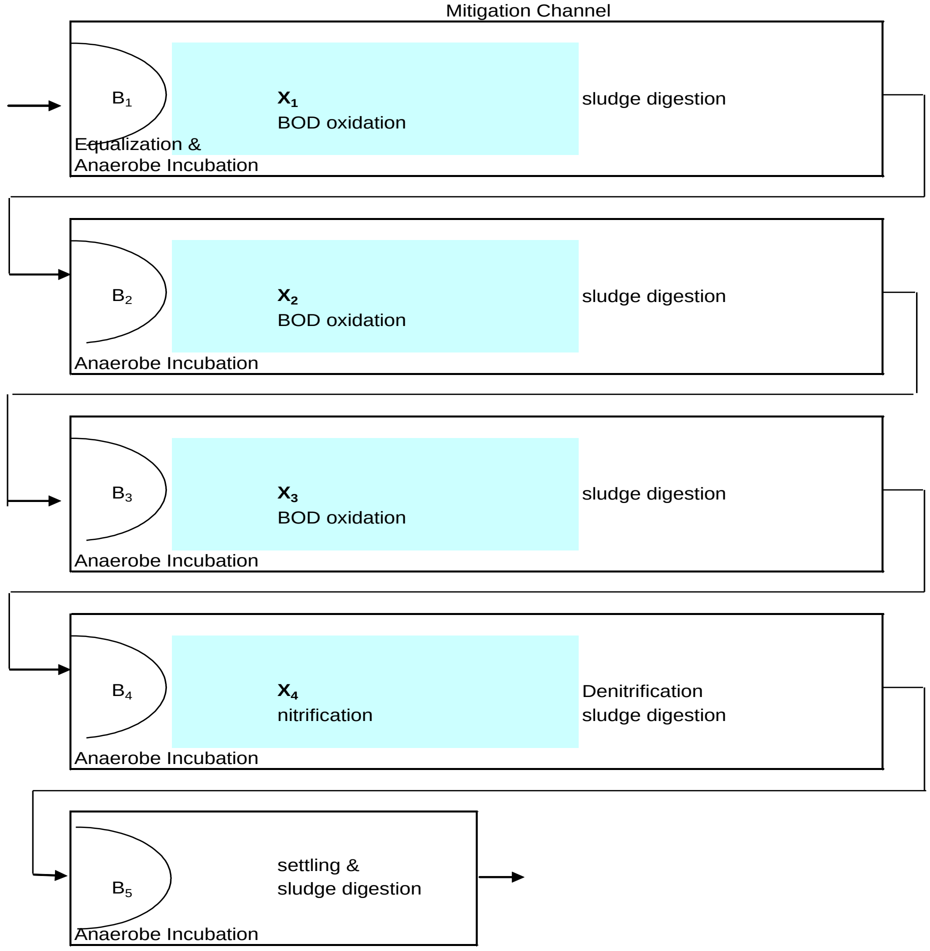
Top-to-bottom curtains are used to form the boundaries of each channel.

Each mitigation channel performs the same process steps: anaerobic incubation, aerated horizontal mixing and anoxic settling. The steps are repeated based on the site potential, the permit requirements and the nutrient load.

TYPICAL TWO-LAGOON SET-UP



PROCESS FLOW BLOCK DIAGRAM
Mitigation Channel



Anaerobic Incubation

A Blue Frog (BF) is a low horsepower (3hp) water circulator which pulls water horizontally from the 3' level. The water is expelled from an annular space radially along the lagoon surface. As the streamlines diverge from the BF, subsurface water is induced to flow up and radially from the BF. A floating boom is deployed about 50' from the BF in a generally semicircular (or circular) manner.

Horizontal-flowing surface water piles up at the boom to create a vertical downward driving force. The down-flowing water ricochets off the sludge directly under the boom and follows a curvilinear diagonal path back to the BF inlet. As the diagonal-flowing water returns to the BF, a countercurrent is induced below the BF in the donut-shaped annulus defined by the bottom and the diagonal-flowing water.

The produced current is aerobic; the countercurrent is anaerobic. Both currents bring nutrients and microbes into gentle-but-intimate contact. The population of the slow-growing anaerobes triples because nutrient availability is no longer rate limiting; the population of the aerobes does not change because oxygen availability controls the rate of aerobe growth.

In the first mitigation channel, the anaerobic incubator also functions as an equalization basin. The retention time in most incubators is 6-16 hours.

Water flows out of the incubator at the sludge/water interface directly below the boom. Anaerobes are expressed below the thermocline; aerobes migrate through the thermocline seeking oxygen.

Horizontal Aerated Mixing

The second zone is a highly efficient aeration zone. The BF is converted into a Gold Frog (GF) by adding two pairs of patented impinging venturis (air/water contactors). Adjacent water is pumped [0.4MGD with 5hp @ 20psi] to the impinging venturis (not shown on sketch). As taught in US #Patent 5,772,886, when gas/liquid mixtures collide at a combined velocity >7ft/sec, the pre-existing bubbles are fractionated. The fragments are so small that they do not float out of the narrow water column until all the oxygen is extracted. [In fact, when casually observed, it looks like there is no gas in the water. A more careful observation (in clean water) will show an effervescent zone adjacent to the BF and about 10' out where large gas fragments percolate out and are lost, an opaque zone where light is reflected from very small bubbles (from 10' to about 200' out) and a dark zone where there are no bubbles (>200' out).]

The fractured-bubble/water mixture is injected into the annular space in the GF. The horizontal-flowing water entrains the tiny bubbles and distributes them across the middle of the mitigation channel. Dissolved oxygen (DO) increases down to the 3' inlet level as very small bubbles follow the liquid path back to the inlet. In practice, all the water above the thermocline in a 200' radius from the GF has higher DO.

The GF is typically placed 75' downstream of the boom. Tiny entrained bubbles ricochet off the boom and return to the GF inlet to create an upstream, high DO zone to match up with the higher nutrient load downstream of the incubator. The tiny bubbles do not travel more than about 200' downstream of the GF. The end of this downstream, lower-DO zone has much less oxygen as the microbes consume oxygen and create sludge. The sludge begins to settle and is partially digested by the increased anaerobe population.

Mitigation Channels in Series

Mitigation channels are typically placed in series. The upstream channels have lower DO because the rapid cBOD oxidizers consume oxygen as fast as it is added. After two or three channels, much of the cBOD is oxidized.

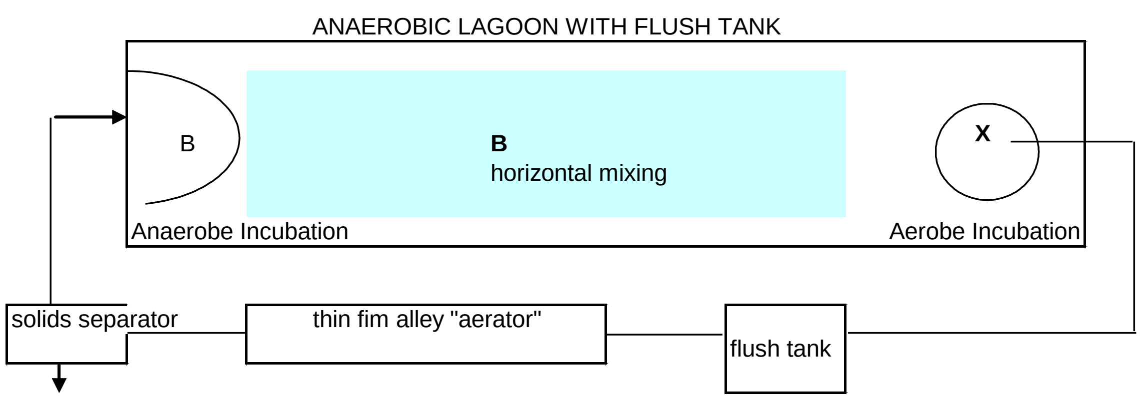
The cBOD oxidation process produces sludge and alkalinity. The alkalinity buffers the pH at the ideal nitrification pH and is the source of carbon for the nitrification bacteria. By the third or fourth channel, the cBOD oxygen demand has declined enough to allow the horizontal aerator to add more oxygen than the cBOD demands. Dissolved oxygen rises above the minimum needed to sustain nitrification bacteria. Alkalinity has increased enough to supply the carbon that nitrification bacteria need. Ammonia is now biologically oxidized to nitrate. Downstream of the tiny bubble zone, the channel becomes anoxic and the nitrate is reduced by de-nitrification bacteria to N_2 gas and sludge.

Final Settling

Incubation and horizontal mixing keep solids in suspension. A final incubator is used at the inlet to the settling lagoon to insure that a vital anaerobic population is maintained. These anaerobes are spread below the thermocline where final sludge is digested. Above the thermocline suspended solids gradually settle. Malodor is a potential issue in settling-lagoons. The BF in the incubator is an intentionally-cavitating mixer. When the BF cavitates it bobs up and down creating circumferential waves. These high surface-area waves propagate through the boom and keep the settling lagoon surface "sweet".

Anaerobic Lagoons:

Anaerobic lagoons usually consist of a single mitigation channel. Settling is not required because the turbid water is recirculated to a flush barn.



The anaerobic incubator is identical in design and function to an aerated lagoon. The horizontal aerator is replaced with a BF horizontal circulator (to keep the main body of the lagoon anaerobic & gently mixed). A 300' circumference boom is deployed around a central GF and a floating surface return pump to form an aerobic incubator in an otherwise anaerobic lagoon. The return water is taken only from the aerobic produced current.

The aerobe-rich water is transferred to the flush tank and periodically distributed along the alleyway. The alleyway functions as a thin film aerator. The incubated aerobes grow rapidly in this temporarily-oxygen-rich environment, consuming slime, pathogens and malodor-producing bacteria. Nitrification bacteria oxidize ammonia on the alley.

The low viscosity, oxidized water separates easily from entrained solids, reducing the organic load on the lagoon.

When the nitrate-rich water returns to the anaerobic lagoon, de-nitrification bacteria produce N_2. When the water is subsequently field-applied, the nitrogen applied to the field is reduced by 50%.

The upstream anaerobic incubator creates a robust population of sludge-digesting organisms. The angle of repose of the sludge is reduced; sludge flows to the lowest point in the lagoon where visible gas (nitrogen, methane & CO_2) is seen percolating of the flat part of the lagoon.

Food Processing Lagoons

Food processing lagoons are a special case because of the high cBOD load (up to 10,000mg/l BOD).

In these situations the basic mitigation channel concept is maintained, but additional GFs are added in each channel to add the oxygen required by the high load.

In some lagoons, the .4MGD of recycled water used to feed the venturis is taken from the settling lagoon. This water contains dilute "activated sludge" fully acclimated to the nutrients in the industrial lagoon. Thus by careful placement of the venturi water pump, the lagoon system can be made to recirculate and activated sludge can seed the process.