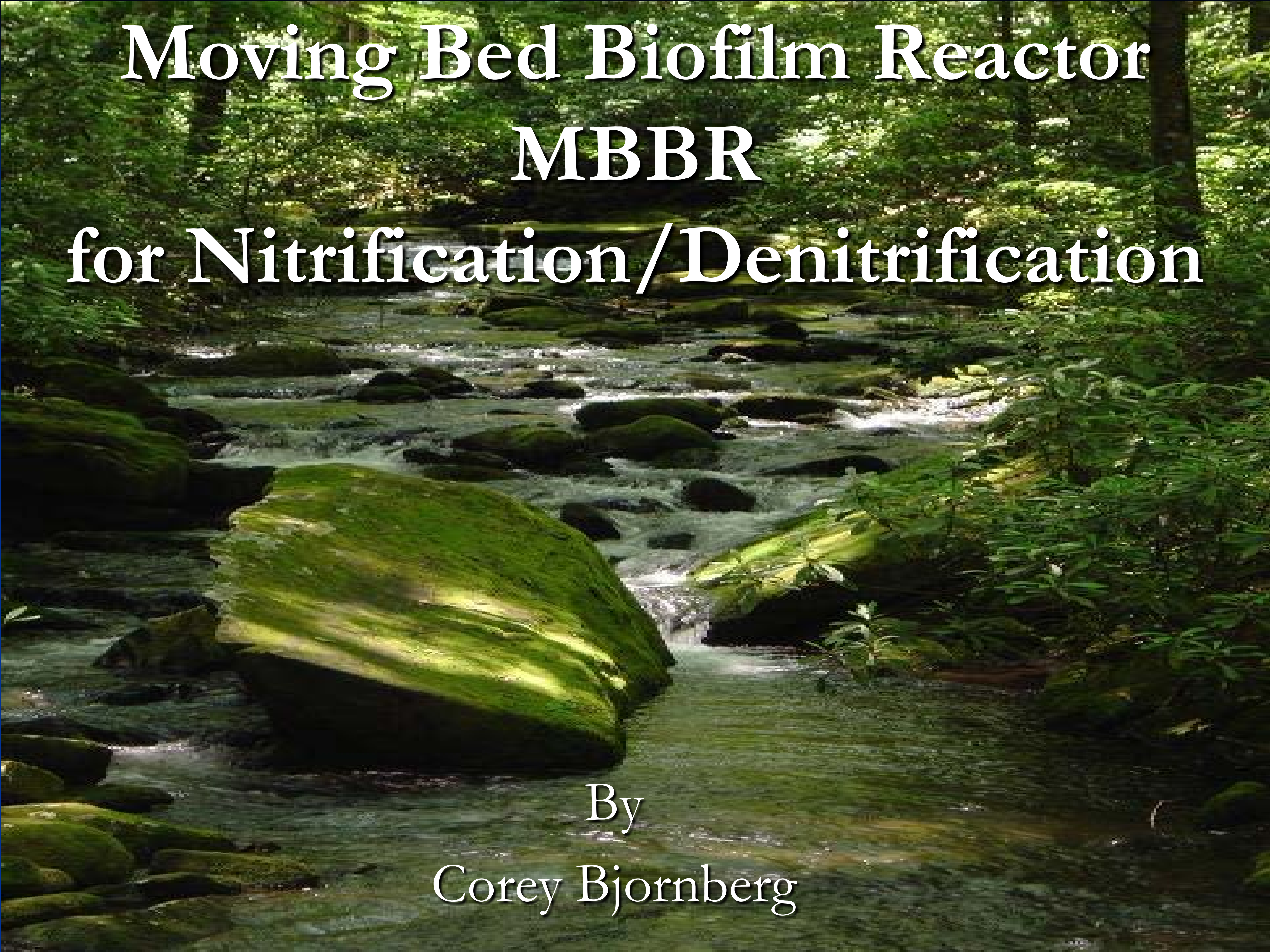


Moving Bed Biofilm Reactor
MBBR
for Nitrification/Denitrification

By

Corey Bjornberg

Nitrogen Sources

- Natural Decomposition of Organics
- Non-point Sources (fertilizers)
- Point Sources
  1) Industry
  2) Wastewater

Negative Impacts of Nitrogen on the Environment

- Nitrate in drinking water can cause Blue Baby Syndrome
- Increased levels of nitrate in water supplies can increase the acidity of the water and make toxic metals such as mercury more soluble
- Growth of nuisance algae blooms can cause decreased water quality and cause fish kills

Nitrification

- Two Step Biological Process

$$NH_4\text{-}N \xrightarrow{\text{oxidized}} NO_2\text{-}N \xrightarrow{\text{oxidized}} NO_3\text{-}N$$

- Aerobic Autotrophic Bacteria

$$NH_4\text{-}N \xrightarrow{\text{oxidized}} NO_2\text{-}N$$ (Nitrosomonas)

$$NO_2\text{-}N \xrightarrow{\text{oxidized}} NO_3\text{-}N$$ (Nitrobacter)

- Note these are documented as dominate bacteria but others exist in each step

Denitrification

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Nitrate **Nitrite** **Nitric Oxide** **Nitrous Oxide** **Nitrogen Gas**

- Anaerobic Conditions
- Heterotrophic and Autotrophic Bacteria
- Nitrite or Nitrate is electron acceptor
- Carbon Source Required (Methanol)

$$5CH_3OH + 6NO_3^- \rightarrow 3N_2 + 5CO_2 + 7H_2O + 6OH^-$$

Moving Bed Biofilm Reactor

Activated Sludge

Trickling Filter

MBBR

Advantages of MBBR

- Smaller Footprint
- Utilize whole tank volume for biomass
- Less Sludge Produced (Better Settling)
- No Return Activated Sludge
- Easy Expansion (more media)
- No Media Clogging
- Reliability and Ease of Operation
- Easy to Retrofit Existing Basins

Design Example

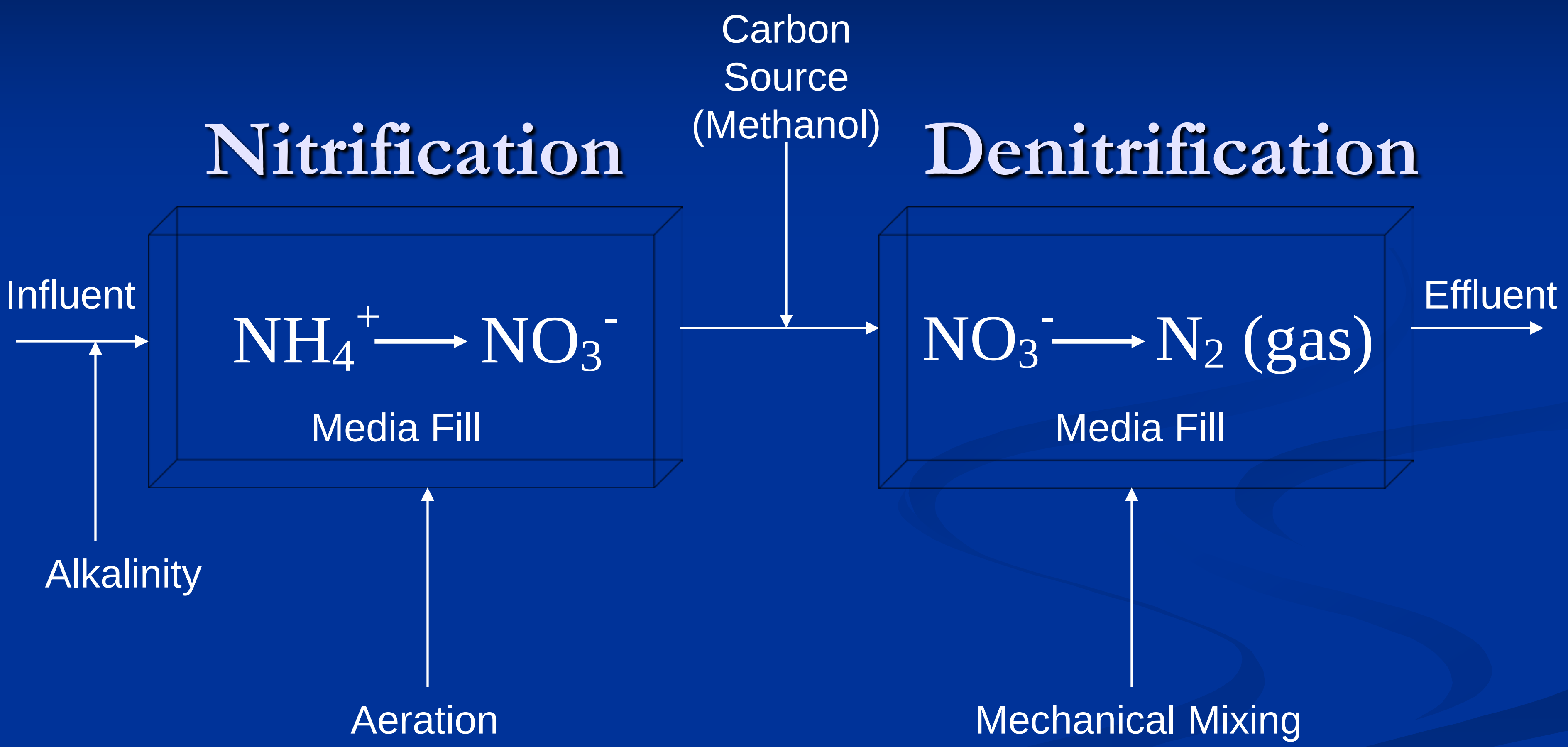
Outline

- Nitrogen Removal
- Tertiary Treatment
- Nitrification
- Denitrification
- Municipal Wastewater

Goals

- Ammonia-N<5 mg/L
- Nitrate-N<5 mg/L
- Total N<15 mg/L

Basic Design



Design Parameters

- Primary Clarifier Effluent used as Basin Influent
- Typical Values Taken From Moorhead WWTF
- Process Design for 20°C
- Steady State Conditions
- Completely Mixed Reactor
- Kaldnes Parameters

Influent Water Characteristics		
Flow	6	mgd
Flow	9.3	cfs
NH_4^+-N	25	mg/L
NH_4^+-N	1251.9	lb/d
BOD	6.7	mg/L
pH	6.6	
DO	6.9	mg/L
TKN	30	mg/L
TSS	6.9	mg/L

Nitrification Tank Design

- Nitrification rate of 1 $gNH_4^+\text{-}N/m^2d$ (Kaldnes)
- Decided on 30% Fill
- Resultant SA of 150 m^2/m
- Ammonia-N Load of 1250 lb/d
- Reactor Volume of 130,000 ft^3
- Depth of 12 ft
- Length to Width 2:1 used
- HRT 3.9 hrs

Media Design and Characteristics

-7 mm Long and 10 mm Diameter

-Density of 0.96 g/cm^3

-Surface Area of 500 m^2/m^3

-Typical Fill of 30-50%

Aeration Requirements

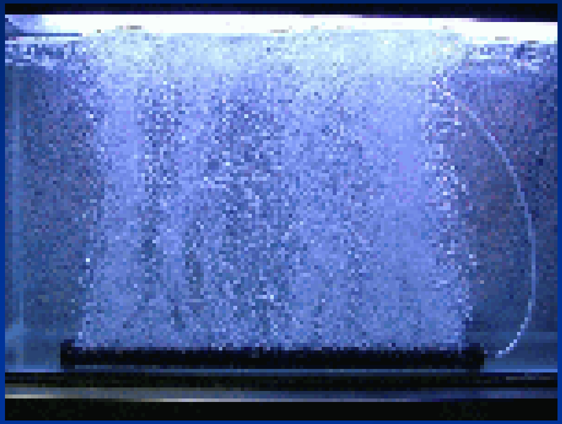
- Course Bubble Diffusers used to Suspend Media and Oxygen Requirements
- Oxygen Transfer Rate of 1%/ft depth Results in 11% Oxygen Transfer Rate (Kaldnes)
- Based on earlier stoichiometry 4.6 gO_2/gNH_4^+-N (Nitrification)
- Ammonia Loading used to determine 110 kgO_2/hr
- Standard Oxygen Transfer Rate Determined

$$SOTR = AOTR\left[\frac{C_{s,20}}{\alpha F(\beta \times \bar{C}_{s,T,H} - C)}\right] =$$

- Air Flow Rate then Determined 4000ft^3/min

$$Air\_flow = \frac{SOTR}{SOTE(60\,\min/h)((0.270\,kgO_2/m^3 air)}$$

- Diffuser Grid Pattern Design



Alkalinity Requirements

Stoichiometry

$$NH_4^+ + 2HCO_3^- + 2O_2 \rightarrow NO_3^- + 2CO_2 + 3H_2O$$

7.14 g Alkalinity as CaCO3/g N is required

Design Considerations

- Assumed Influent Alkalinity of 120 mg/L as $CaCO_3$
- Desired Effluent Alkalinity of 80 mg/L as $CaCO_3$
- Alkalinity Required used for Nitrification is 164 mg/L as $CaCO_3$
- Alkalinity Addition Needed is 124 mg/L as $CaCO_3$

- Total Alkalinity Required 6,200 lbs/d
- Strictly Based on Stoichiometry (Further Investigation Needed)

Denitrification Tank Design

- Denitrification rate of 2 gNH_4^+-N/m^2d (Kaldnes)
- Decided on 30% Fill
- Resultant SA of 150 m^2/m
- Nitrate-N Load of 1,050 lb/d
- Reactor Volume of 56,000 ft^3
- Depth of 12 ft (Kaldnes)
- Length to Width 2:1 used
- HRT 1.7 hrs

Mechanical Mixing

Media Design and Characteristics

-7 mm Long and 10 mm Diameter

-Density of 0.96 g/cm^3

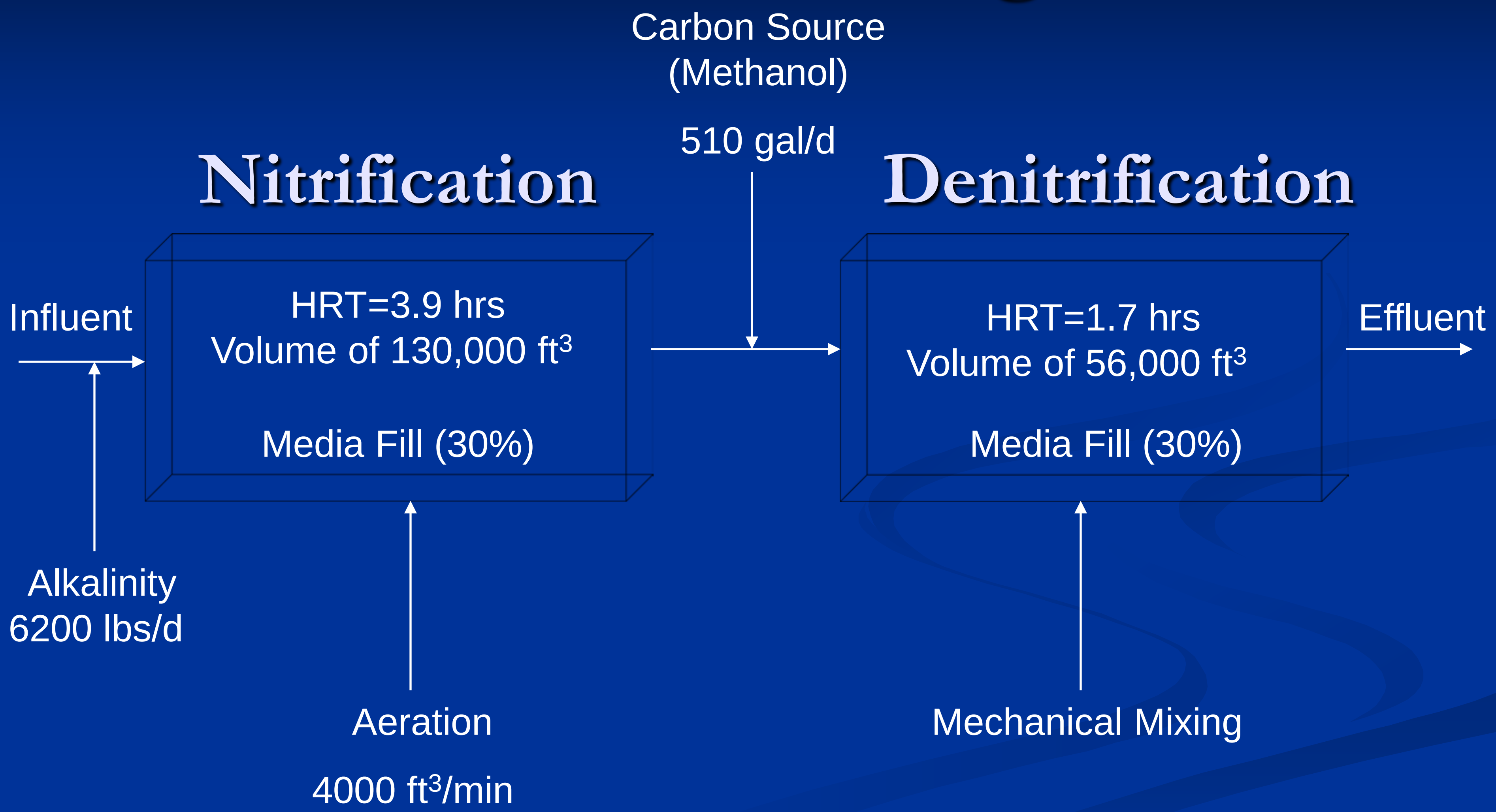
-Surface Area of 500 m^2/m^3

-Typical Fill of 30-50%

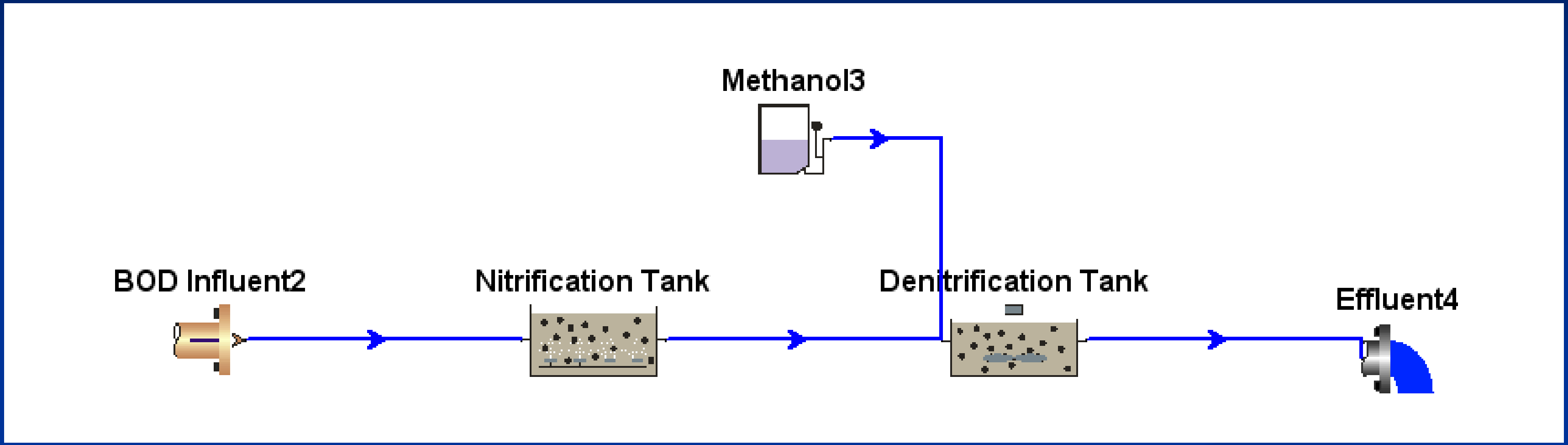
Methanol (CH3OH) Requirements

- Carbon Source for Denitrification
- Typical dose of 3.2 kg of methanol/kg NO_3-N (Metcalf & Eddy)
- Based on Nitrate-N Loading of 480 kg/d
- Dose of 510 gal/d of Methanol Required

Resultant Design



Biowin Modeling



Biowin Schematic (Steady State)

Element	Total N mg/L	Ammonia N mg/L	TKN mg/L	Nitrate-N mg/L	Nitrite-N mg/L	pH	cBOD mg/L	TSS mg/L
Influent	30.0	19.8	30.0	0.0	0.0	6.6	6.7	7.0
Nitrification Tank	29.7	0.8	7.0	22.6	0.1	6.7	4.2	9.2
Denitrification Tank	10.6	0.2	7.6	2.7	0.4	6.9	25.7	34.7
Effluent	10.6	0.2	7.6	2.7	0.4	6.9	25.7	34.7

Biowin Results For Nitrification/Denitrification

Goals accomplished (NH_4^+-N, NO_3^--N<5mg/L, Total N<15 mg/L)

Other Considerations

- Simultaneous Removal of Carbon and Nitrogen
- Sedimentation Tank due to Increased Solids
- More Detailed Design for Alkalinity
- Ability to Utilize Existing Infrastructure
- Variable Temperature, Flow, and Loading Conditions


Thank You!
Questions???