# Mother Road Brewing Company Wastewater Pre-Treatment Design

CENE 486C - STILL WATER TREATMENT ENGINEERING: DANIEL KENNEDY, SERENITY HELM, ALEXANDER (ALEC) MURPHY

Client: Michael Marques, CEO of Mother Road Brewing Company

# Project Purpose

Reduce contaminant of concern (COC) concentrations in the Mother Road Brewing Company (MRBC) wastewater effluent

Lower MRBC's monthly expenditures

Increase MRBC's environmental sustainability

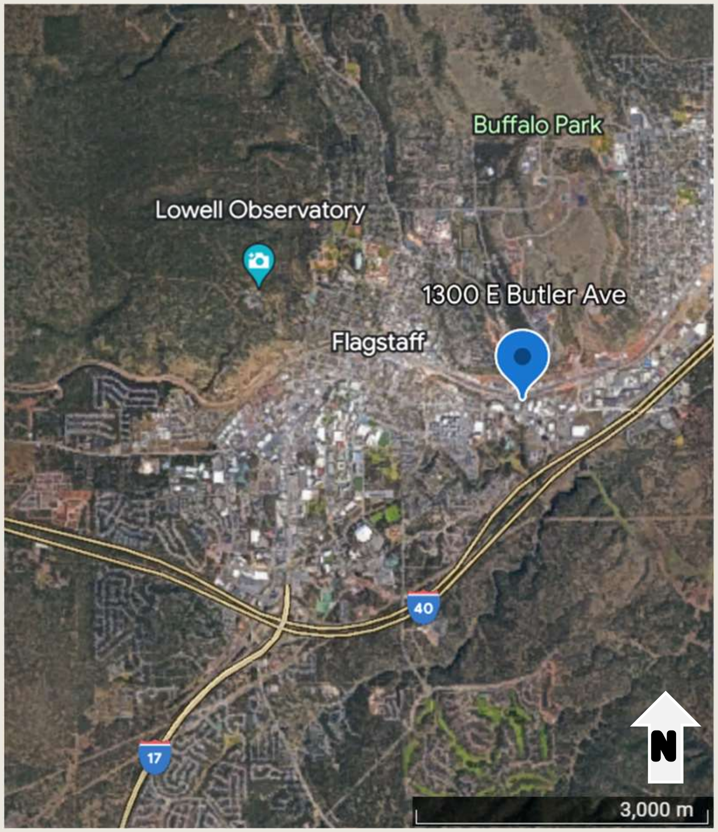



Figure 1: City Location of MRBC Brewery [1]


Figure 2: Street Location of MRBC Brewery [1]

# Site Location

# Project Background

Table 1: Current Concentrations and Regulations [2]

| Contaminant | Current Concentration (mg/L) | Standards for Discharge (mg/L) |
|---|---|---|
| **BOD** | 3,108 – 21,075 | 10,323* |
| **TSS** | 120 – 1,860 | 1,917* |
| **TKN** | 104 – 211 | 173 |

*Limit changes based on discharge rate [2]
Brown: In Exceedance

BOD: Biochemical Oxygen Demand
- Amount of oxygen used by organisms in water

TSS: Total Suspended Solids
- Amount of solids in water that do not settle

TKN: Total Kjeldahl Nitrogen
- Sum of organic nitrogen and ammonia

# Project Background

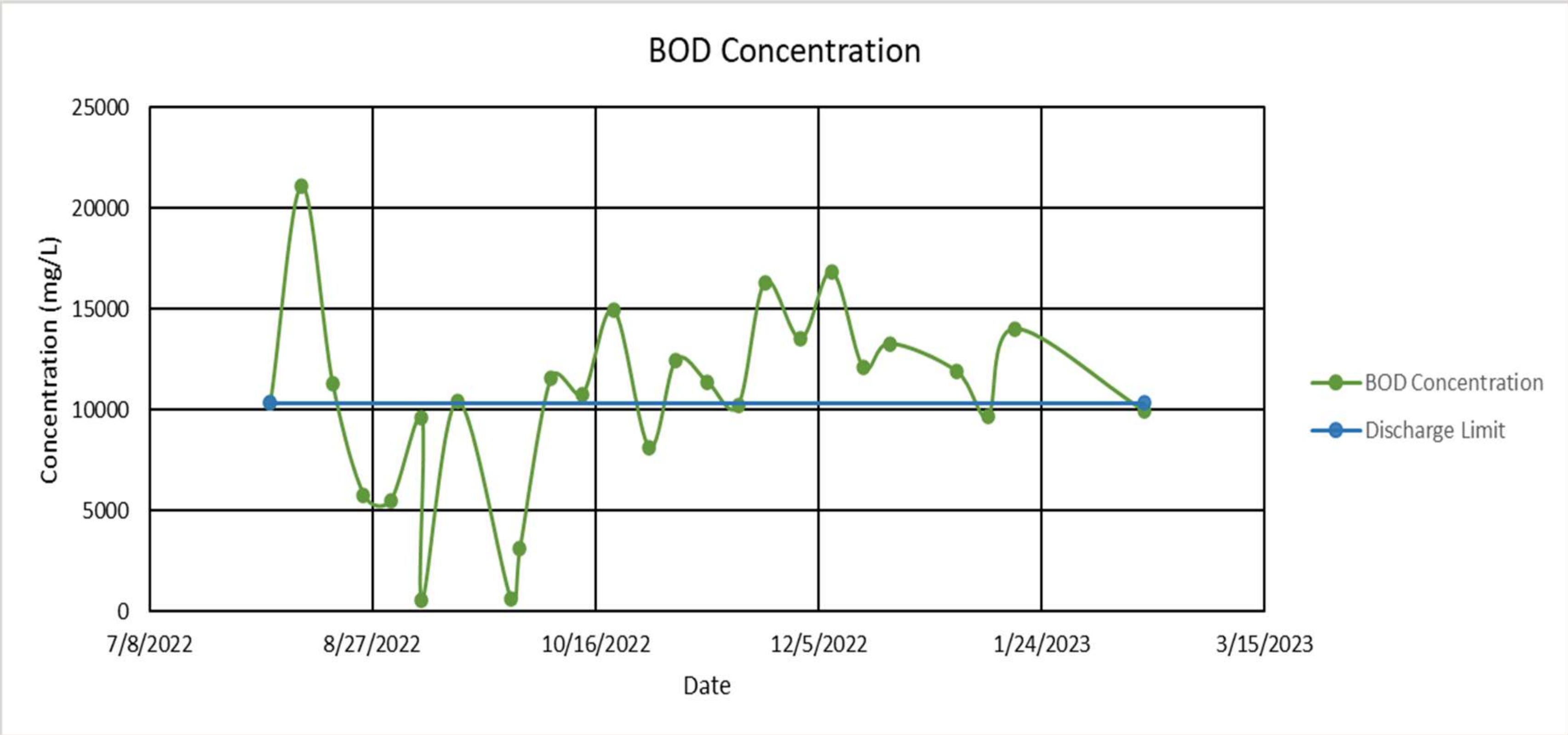



Figure 3: BOD Concentration Graph

# Project Background

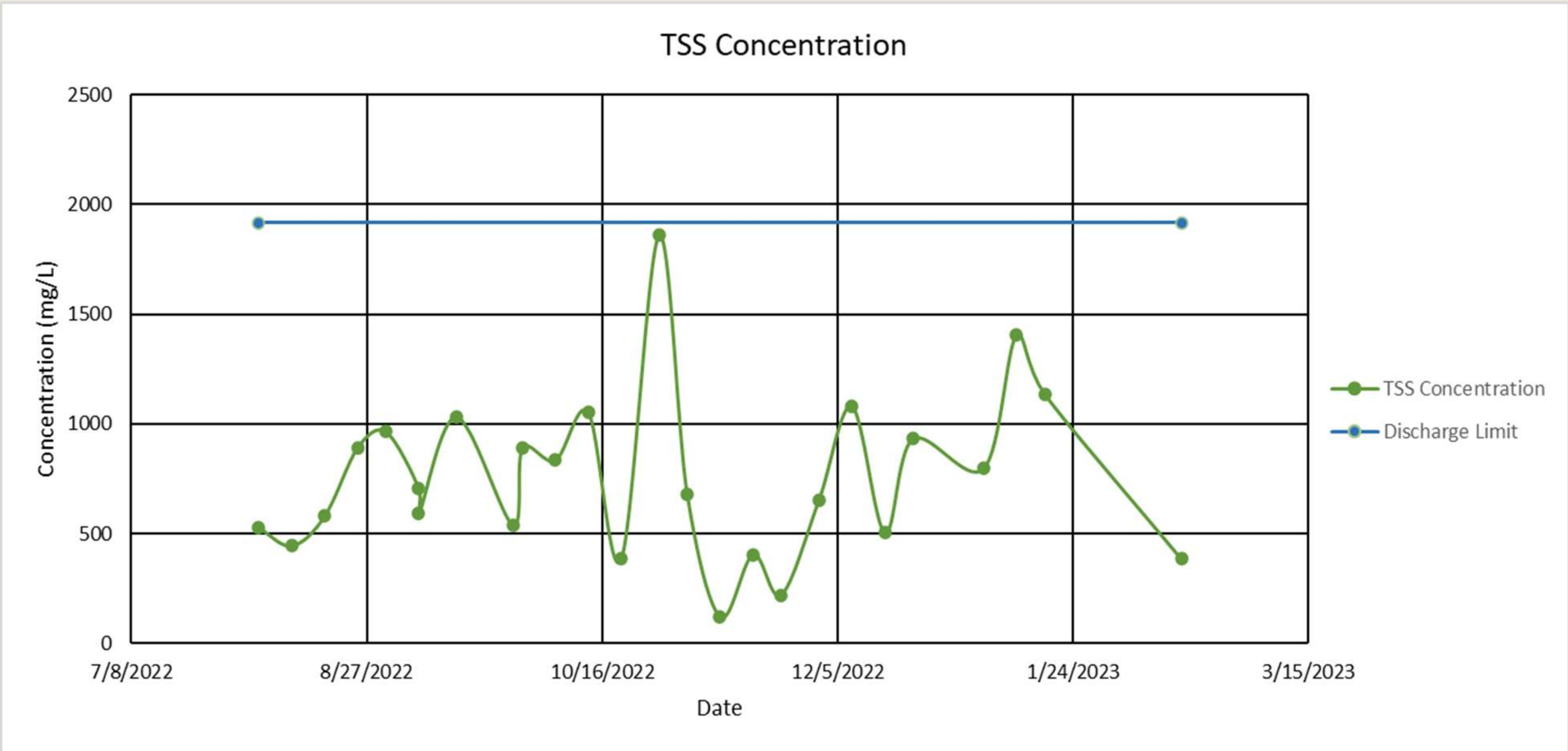



Figure 4: TSS Concentration Graph

# Project Background

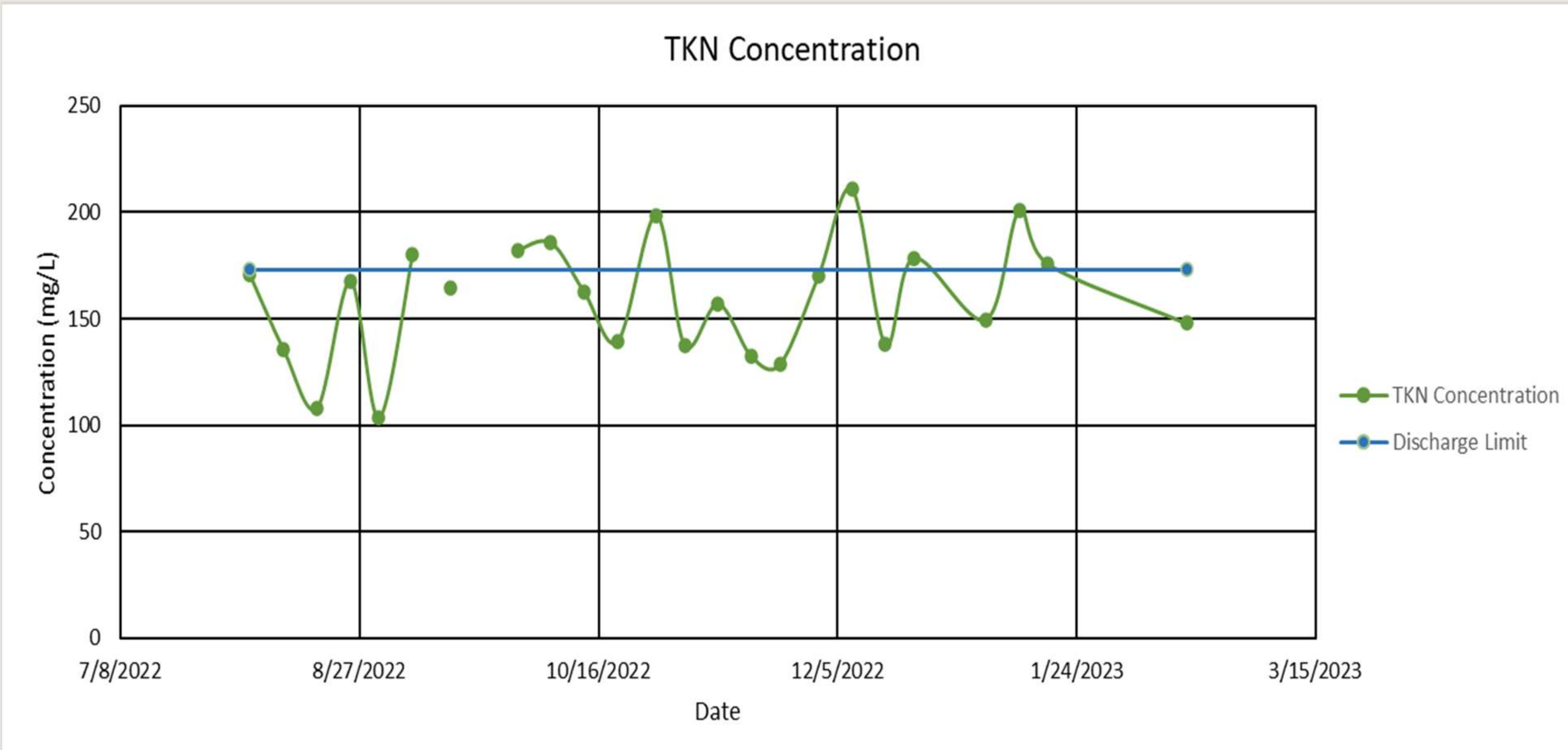



Figure 5: TKN Concentration Graph

# Lab Testing

- **Lab analysis conducted to confirm provided COC data**
- **Max COC accepted for modeling parameters**
- **Additional COCs tested to better understand wastewater characteristics**

Table 2: Lab Test Data, IBE Test Data, and Accepted Data

| COC | Sample Size (n) | Still Water Treatment Engineering Concentration Data (Average mg/L ± Standard Deviation) | IBE Data Range (mg/L) | Accepted Maximum Concentration Values (mg/L) |
|---|---|---|---|---|
| **BOD (mg/L)** | 19 | 824 ± 811 | 3108-21075 | 21075 |
| **TKN (mg/L)** | 4 | 113 ± 0 | 104-211 | 211 |
| **TSS (mg/L)** | 6 | 690 ± 330 | 120-1860 | 1860 |
| **VSS (mg/L)** | 6 | 630 ± 307 | N/A | 937 |
| **COD (mg/L)** | 6 | 10210 ± 5703 | N/A | 14916 |
| **PO4 (mg/L)** | 4 | 5 ± 2 | N/A | 7 |

# The Brewing Process

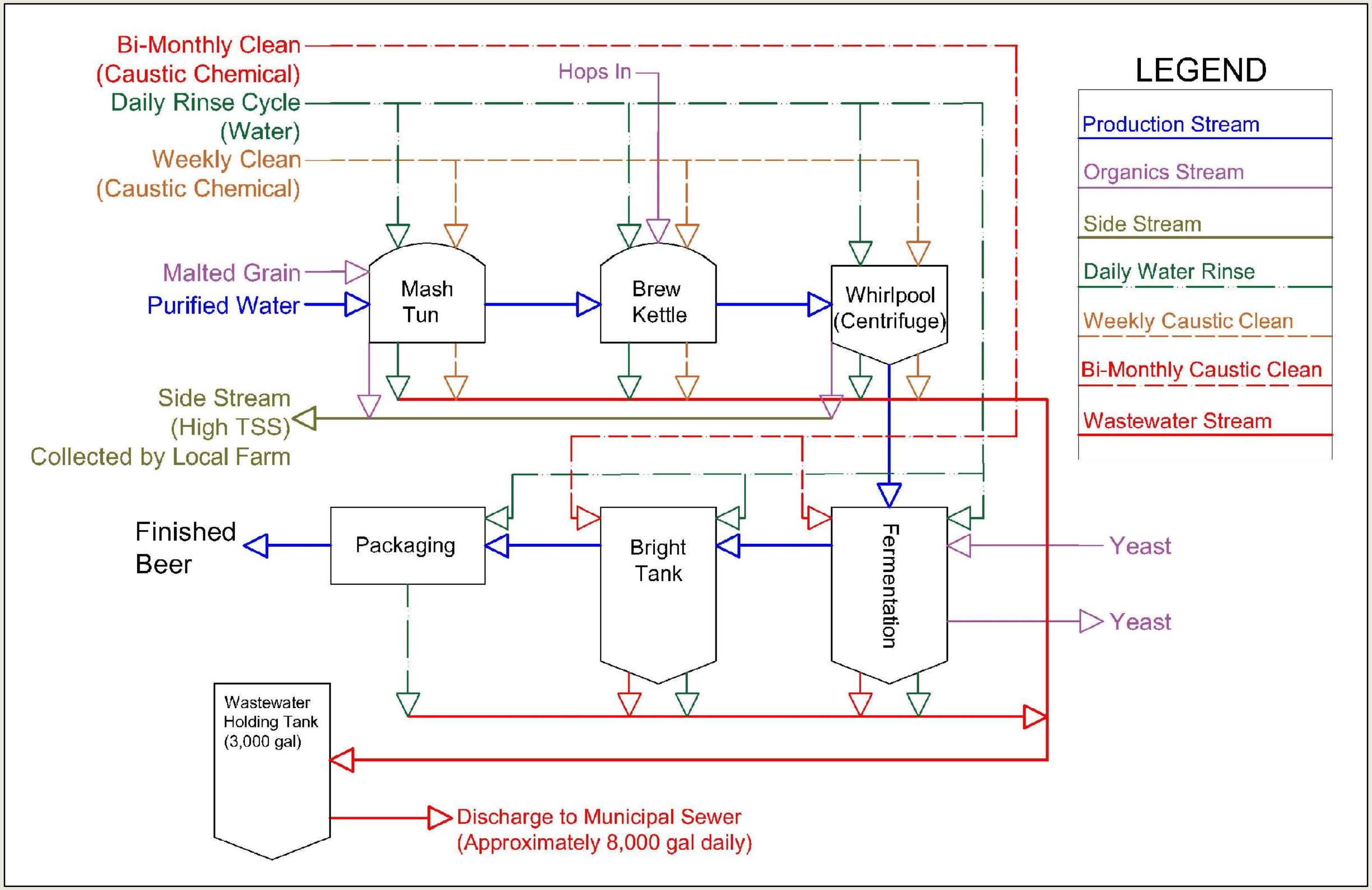
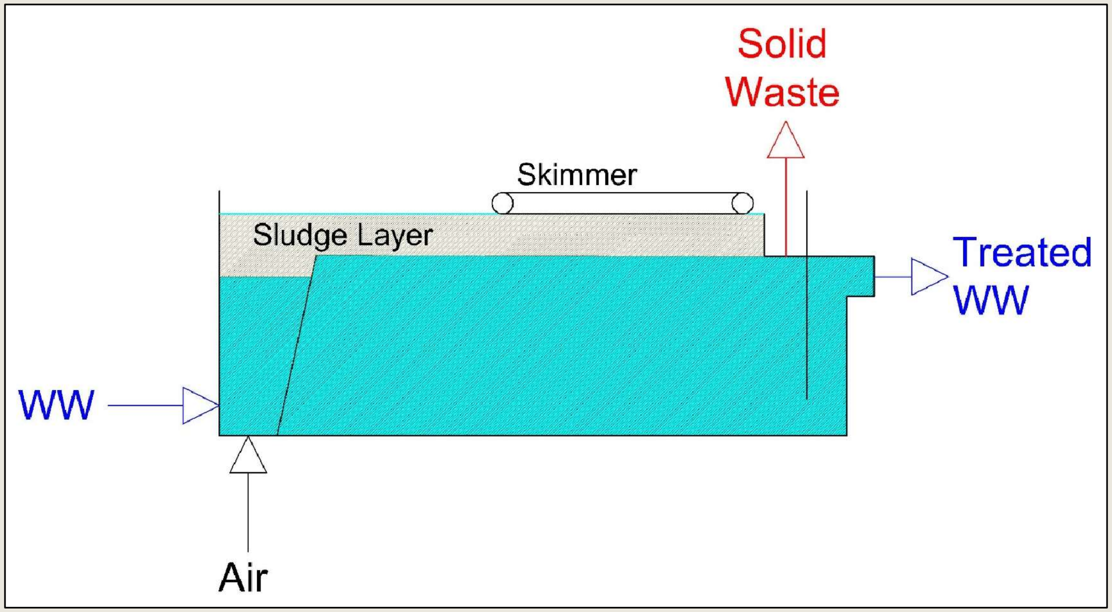



Figure 6: Brewery Process Wastewater Process Flow Diagram

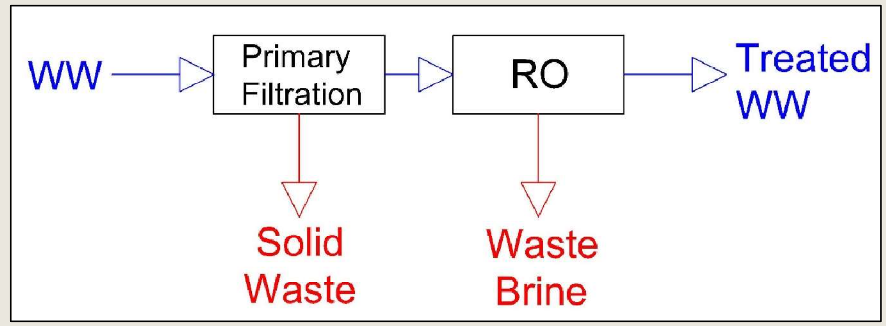
# Treatment Alternatives (BOD)

**Figure 7: Dissolved Air Flotation**




HIGHLIGHTS
- BOD: 50% removal
- Rely on stratification of solids

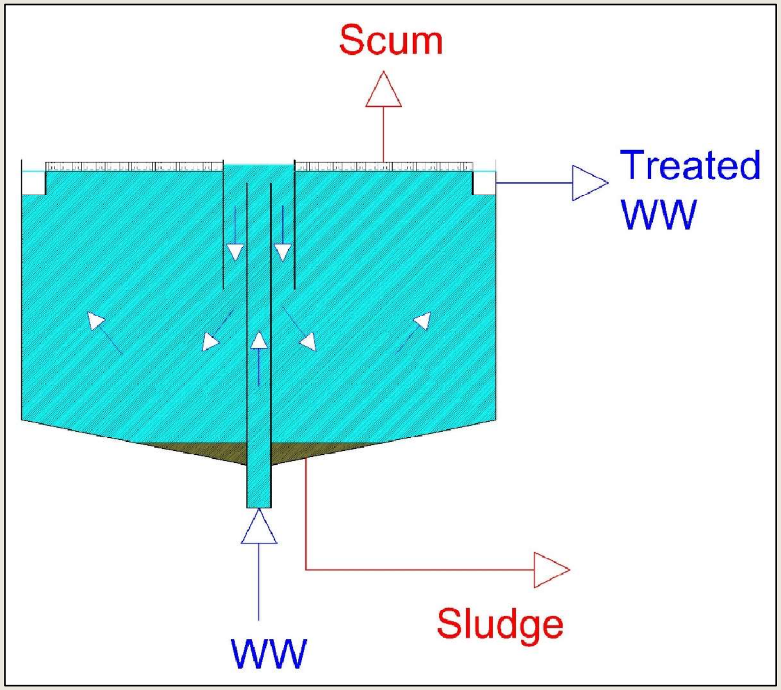
**Figure 8: Reverse Osmosis**




HIGHLIGHTS
- BOD: 99% removal
- Durable system

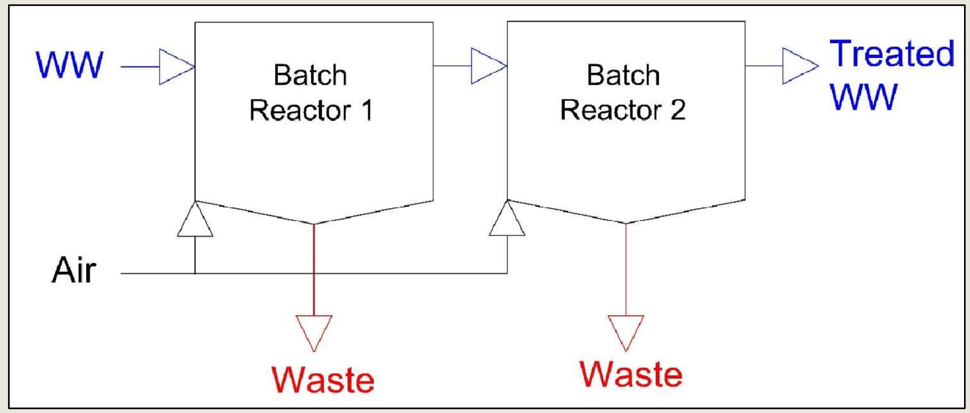
# Treatment Alternatives (BOD)

**Figure 9: Settling Tank**




HIGHLIGHTS
- BOD: 25-35% removal
- Rely on stratification of solids

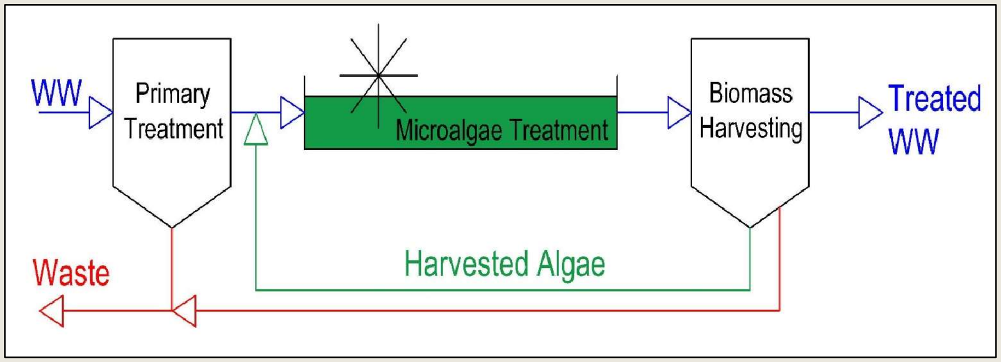
**Figure 10: Anaerobic Sequencing Batch Reactor (SBR)**




HIGHLIGHTS
- BOD: 80% removal
- Suitable for high organic loading rates

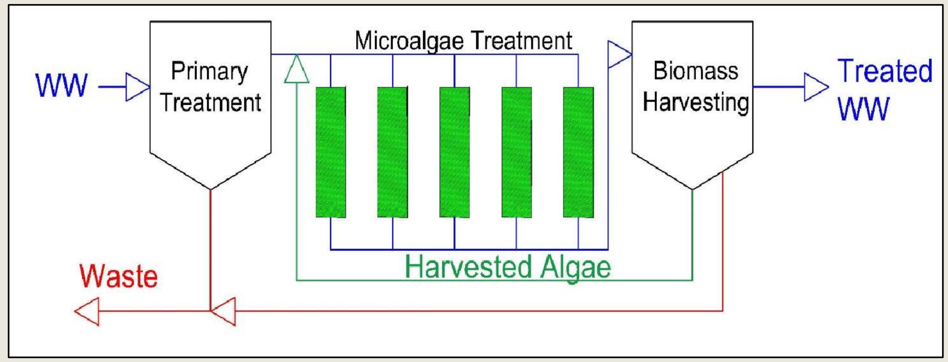
# Treatment Alternatives (TKN)

**Figure 11: Microalgae Raceway Pond**




HIGHLIGHTS
- TKN: 99% removal
- Highly reliant on natural light

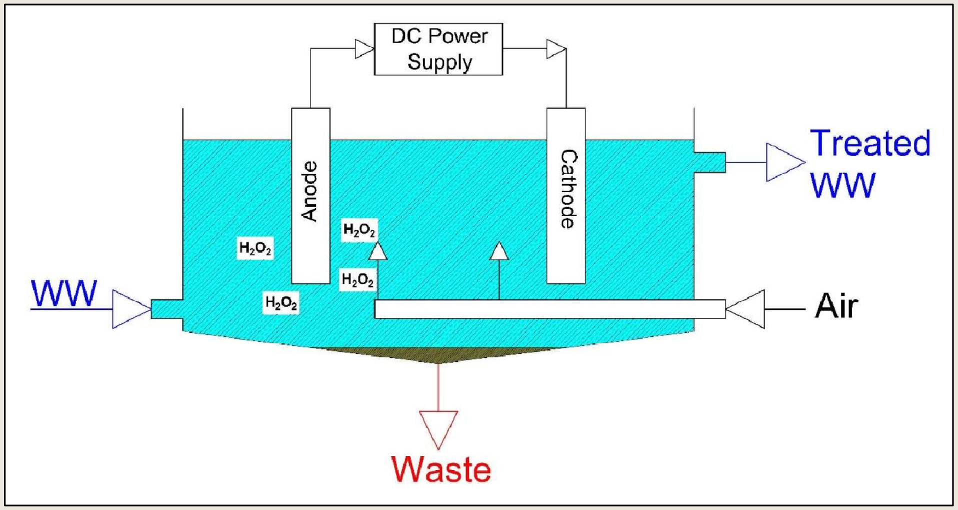
**Figure 12: Microalgae Photobioreactor**




HIGHLIGHTS
- TKN: 99% removal
- Highly reliant on natural light

# Treatment Alternatives (TKN)

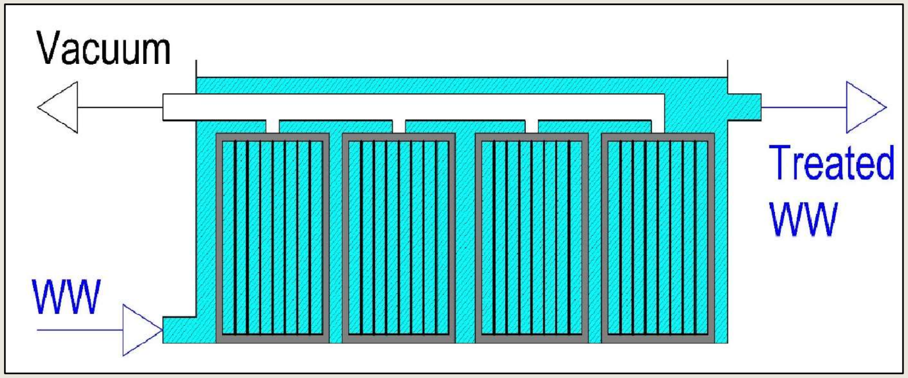
**Figure 13: Electro-Fenton Sequencing Batch Reactor (EF-SBR)**




HIGHLIGHTS

- TKN: 98% removal
- High maintenance and installation cost

**Figure 14: LEAPmbr™**

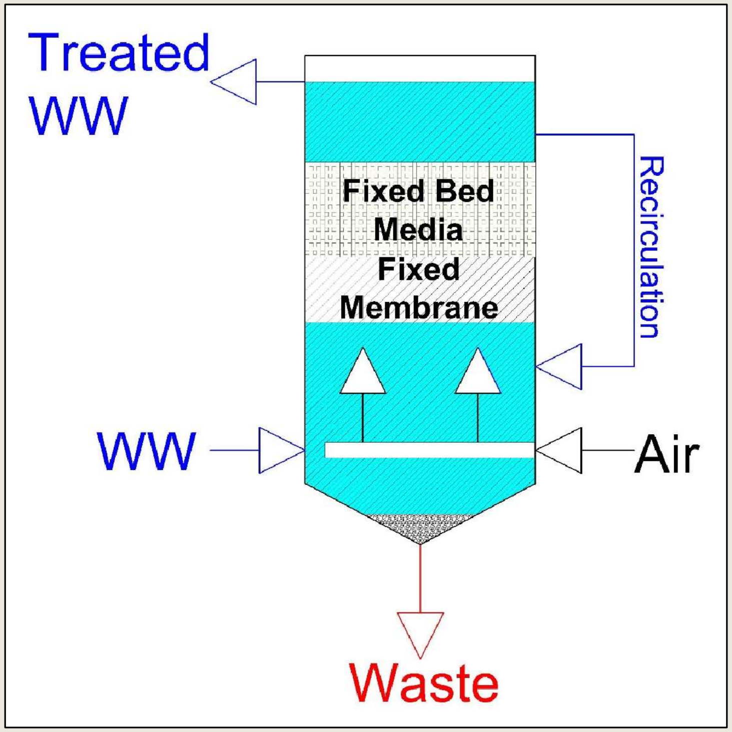



HIGHLIGHTS

- TKN: 90% removal
- High maintenance and installation cost

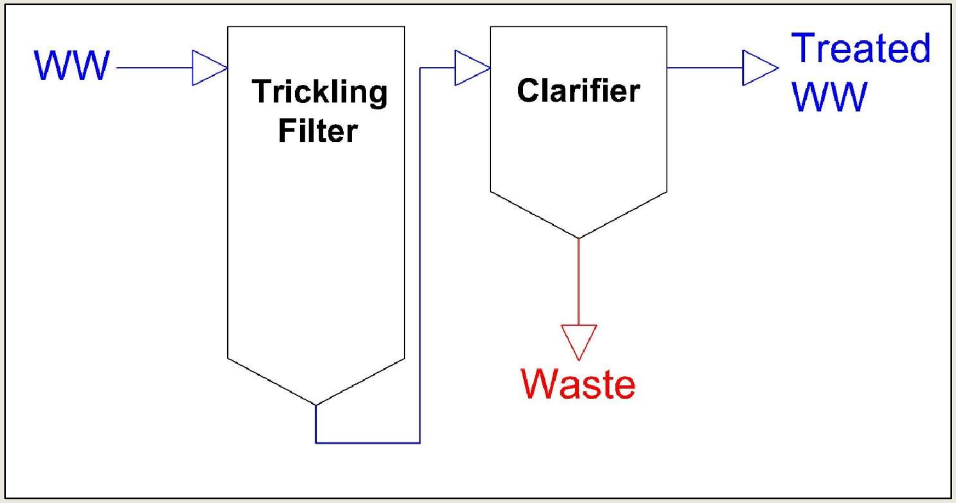
# Treatment Alternatives (BOD & TKN)

**Figure 15: Hybrid Fixed Bed Membrane Bioreactor**




HIGHLIGHTS
- BOD: 95% removal, TKN: 49% removal
- Suitable for high organic loading rates

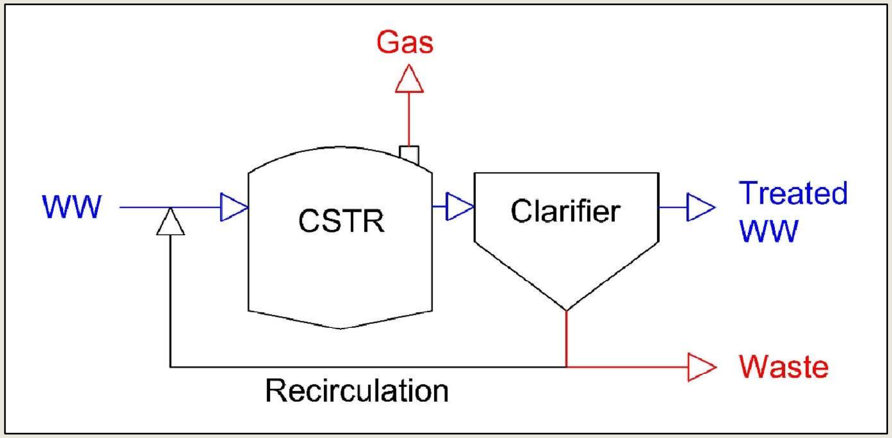
**Figure 16: Trickling Filter**




HIGHLIGHTS
- BOD: 95% removal, TKN: 70% removal
- Proven in brewery wastewater applications

# Treatment Alternatives (BOD & TKN)

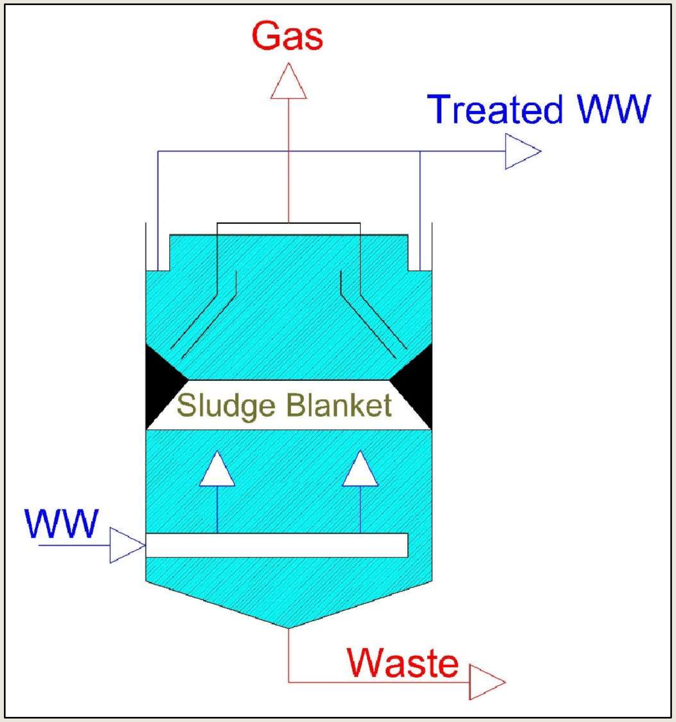
**Figure 17: Anaerobic Continuously Stirred Tank Reactor (CSTR)**




HIGHLIGHTS

- BOD: 80% removal, TKN: 40% removal
- Suitable for high organic loading rates

**Figure 18: Upflow Anaerobic Sludge Blanket (UASB)**




HIGHLIGHTS

- BOD: 80% removal, TKN: 98.3% removal
- Separation of gas, solids, and liquids

# Screening Decision Matrix Scoring

Table 3: Quantitative Scoring

| Score | Capital/Installation Cost | Removal Efficiency Range |
|---|---|---|
| 1 | $90,000+ | 1-9% |
| 2 | $80,001-$90,000 | 10-19% |
| 3 | $70,001-$80,000 | 20-29% |
| 4 | $60,001-$70,000 | 30-39% |
| 5 | $50,001-$60,000 | 40-49% |
| 6 | $40,001-$50,000 | 50-59% |
| 7 | $30,001-$40,000 | 60-69% |
| 8 | $20,001-$30,000 | 70-79% |
| 9 | $10,001-$20,000 | 80-89% |
| 10 | $5,000-$10,000 | 90%+ |

Table 4: Qualitative Scoring

| Score | 0 | 5 | 10 |
|---|---|---|---|
| **Physical Footprint** | Normally greater than 8' x 20' in area | Can be easily decreased in area | Normally less than 8' x 20' in area |
| **Environmental Dependency** | More than one dependency | One dependency | Zero dependency |
| **Reliability** | Has not been used in practice | N/A | Has been used in practice |

# Screening Decision Matrix Scoring

Table 5: Scoring Percentages

| | **Quantitative Data** | **Qualitative Data** |
|---|---|---|
| **Percent of Total Score** | **75%** | **25%** |
| **Capital/Installation Cost** | 40% | N/A |
| **Researched Efficiency** | 60% | N/A |
| **Physical Footprint** | N/A | 50% |
| **Environmental Dependency** | N/A | 10% |
| **Reliability** | N/A | 40% |

# BOD Technologies Screening Decision Matrix

Table 6: BOD Removal Technologies Screening Decision Matrix

| | Quantitative Subtotal | Weighted Score (75%) | Qualitative Subtotal | Weighted Score (25%) | Grand Total |
|---|---|---|---|---|---|
| **Hybrid Fixed Bed Membrane Bio-Reactor** | 8.4 | 6.30 | 7 | 1.75 | 8.05 |
| **Anaerobic CSTR** | 9 | 6.75 | 7 | 1.75 | 8.50 |
| **Upflow Anaerobic Sludge Blanket** | 6.6 | 4.95 | 6.5 | 1.63 | 6.58 |
| **Trickling Filter** | 10 | 7.50 | 9.5 | 2.38 | 9.88 |
| **Dissolved Air Floatation** | 6.8 | 5.10 | 4.5 | 1.13 | 6.23 |
| **Membrane Filtration** | 8.4 | 6.30 | 7.5 | 1.88 | 8.18 |
| **Settling Tank** | 4.8 | 3.60 | 7 | 1.75 | 5.35 |
| **Aerobic Sequencing Batch Reactor** | 8.6 | 6.45 | 7 | 1.75 | 8.20 |

# TKN Technologies Screening Decision Matrix

Table 7: TKN Removal Technologies Screening Decision Matrix

| | Quantitative Subtotal | Weighted Score (75%) | Qualitative Subtotal | Weighted Score (25%) | Grand Total |
|---|---|---|---|---|---|
| **Hybrid Fixed Bed Membrane Bio-Reactor** | 5.4 | 4.05 | 7 | 1.75 | 5.80 |
| **Anaerobic CSTR** | 6.6 | 4.95 | 7 | 1.75 | 6.70 |
| **Upflow Anaerobic Sludge Blanket** | 7.2 | 5.40 | 6.5 | 1.63 | 7.03 |
| **Trickling Filter** | 8.8 | 6.60 | 9.5 | 2.38 | 8.98 |
| **Electro-Fenton Sequential Batch Reactor** | 6.4 | 4.80 | 3.5 | 0.88 | 5.68 |
| **LEAPmbr** | 6.4 | 4.80 | 3.5 | 0.88 | 5.68 |

# Selected Alternatives

Figure 16: Trickling Filter

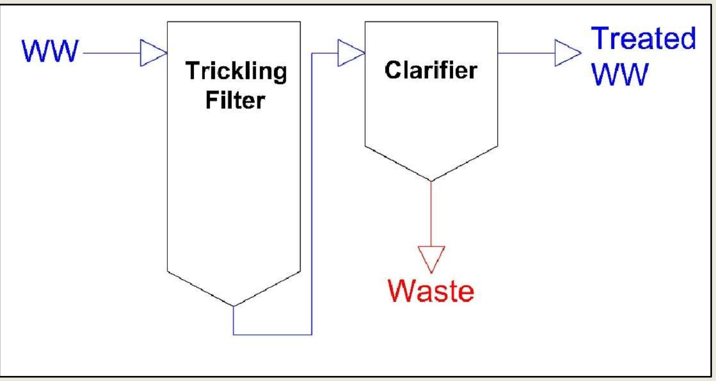



Figure 17: Anaerobic CSTR

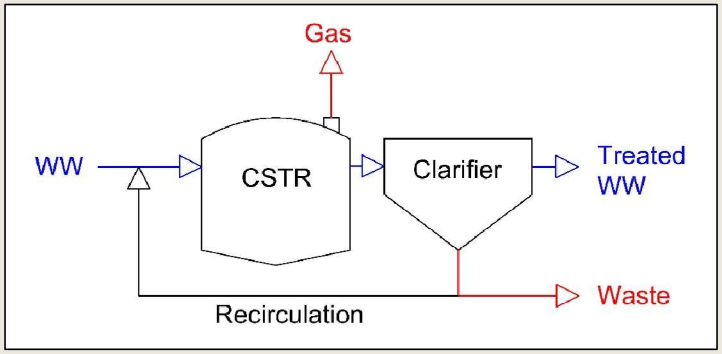
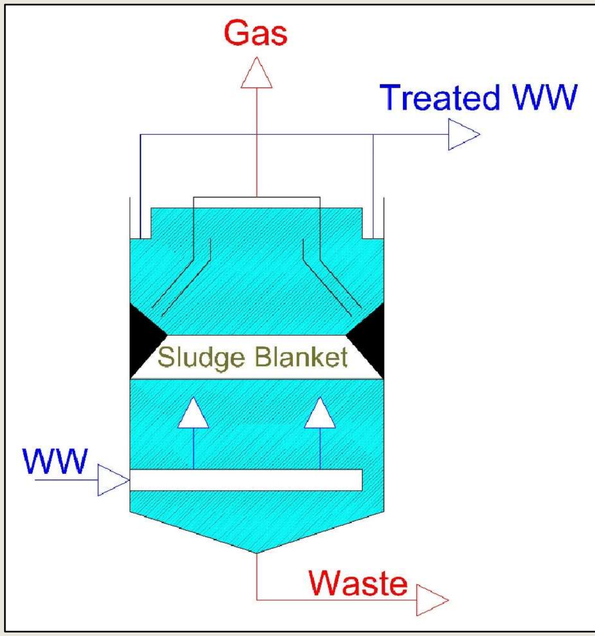
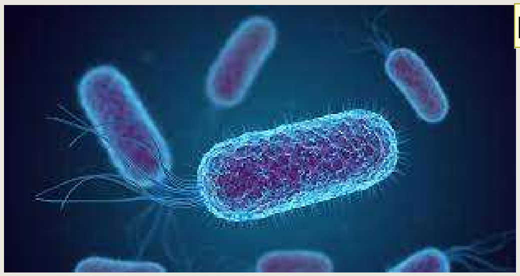



Figure 18: Upflow Anaerobic Sludge Blanket



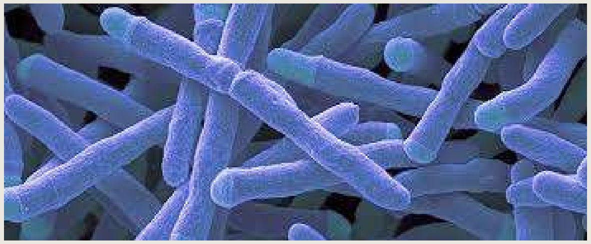
# Reactor Microbial Activity

Original Microbes



DK0

Increased Microbe Numbers



BOD → $CH_4$ and $CO_2$

TKN → Sludge

## Slide 21

**DK0** Make more professional
Daniel Brian Kennedy, 2023-04-28T00:41:56.829

**DK0 0** Add that microbes work at various rates, temperature, oxygen amounts, etc.
Daniel Brian Kennedy, 2023-04-28T00:42:37.721

# Modeling Results

## ANAEROBIC PROCESSES

Table 8: Anaerobic Modeling Results

| Parameter | Value |
|---|---|
| Hydraulic Retention Time (Days) | 0.275 ✓ |
| Minimum Required Solids Residence Time (Days) | 2.15 (Requires Recirculation) |
| Minimum Required Substrate (mg/L) | 0.018 ✓ |

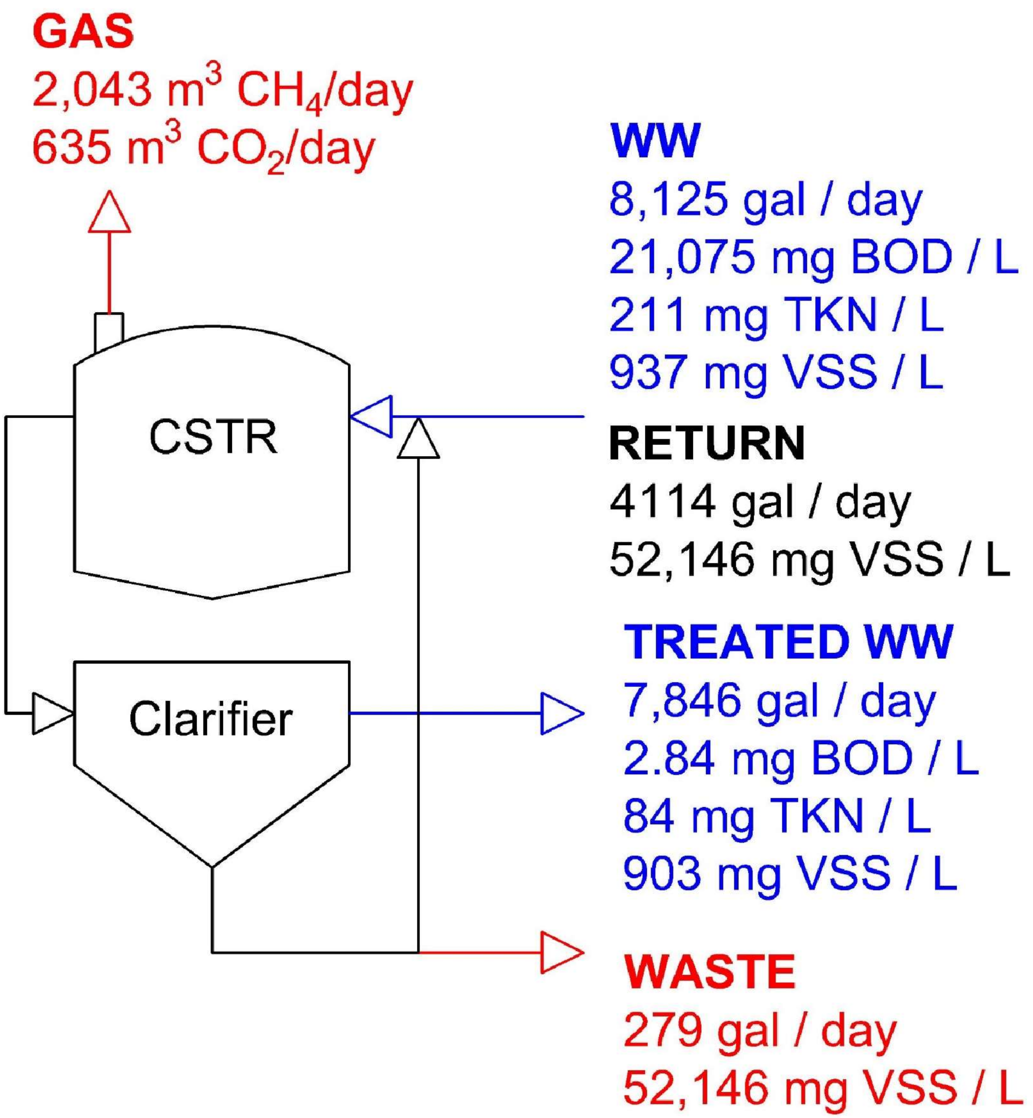
## TRICKLING FILTER RESULTS

Table 9: Trickling Filter Modeling Results

| Parameter | Value | Typical Values |
|---|---|---|
| Hydraulic Loading (ft/d) | 22 (Low) | 131 |
| Surface Loading ($mg/ft^2*d$) | 15,800 (High) | 654 |
| Volumetric Loading ($mg/ft^3*d$) | 962,000 (High) | 11 |

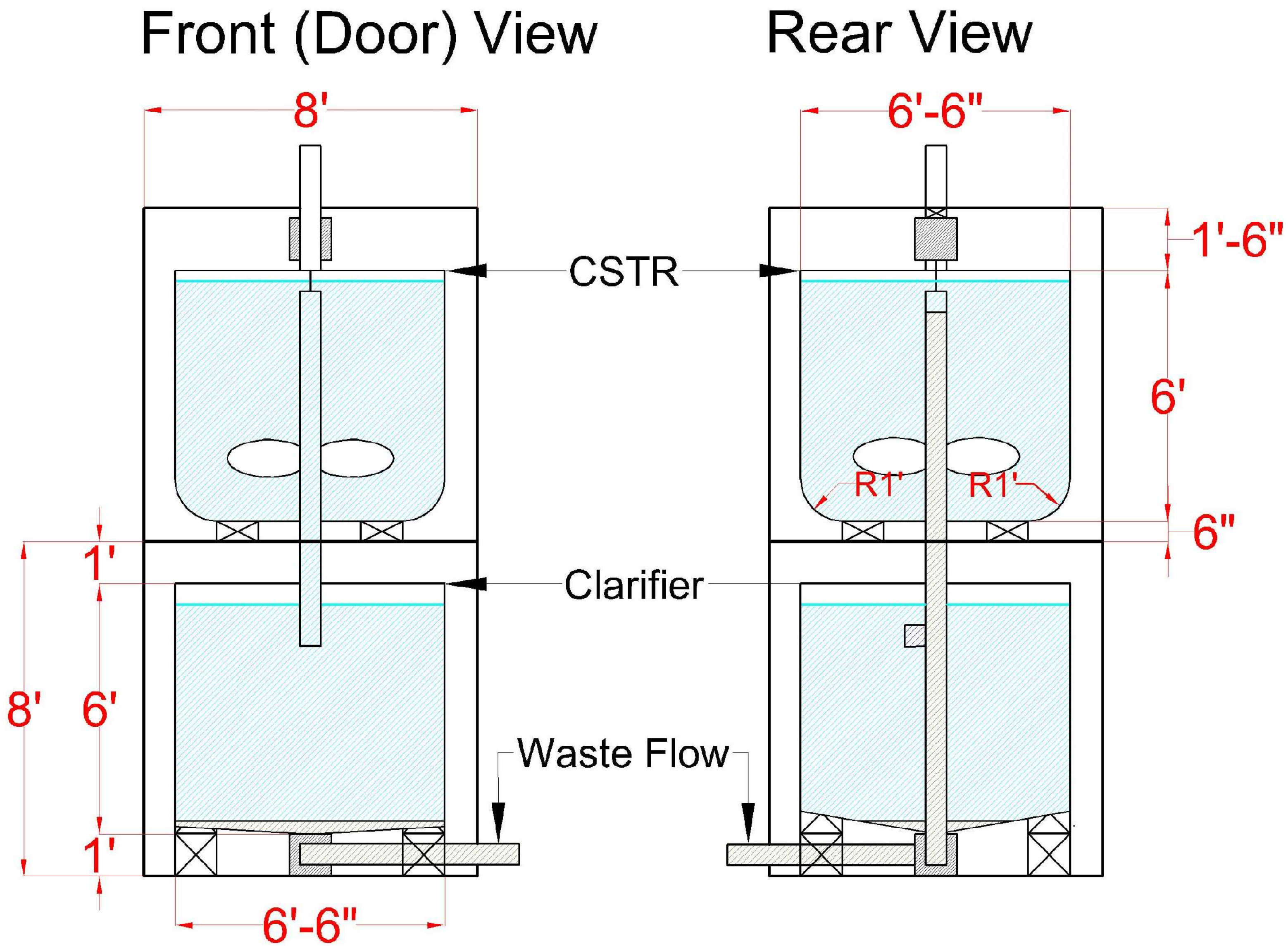
# Final Design

- **Model calculated theoretical treatment of MRBC wastewater**
  - **BOD Effluent: 2.84 mg/L**
  - **TKN Effluent: 84 mg/L**
- **Required Return Flow Rate:**
  - **4,114 gal/day**
- **Methane Production:**
  - **2,043 m3/day**
  - **846 kW**



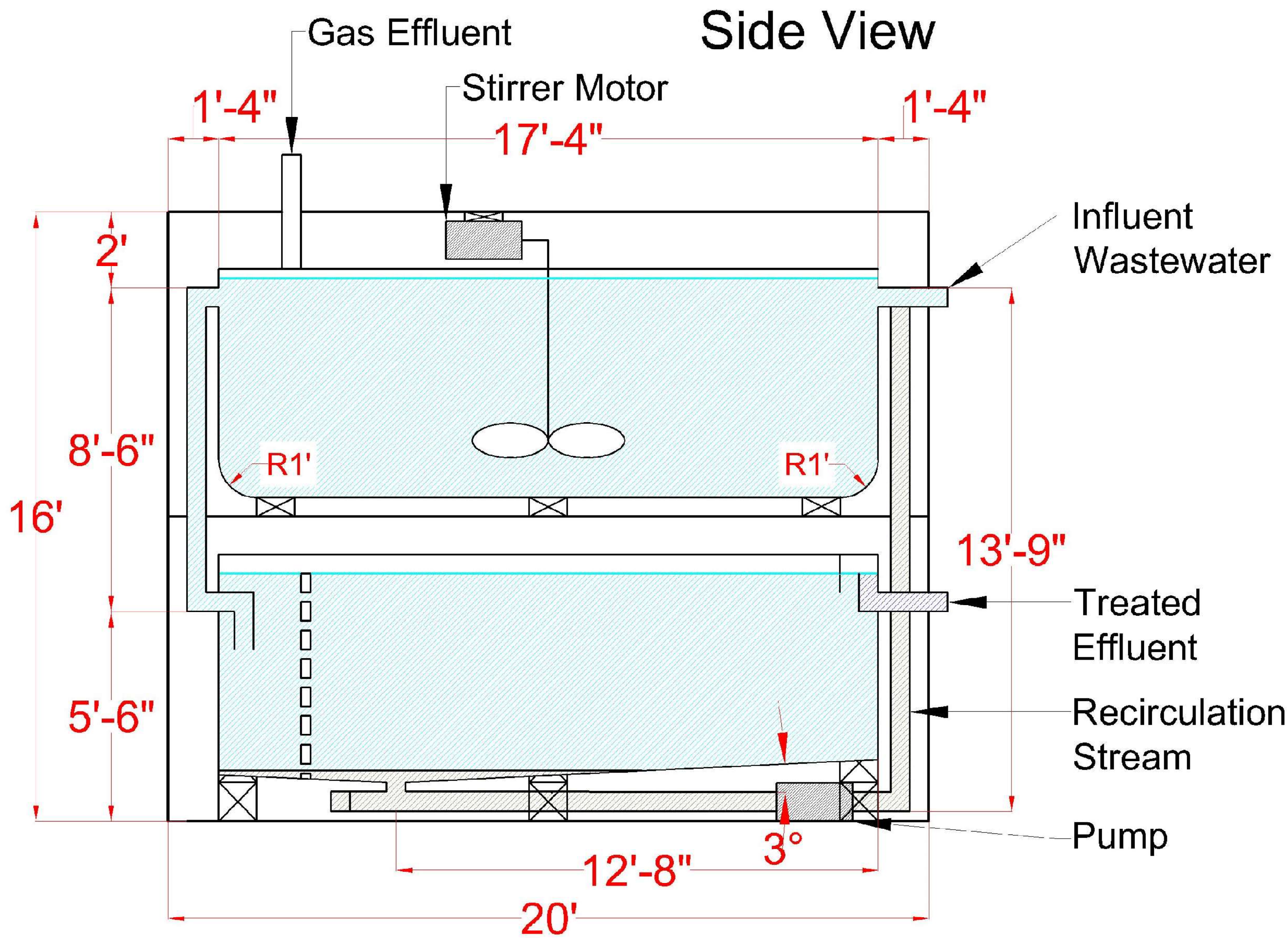
# Final Design

- **Additional shipping container required**



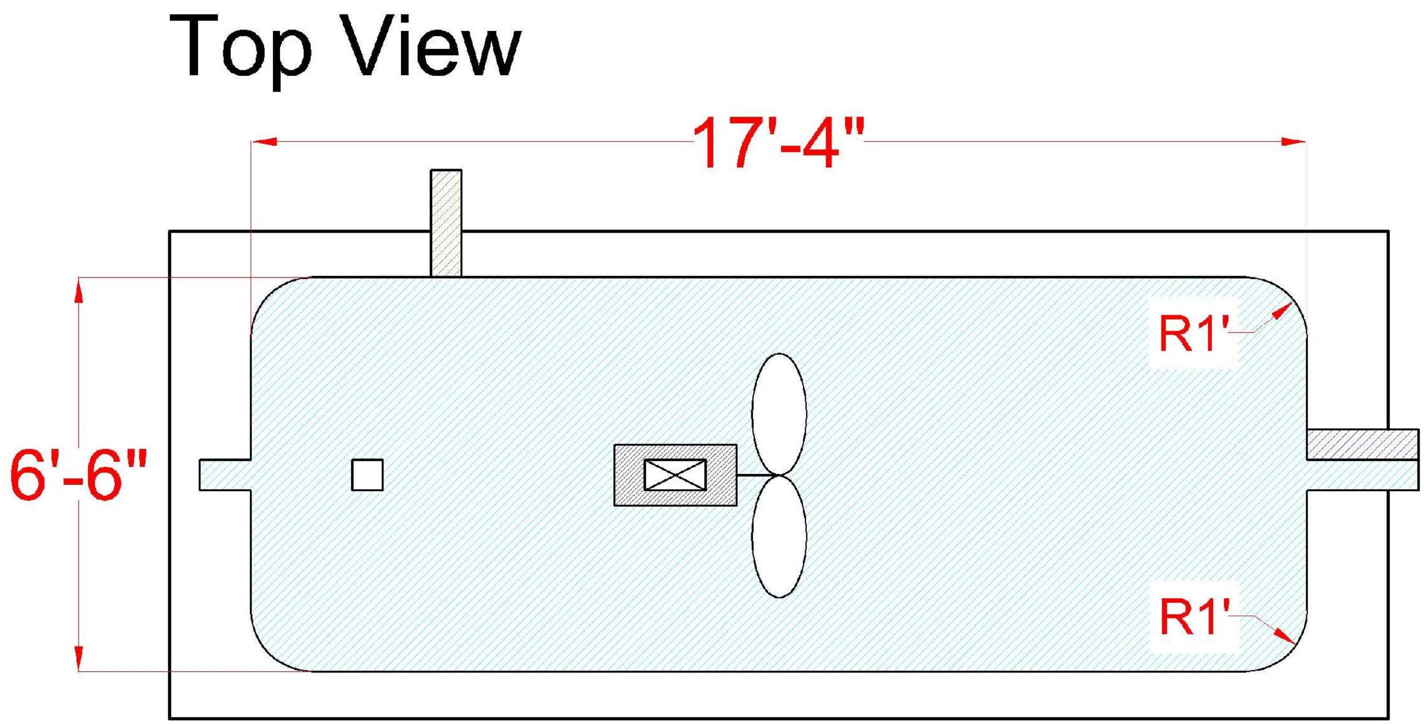
# Final Design

**(Continued)**



# Final Design

**(Continued)**



# Methane Control Options

## 1. Flaring/Burning

- Methane burned in a flare stack to convert methane to carbon dioxide

## 2. Cogeneration

- Methane is converted to renewable energy using a gas engine and generator [3] (Saves $3,250.05/day of electricity)

## 3. Capture and Refine

- Methane is captured in a column and is sent to be refined by reacting with steam in the presence of a catalyst

# Pricing For Design Materials

Table 10: Design Pricing

| Design Equipment | Price Range |
|---|---|
| CSTR Tank and Impeller | $15,000-$25,000 [4] |
| Clarifier | $10,000-$35,000 [5] |
| Shipping Container (Per Container) | $1,500-$3,000 [6] |
| Pump | $1,000-$2,000 [7] |
| **Total** | **$29,000-$68,000** |

# Project Impacts

Table 11: Project Impacts

| Pros | Cons |
|---|---|
| Improve Rio De Flag WWTP performance | Design maintenance and construction costs |
| Remove MRBC’s monthly fine | Increased electricity usage |
| Sludge production can be used as fertilizer | Concentration of contaminants in sludge |
| Possible energy production using methane | Permitting of methane flare/gas emissions management |
| Promote sustainable local businesses | Poor aesthetics and odor |

# Final Process Design

# References

[1] Google, "Google Earth," The Alphabet Company, 2022

[2] City of Flagstaff, "Chapter 7-02 Wastewater Regulations," 2022 [Online].

[3] D. Moldal, "Wastewater Treatment, Powered by Biogas," WaterWorld, 2021.

[4] "stirred tank reactor continuous stirred tank reactor 50000l vacuum stirred tank reactor," Alibaba.

[5] "How Much Does a Wastewater Treatment System Cost? (Pricing, Factors, Etc.)," SAMCO, 2016.

[6] "California Shipping Container Homes," We Will Transport It.

[7] "Centrifugal Pump: 1 hp, 115/230V AC, 85 ft Max Head, 1 1/4 in , 1 in Intake and Disch," Grainger.

[8] B. E. Rittman, "12 Aerobic Biofilm Processes," in Environmental Biotechnology: Principles and Applications, Second Edition, New York, McGraw Hill, 2020, pp. 475-500.

Thank you!

Are there any questions?

# Chemical Equations

$$R = f_e R_a + f_s R_c - R_d$$

Where:

$R$ = General stoichiometric reaction (unitless)

$f_e$ = The percentage adjustment factor for the energy generation (unitless)

$f_s$ = The percentage adjustment factor for the synthesis reaction (unitless)

$R_d$ = Electron Donor Half Reaction (unitless)

$R_a$ = Electron Acceptor Half Reaction (unitless)

$R_c$ = Cell Synthesis Half Reaction (unitless)

[8]

# Chemical Equations

Aerobic

$$\frac{21}{793}NH_4 + \frac{21}{793}HCO_3 + \frac{1}{40}O_2 + \frac{1}{54}C_{13}H_{23}O_9N = \frac{19}{450}CO_2 + \frac{9}{200}C_5H_7O_2N + \frac{73}{600}H_2O$$

Anaerobic

$$\frac{1}{54}C_{13}H_{23}O_9N + \frac{19}{300}H_2O = \frac{55}{613}CO_2 + \frac{1}{74}NH_4 + \frac{1}{74}HCO_3 + \frac{9}{80}CH_4 + \frac{1}{200}C_5H_7O_2N$$

[8]

# Chemical Equation Results

Table 12: Stoichiometric Yield Factors

| **Yield Factors** | | |
|---|---|---|
| Description | Unit | Value |
| Growth Yield Factor (Y) | (g VSS / g BOD) | 0.09 |
| Substrate Yield Factor | (g O2/g Substrate) | 0.13 |
| Methane Yield Factor | (g sub/g $CH_4$) | 3.47 |
| CO2 Yield Factor | (g sub/g CO2) | 4.35 |

Table 13: Stoichiometric Gas Production

| **Gas Production** | | |
|---|---|---|
| Description | Unit | Value |
| Methane Production | g $CH_4$/day | 1.46E+06 |
| | m3 $CH_4$/day | 2.04E+03 |
| CO2 Production | g CO2/day | 1.16E+06 |
| | m3 CO2/day | 6.35E+02 |

# Biological Kinetic Constants

Table 14: Stoichiometric Gas Production [3]

**TABLE 6.1** Estimated $f_s^0$, $Y$, $\hat{q}$, $\hat{\mu}$, and $b$ Values for Key Microbial Types in Environmental Biotechnology

| Organism Type | Electron Donor | Electron Acceptor | End Products | C-Source | $f_s^0$ | Gram Donor/ e⁻ eq | Y | $\hat{q}$ | $\hat{\mu}$ | b |
|---|---|---|---|---|---|---|---|---|---|---|
| Aerobic heterotrophs | Carbohydrate BOD | $O_2$ | $CO_2$ | BOD | 0.7 | 8 | 0.49 g VSS/g $BOD_L$ | 27 g $BOD_L$/g VSS-d | 13.2 | 0.8 |
| | Other BOD | $O_2$ | $CO_2$ | BOD | 0.6 | 8 | 0.42 g VSS/g $BOD_L$ | 20 g $BOD_L$/g VSS-d | 8.4 | 0.5 |
| Denitrifiers | BOD | $NO_3^-$ | $CO_2$, $N_2$ | BOD | 0.5 | 8 | 0.35 g VSS/g $BOD_L$ | 16 g $BOD_L$/g VSS-d | 5.6 | 0.3 |
| | $H_2$ | $NO_3^-$ | $N_2$ | $CO_2$ | 0.2 | 1 | 1.13 g VSS/g $H_2$ | 1.25 g $H_2$/g VSS-d | 1.4 | 0.08 |
| | S(s) | $NO_3^-$ | $SO_4^{2-}$, $N_2$ | $CO_2$ | 0.2 | 5.33 | 0.21 g VSS/g S | 6.7 g S/g VSS-d | 1.4 | 0.08 |
| Nitrifying autotrophs | $NH_4^+$ | $O_2$ | $NO_2^-$ | $CO_2$ | 0.14 | 3.5 | 0.23 g VSS/g $NH_4^+$-N | 4.1 g $NH_4^+$-N/g VSS-d | 0.94 | 0.06 |
| | $NO_2^-$ | $O_2$ | $NO_3^-$ | $CO_2$ | 0.10 | 14 | 0.04 g VSS/g $NO_2^-$-N | 15.6 g $NO_2^-$-N/g VSS-d | 0.62 | 0.04 |
| Methanogens | Acetate BOD | Acetate | $CO_2$, $CH_4$ | Acetate | 0.05 | 8 | 0.035 g VSS/g $BOD_L$ | 8.4 g $BOD_L$/g VSS-d | 0.3 | 0.02 |
| | $H_2$ | $CO_2$ | $CH_4$ | $CO_2$ | 0.08 | 1 | 0.45 g VSS/g $H_2$ | 1.1 g $H_2$/g VSS-d | 0.5 | 0.03 |
| Sulfide-oxidizing autotrophs | $H_2S$ | $O_2$ | $SO_4^{2-}$ | $CO_2$ | 0.2 | 4 | 0.28 g VSS/g $H_2S$-S | 5 g S/g VSS-d | 1.4 | 0.08 |
| Sulfate reducers | $H_2$ | $SO_4^{2-}$ | $H_2S$ | $CO_2$ | 0.05 | 1 | 0.28 g VSS/g $H_2$ | 1.05 g $H_2$/g VSS-d | 0.29 | 0.02 |
| | Acetate BOD | $SO_4^{2-}$ | $CO_2$, $H_2S$ | Acetate | 0.08 | 8 | 0.057 g VSS/g $BOD_L$ | 8.7 g $BOD_L$/g VSS-d | 0.5 | 0.03 |
| Fermenters | Sugar BOD | Sugar | $CO_2$, BOD | Sugar | 0.18 | 8 | 0.13 g VSS/g $BOD_L$ | 9.8 g $BOD_L$/g VSS-d | 1.3 | 0.08 |

*Notes:*
- $Y$ is computed assuming a cellular VSS composition of $C_5H_7O_2N$.
- $\hat{q}$ is computed using $\hat{q}_e = 1e^-$ eq/g $VSS_a$-d.
- $\hat{\mu}$ and $b$ have units of $d^{-1}$.

# Anaerobic Modeling Equations

Hydraulic Retention Time [8]

$$\theta = \frac{\theta_x Y(S_0 - S)}{X(1 + b\theta_x)}$$

Minimum Required Substrate [8]

$$S_{min} = \frac{Kb}{Yq - b}$$

Minimum Allowable Solids Residence Time [8]

$$\theta_x^{min} = \frac{K + S^0}{S^0(Yq - b) - bK}$$

Table 15: Anaerobic Modeling Input Values

| Variable Notation | Variable Meaning | Fixed Input Value |
|---|---|---|
| K | Half Saturation Constant (mgBOD/L) | 10 |
| $S^0$ | Influent BOD Concentration (mgBOD/L) | 21075 |
| Y | Growth Yield Factor (gVSS/gBOD) | 0.091 |
| q | Maximum Specific Rate of Substrate Utilization (gBOD/gVSS*day) | 8.4 |
| b | Monod Decay Constant ($day^{-1}$) | 0.02 |

# Trickling Filter Modeling Equations

Hydraulic Loading Rate [8]

$$HL = \frac{Q + Q^r}{A_{pv}}$$

BOD Surface Loading Rate [8]

$$SL = \frac{QS^0}{A_{pv}da}$$

Volumetric Loading Rate [8]

$$VL = \frac{QS^0}{A_{pv}d}$$

Table 16: Trickling Filter Modeling Input Values

| Variable Notation | Variable Meaning | Fixed Input Value |
|---|---|---|
| $Q$ | Incoming Flow Rate ($ft^3/d$) | 1086 |
| $Q^r$ | Return Flow Rate ($ft^3/d$) | 1000 |
| $A_{pv}$ | Cross-Sectional Area of Filter ($ft^2$) | 96 |
| $S^0$ | Incoming BOD Concentration ($mg/ft^3$) | 590,000 |
| d | Depth of Filter (ft) | 7 |
| a | Approximate Media Surface Area ($ft^{-1}$) | 61 |

# CSTR Design Modeling Results

Table 17: CSTR Modeling Results

| Parameter | Description | Units | Value |
|---|---|---|---|
| $\theta$ | Hydraulic Retention Time | (day) | 0.62 |
| $[\theta_x^{min}]_{lim}$ | Organism Washout SRT | (day) | 1.35 |
| $SF_{selected}$ | Input Safety Factor | (unitless) | 5.00 |
| $\theta_{x\text{-}selected}$ | Selected SRT | (day) | 6.75 |
| $S^4$ | Reactor Effluent Substrate | (mg/L) | 2.84 |
| $X_a^3$ | Reactor Active Biomass | (mg VSS/L) | 18344 |
| $X_i^3$ | Reactor Inert Biomass | (mg VSS/L) | 10722 |
| $X_v^3$ | Reactor Total Biological Solids | (mg VSS/L) | 29065 |
| $X_a^1$ | Input Active Biomass | (mg VSS/L) | 16663 |
| $TKN^4$ | Effluent TKN | (mg/L) | 84.40 |

# System Mass Balance

Table 18: CSTR Mass Balance (Pt 1, 2)

| **Iteration 1: Assume No Return Flow** | | | |
|---|---|---|---|
| Step 1: Calculate Mass Rates | | | |
| **Variable** | **Description** | **Units** | **Value** |
| $m_a^1$ | WW Influent Active Mass Rate | (mg/d) | 0.00E+00 |
| $m_a^2$ | CSTR Influent Active Mass Rate | (mg/d) | 5.12E+08 |
| $m_a^3$ | CSTR Effluent Active Mass Rate | (mg/d) | 5.64E+08 |
| $m_a^4$ | Effluent WW Active Mass Rate | (mg/d) | 1.69E+07 |
| $m_a^5$ | Settled Active Mass Rate | (mg/d) | 5.47E+08 |
| **Iteration 2: Assume Mass Rate CSTR Influent = Mass Rate Return** | | | |
| Step 1: Calculate Remining Mass  Rates | | | |
| **Variable** | **Description** | **Units** | **Value** |
| $m_a^7$ | Return Active Mass Rate | (mg/d) | 5.12E+08 |
| $m_a^6$ | Waste Active Mass Rate | (mg/d) | 3.48E+07 |

# System Mass Balance

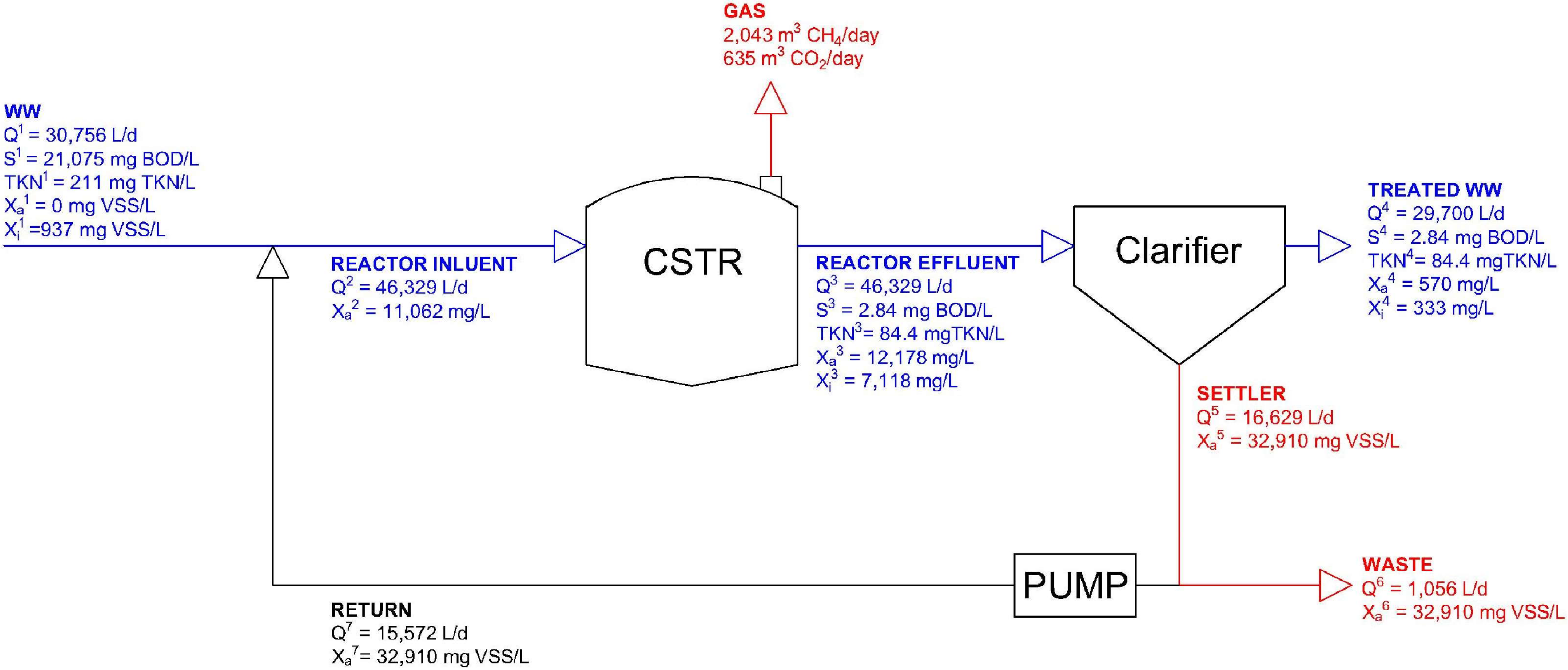
Table 19: CSTR Mass Balance (Pt. 3)

**Iteration 3: Balance Flow and Concentration By Iterating**

Step 1: Given All Mass Rates, Balance Flow & Active Concentration

| Location | Variable | Description | Units | Value |
|---|---|---|---|---|
| 1 | $m_a^1$ | WW Influent Active Mass Rate | (mg/d) | 0.00E+00 |
| | $Q^1$ | Influent Flow Rate | (L/d) | 30757 |
| | $X_a^1$ | Influent Active Biomass | (mg/L) | 0 |
| | $m_a^{1\text{-CHECK}}$ | CHECK WW Influent Active Mass Rate | (mg/d) | 0 |
| 2 | $m_a^2$ | CSTR Influent Active Mass Rate | (mg/d) | 5.12E+08 |
| | $Q^2$ | CSTR Influent Flow | (L/d) | 46329 |
| | $X_a^2$ | CSTR Influent Active Biomass | (mg/L) | 11062 |
| | $m_a^{2\text{-CHECK}}$ | CHECK CSTR Influent Active Mass Rate | (mg/d) | 5.12E+08 |
| 3 | $m_a^3$ | CSTR Effluent Active Mass Rate | (mg/d) | 5.64E+08 |
| | $Q^3$ | CSTR Effluent Flow | (L/d) | 46329 |
| | $X_a^3$ | CSTR Effluent Active Biomass | (mg/L) | 12178 |
| | $m_a^{3\text{-CHECK}}$ | CHECK CSTR Effluent Active Mass Rate | (mg/d) | 5.64E+08 |
| 4 | $m_a^4$ | Effluent WW Active Mass Rate | (mg/d) | 1.69E+07 |
| | $Q^4$ | Effluent WW Flow | (L/d) | 29700 |
| | $X_a^4$ | Effluent WW Active Biomass | (mg/L) | 570 |
| | $m_a^{4\text{-CHECK}}$ | CHECK Effluent WW Active Mass Rate | (mg/d) | 1.69E+07 |

| | | | | |
|---|---|---|---|---|
| 5 | $m_a^5$ | Settled Active Mass Rate | (mg/d) | 5.47E+08 |
| | $Q^5$ | Settled Flow | (L/d) | 16629 |
| | $X_a^5$ | Settled Active Biomass | (mg/L) | 32910 |
| | $m_a^{5\text{-CHECK}}$ | CHECK Settled Active Mass Rate | (mg/d) | 5.47E+08 |
| 7 | $m_a^7$ | Return Active Mass Rate | (mg/d) | 5.12E+08 |
| | $Q^7$ | Return Flow | (L/d) | 15572 |
| | $X_a^7$ | Return Active Biomass | (mg/L) | 32910 |
| | $m_a^{7\text{-CHECK}}$ | CHECK Return Active Mass Rate | (mg/d) | 5.12E+08 |
| 6 | $m_a^6$ | Waste Active Mass Rate | (mg/d) | 3.48E+07 |
| | $Q^6$ | Waste Flow | (L/d) | 1056 |
| | $X_a^6$ | Waste Active Biomass | (mg/L) | 32910 |
| | $m_a^{6\text{-CHECK}}$ | CHECK Waste Active Mass Rate | (mg/d) | 3.48E+07 |



GAS
2,043 m$^3$ $CH_4$/day
635 m$^3$ $CO_2$/day
WW
$Q^1$ = 30,756 L/d
$S^1$ = 21,075 mg BOD/L
$TKN^1$ = 211 mg TKN/L
$X_a^1$ = 0 mg VSS/L
$X_i^1$ =937 mg VSS/L
CSTR
REACTOR INLUENT
$Q^2$ = 46,329 L/d
$X_a^2$ = 11,062 mg/L
REACTOR EFFLUENT
$Q^3$ = 46,329 L/d
$S^3$ = 2.84 mg BOD/L
$TKN^3$= 84.4 mgTKN/L
$X_a^3$ = 12,178 mg/L
$X_i^3$ = 7,118 mg/L
Clarifier
TREATED WW
$Q^4$ = 29,700 L/d
$S^4$ = 2.84 mg BOD/L
$TKN^4$= 84.4 mgTKN/L
$X_a^4$ = 570 mg/L
$X_i^4$ = 333 mg/L
SETTLER
$Q^5$ = 16,629 L/d
$X_a^5$ = 32,910 mg VSS/L
PUMP
WASTE
$Q^6$ = 1,056 L/d
$X_a^6$ = 32,910 mg VSS/L
RETURN
$Q^7$ = 15,572 L/d
$X_a^7$= 32,910 mg VSS/L