Anaerobic Treatment of Pulping Effluents

Achieving Economic Feasibility

or

Why I Love My Job

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HB Consulting LLC

Why Anaerobic Treatment?

- Advantages
  - Low energy consumption
  - Generates a 60-70% methane-rich bio-gas
  - Reduces biological treatment production of CO_2
  - Reduces the quantity and improves the dewatering of secondary sludge compared with activated sludge system
  - Requires lower nutrient addition rates
- Disadvantages
  - Generally used for pre-treatment ahead of an aerobic system for 70-80% BOD removal
  - Can be more sensitive to upsets
  - Requires high organic concentrations

Economic Challenges

- While systems in some countries, including Canada, are government subsidized, systems in the USA are generally not.
- More easily justified are systems that are considered as part of effluent treatment expansion requirements to meet compliance limits.
- Effluent treatment systems that are already compliant with permit limits are challenged to justify anaerobic treatment based on economic merits, including the value of any carbon credits.

Ideal Candidates

- Uniform composition
- Neutral pH, not subject to large pH swings
- Not subject to significant spills of liquor, soap, turpentine
- Temperature < 100 ^{o}F
- Soluble COD > 2000 mg/L

Typical Candidate Effluents

- Kraft Mill
  - Vapor condensates
- Sulfite Mills
  - Bleach Plant Extraction Stage
  - Vapor condensates
- BCTMP Filtrates

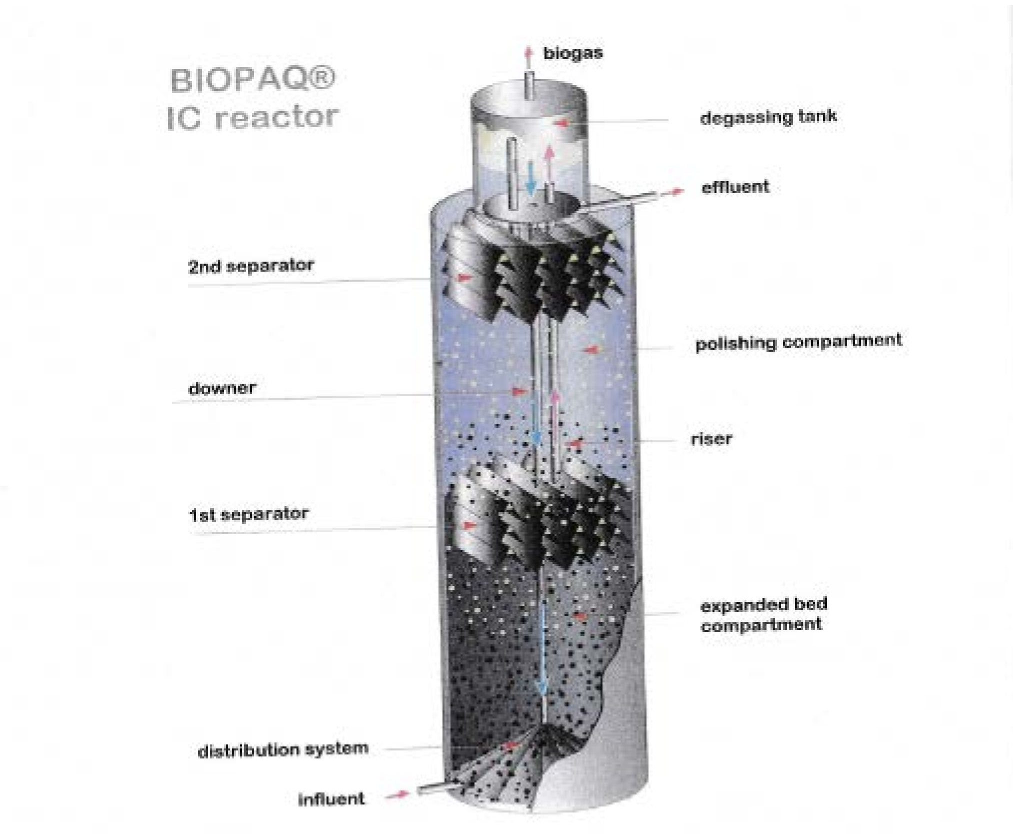
Installed Systems

- Most systems
  - Require primary clarification
  - < 5 mgd
  - > 3000 mg/L COD
  - BODre is ~ 70-75%
  - CODre is ~ 80-85%
  - May require micronutrient addition
  - Employ an Equalization Tank for pH control and chemical addition

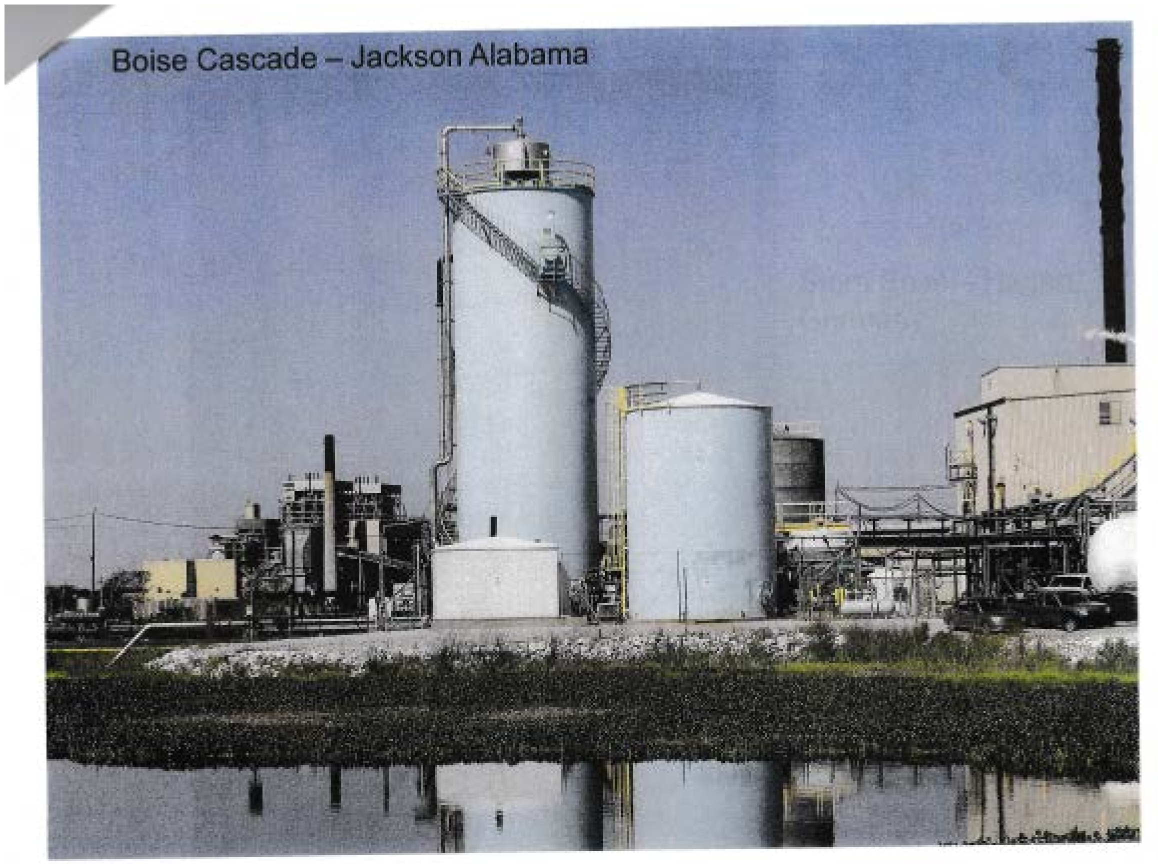
Acronyms

- UASB – Upflow Anaerobic Sludge Blanket
- AHD – Anaerobic Hybrid Digester
- ECSB – External Circulation Sludge Bed
- IC – Internal Circulation
- CGR – Methane C Generating Reactor
- AnMBR – Anaerobic Membrane Reactor
- FOG – Fat, Oil, Grease
- BCTMP – Bleached Chemical Thermomechanical Pulp
- VFA – Volatile Fatty Acids
- BVF – Bulk Volume Fermenter

Example Anaerobic Reactor



Example Anaerobic System



Example Systems

- Quesnel River Pulp, BC
  - BCTMP/TMP system was one of the largest at 5 mgd
  - Operated from 1989-2005 when replaced with a low sludge yield, suspended media activated sludge system
  - Reasons cited include, peroxide and sulfide toxicity, high O & M costs
- Millar Western, Whitecourt, Alberta
  - BCTMP start-up expected late 2013, delayed until late 2016
- Alaska Pulp – Sitka, AK
  - 1989
  - 3.7 mgd Dissolving Sulfite evaporator condensate and caustic extraction filtrate
  - Operating at 2/3 design due to solids clarification limits.
- Tembec – Matane, Quebec
  - 3.4 mgd aspen BCTMP effluent
  - Operating since 2012
  - 7300 mg/L COD
  - IC-UASB Paques design
  - $26M Cdn, most of which is gov't subsidized

Example Systems

- Tembec – Temiscaming, Quebec
  - Operating since 2006
  - 4.7 mgd aspen BCTMP and Dissolving Sulfite Acid Condensate
  - 7000 mg/L COD
  - IC-UASB Paques Design
    - Easy to operate and monitor
    - Very satisfied with performance
- Boise-Cascade – Jackson, MS
  - Operating since 1999
  - 0.6 mgd Kraft mill condensates
  - 6000 mg/L COD
  - Paques IC
- RockTenn – Syracuse, NY
  - 1.5 mgd Corrugated Packaging effluent
  - 7500 mg/L COD
  - Operates two different reactor designs, 1 ADI, 1 Paques IC

Example Systems

- Slave Lake Pulp - AK
  - Operating since 2014
  - BCTMP
  - ADI-BVF reactor
  - 5-19,000 mg/L COD
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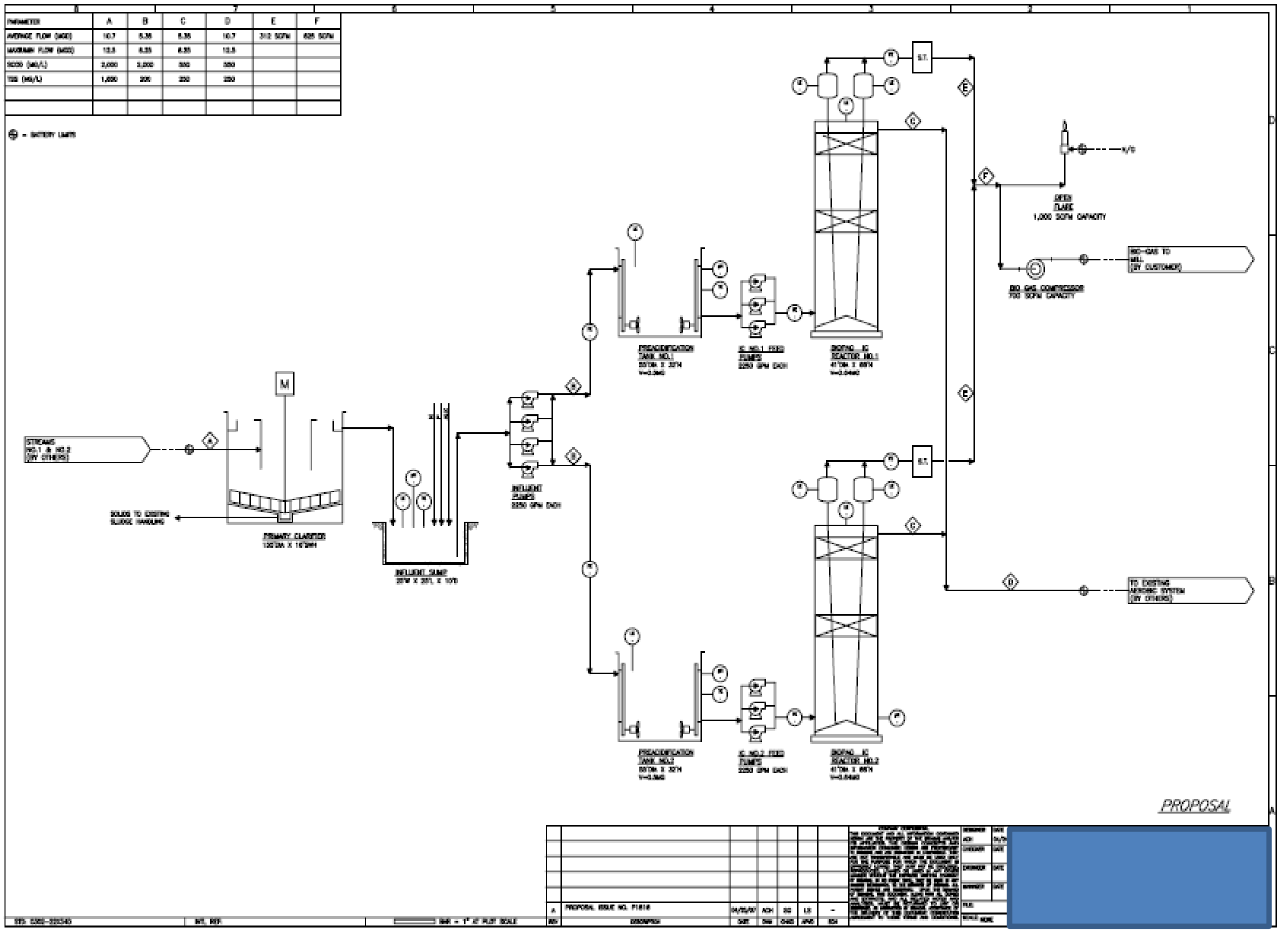
Case Study

- This study assesses the feasibility of pre-treating BCTMP Mill effluent using anaerobic treatment ahead of existing joint activated sludge treatment with Kraft Mill effluents.
  - BCTMP filtrates represent ~15% of the total flow and ~40% of the total organic load.
    - 6 mgd, 3500 mg/L COD, 120 ^{o}F
  - Addition of Kraft Mill stripped condensates to the anaerobic system is an option.

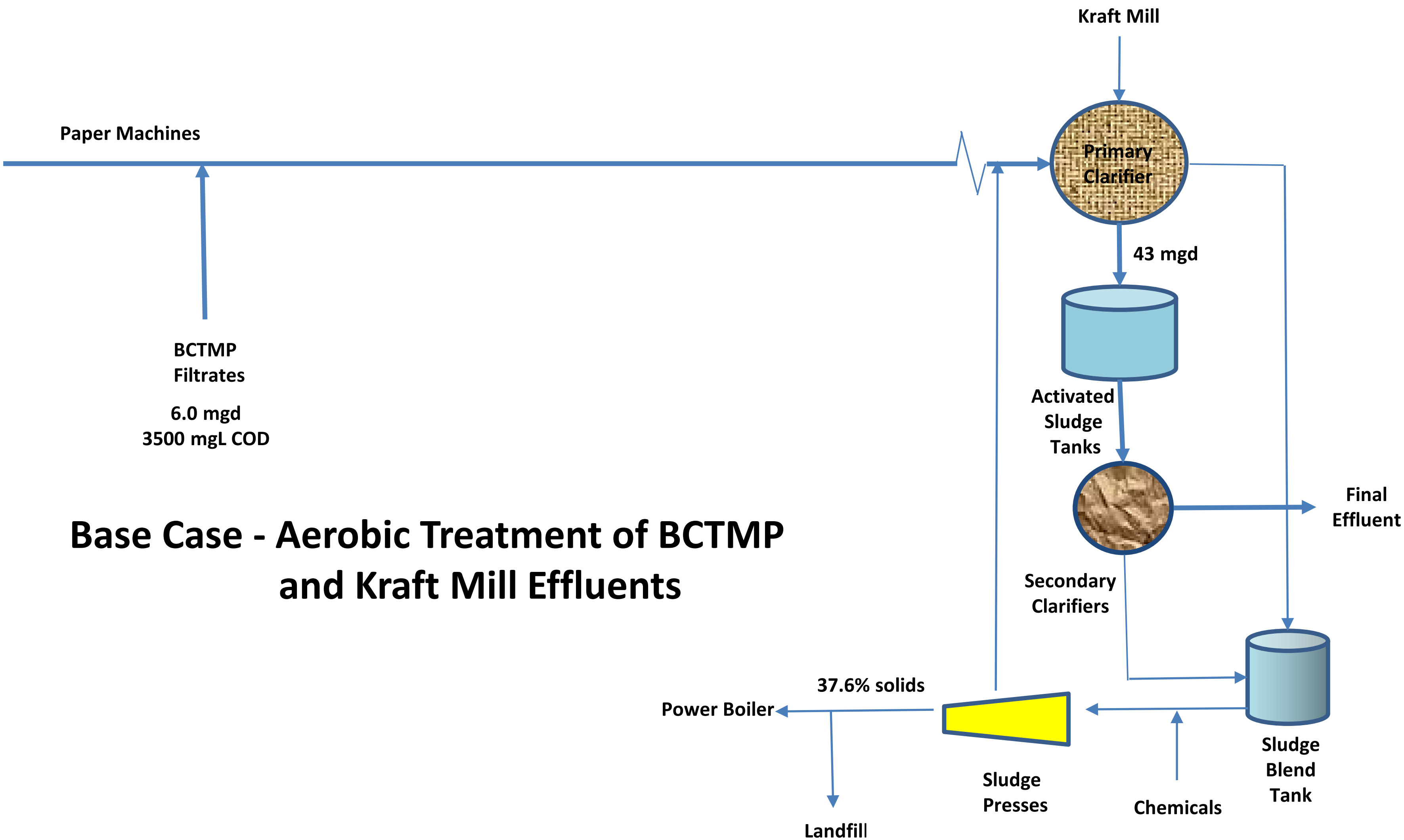
Anaerobic System Design Elements

- Primary Clarification, if not available at site
- Indirect Cooling
  - Non-contact evaporative cooling tower for large volumes
  - Heat exchanger for small volumes
- Equalization
  - pH control
  - Flow and organic load dampening
  - Nutrient addition
- Anaerobic Reactors
- Bio-Gas Handling
  - Compressor
  - Sulfide Scrubbing, if needed
- Gas Turbine, if appropriate

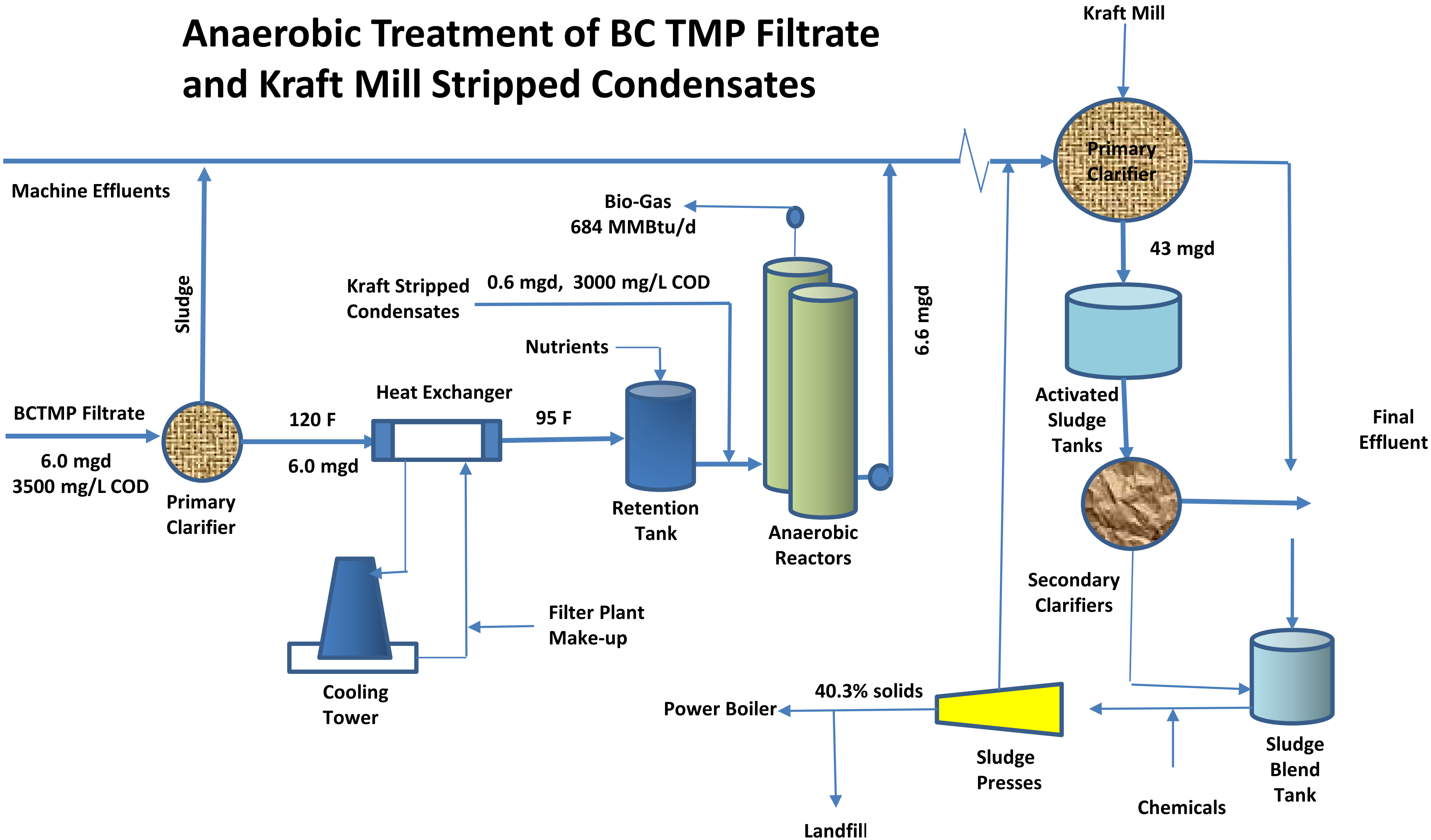
Example Vendor Proposal



Base Case - Aerobic Treatment of BCTMP and Kraft Mill Effluents



Anaerobic Treatment of BC TMP Filtrate and Kraft Mill Stripped Condensates



Evaluation Process

- Review of relevant existing systems
- Visit existing operations
- Determine treatability of various stream combinations
- Treat all or just the most concentrated streams
- Review logistics for best treatment system location: At effluent generation site or at existing effluent treatment system
- Determine project scope
  - Treat target effluent only
  - Add Kraft stripped condensate and eliminate generation of methanol-rich stream
  - Install capability to burn NCG in recovery boiler and shutdown Incinerator
  - Add Bio-gas Turbine to generate electricity

Evaluation Process

- Calculate savings
  - Initial economic feasibility is based on optimistic assumptions of savings on the premise that if the project is not economically feasible under the best of circumstances, realistic values will not improve results.
  - Direct Cost Saving Factors are those associated with anaerobic treatment relative to activated sludge operation
  - Indirect Cost Saving Factors are those benefits that are generally site-specific opportunities resulting from having anaerobic treatment added.
  - Assess monetary benefit of reducing Green House Gases
- Estimate capital cost
- Assess opportunity for subsidized funding
- Option analysis
- Pilot Plant
- Finalize Design

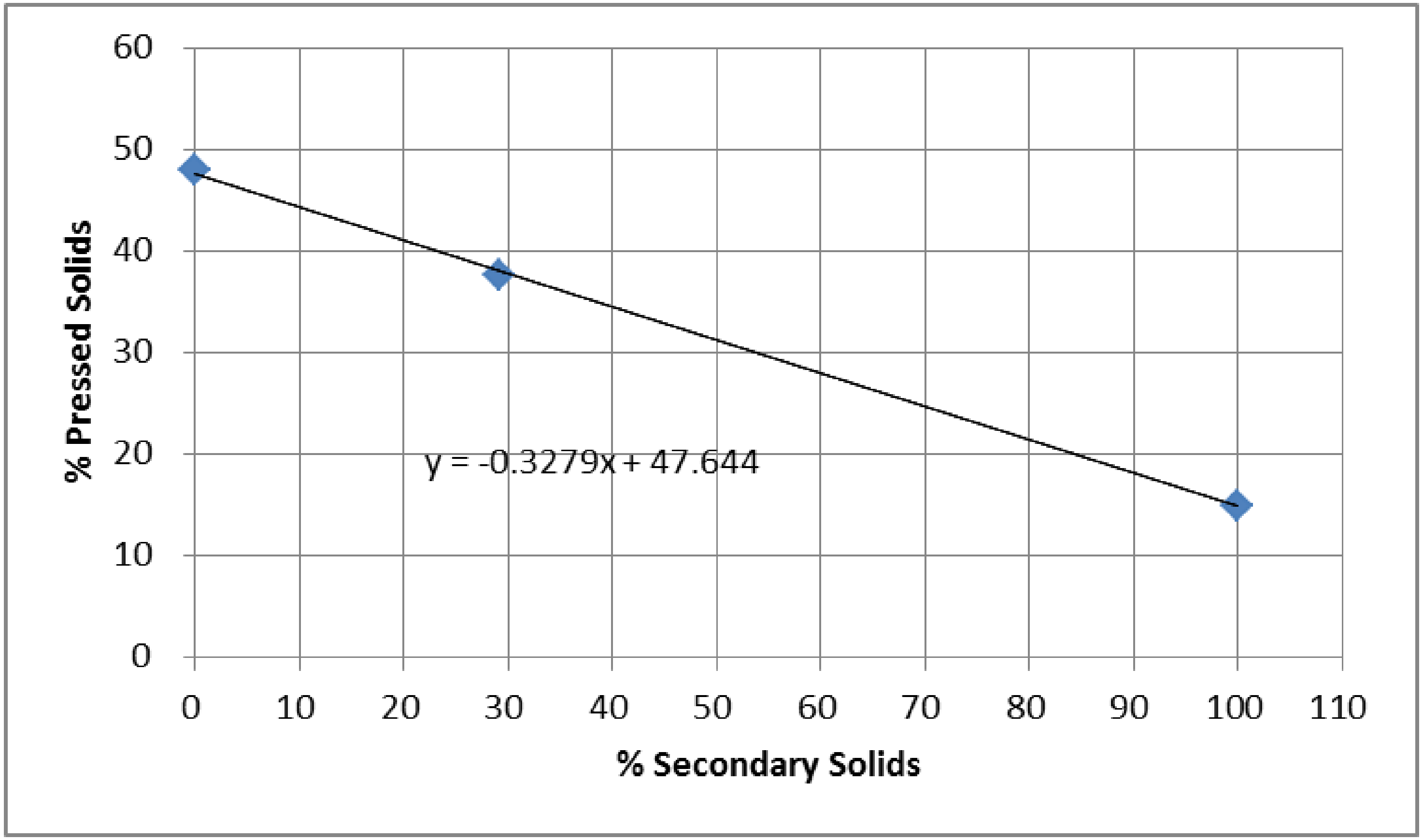
Direct Cost Saving Factors

- Electricity savings
  - Reduced aeration HP
  - Less the HP required for incremental pumping for anaerobic system
  - Reduced sludge dewatering HP
  - Generate electricity by adding a Bio-Gas Turbine
- Reduced nutrient requirements
  - 0.5 times that for activated sludge
- Reduced secondary solids generation
  - 0.11 lbs vs 0.45 lbs/lb BODre in Activated Sludge System

Direct Cost Saving Factors, cont'd

- Reduced sludge dewatering chemicals
  - Coagulants
  - Flocculent
  - f(% secondary solids, quantity)
- Increased sludge % solids
  - Anaerobic solids treated as primary (granular) solids
  - f(fraction secondary solids)
- Reduced sludge disposal costs
  - Landfill trucking and tipping fees
  - Decreased fuel demand for incineration
- Reduced steam heating for sludge dewatering
- Bio-gas generation replacing fossil fuel usage at 5000 BTUs/lb CODre

Sludge Dewatering f(secondary solids)



Indirect Cost Saving Factors

- Steam savings in foul condensate treatment by operating methanol distillation system as an odor stripper and diverting stripped condensate to anaerobic treatment.
  - > 65% reduction in steam:feed ratio for odor and turpentine only vs methanol stripping.
    - Savings based on method of stripping system heat recovery.
  - Eliminate methanol solution or SOG incineration with Stripper vent treated as a CNCG stream.
    - May permit shutdown of stand alone Incinerator for all NCG and foul turpentine is burned in the Recovery Furnace.
      - Save operating and maintenance costs for an Incinerator.
      - Eliminate caustic use for SO_2 scrubbing; Reduced lime demand for recausticizing
      - Eliminate natural gas usage
      - Recover heat value of NCG and turpentine (if boiler is not a bottle-neck)
- Reduced carbon impact in the form of reduced CO_2 emissions and sludge incineration/landfill decomposition.
  - Equivalent to methane carbon production from anaerobic system

Condensate Distillation Systems

- Operating pressure affects methanol distillation steam:feed ratios for 92% efficiency.
    - 10 psia – 15% steam:feed
    - 50 psia – 18% steam:feed
    - Higher operating pressures increases the options for heat recovery of stripping column vapor:
        - Low pressure: water heating
        - Medium pressure: liquor pre-heating
        - High pressure: liquor evap’n, low pressure steam generation
- Savings are affected by method of heat recovery

Odor Stripping Operation

- Switching from methanol distillation to odor stripping reduces steam demand by over 2/3.
  - A significant reduction in steam input to the column lowers the vapor velocity such that the number of open valves will need to be closed.
  - Column operating pressure can be lowered if desired.
  - Column would be operated with total reflux condensing.
  - Stripped condensate needs to be hard-piped to the anaerobic reactor per Cluster Rules.
  - Stripped condensate may need to be cooled to keep reactor temperature in specs.

Odor Stripping - Example Impact

- Most condensate distillation systems are sized to treat 300-700 gpm and generated a Methanol-rich stripper off-gas [SOG] containing all the TRS and Turpentine that was in the foul condensate.
- Cluster Rule compliance requires 92% methanol stripping efficiency. A medium pressure system of, say 25 psia requires about 16% Steam:Feed.
  - A 500 gpm (~ 250,000 pph) system will require ~40,000 pph steam.
  - If ¾ of the overhead stripper vapor heat (est 85% of heat input = 34,000 pph) is recovered by pre-heating liquor to the evaporators, saving about 20%, (5:1 steam economy) or about 5000 pph in evaporator steam.
  - As an odor stripper, steam use drops to about 5%, or ~13,000 pph.
  - Many mills typically operate with an excess of warm water, in which case, loss of warm water production has limited value.
  - Net steam savings is 40,000 – 5,000 – 13,000 = ~ 22,000 pph.

Estimated Direct Cost Savings Summary

• Biological Treatment	
– Nutrients	$ 440k
– Aeration Hp	300k
• Sludge Dewatering	
– Chemicals	$ 773k
– Landfill	93k
– Utilities	48k
• Fuel Impacts	
– Bio-Gas [at nat'l gas price]	$1,231k
• System Maint & Labor	$ 400k

Total Savings	**$ 2,485k**

Estimated Indirect Cost Savings Summary

- Odor Stripping
  - Steam $ 924k
- Incinerator Shutdown
  - Maintenance $ 92k
  - Caustic for SO_2 Scrubbing
    as Kiln fuel saviings 55k
  - Auxiliary fuel 242k
- Burn NCG in Recovery Boiler
  - Fuel value $399k

Total Savings $ 1,712k

Bio-Gas Turbine

- A bio-gas turbine would generate power equivalent to ~33% of its fuel value at 10,600 Btu/kwh:
  – ((684 MMBtu/d)/10,600kwh)/24000= 2.69 MW
- If bio-gas fuel value is $1,231k/yr at $5/MM Btu
- Gas Turbine annual savings at $150/MWh
  – Electricity value = 2.7*24*360*150 = $3486k/yr
  – Fuel value = 684 MMBtu – (2.69*24000*3412 Btu/kwh) = 462 MMBtu/d *360*$5 = $833k/yr
  – **Net increase = $3486k + 833k - $1231k = $ 3,088k/yr**

Summary

- Anaerobic systems have become more accepted as pre-treatment ahead of aerobic treatment systems within the Pulp and Paper industry, particularly for BCTMP, Kraft condensate, sulfite acid condensates, and Sulfite Caustic Extraction Liquor.
- Unless subsidies are available, sufficient green house benefits are derived or treatment system expansion requirements are necessary, adding anaerobic treatment can be a economic challenge to justify.
- Current designs appear to have addressed many of the issues that affected past performance.
- Key advantages are low energy consumption, low sludge yields, easy to dewater sludge, and bio-gas generation.

Summary

- **This case study evaluated pre-treatment of BCTMP filtrates and Kraft stripped condensates and the additional benefits derived from making it feasible to consider burning NCG and foul turpentine in the Recovery Boiler and shutting down a foul stream Incinerator.**
- **Estimated pre-tax return on the direct cost savings due to anaerobic treatment for this case study was about 16%**
- **Estimated pre-tax return, when indirect cost savings are included, increased to 26%.**
- **Addition of a Bio-gas turbine may further increase overall project return.**