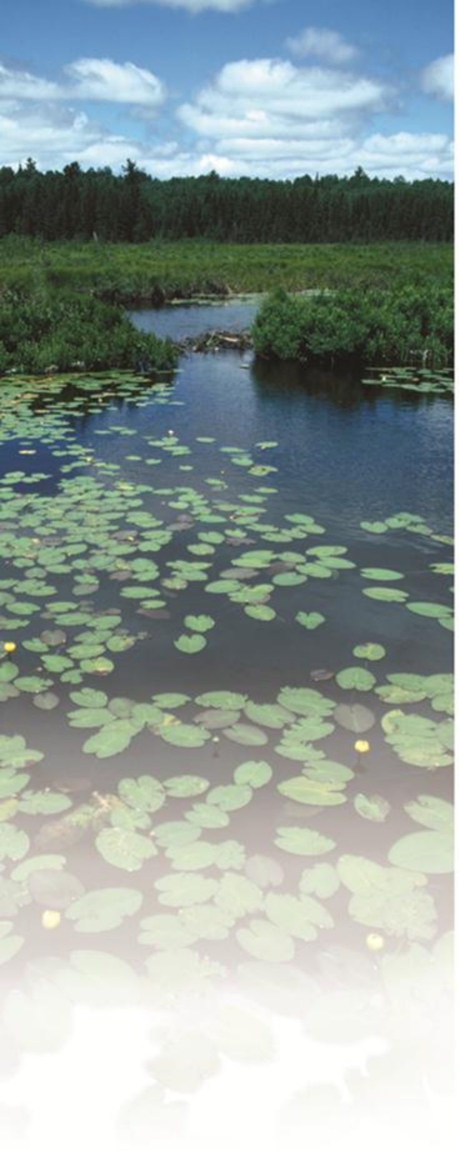


General Operational Considerations in Nutrient and Wet Weather Flow Management for Wastewater Treatment Facilities

Part II

Samuel Jeyanayagam, PhD, PE, BCEE
Julian Sandino, PhD, PE, BCEE

CH2MHILL

Ohio WEA Plant Operations Workshop
September 28, 2011

Presentation Outline

- Why Remove Nutrients?
- Overview of Wastewater Treatment
- Nutrient Removal Fundamentals
  - Phosphorus Removal

Part I

  - Nitrogen Removal
- Sustainability Considerations
- Design & Operational Considerations

Part II

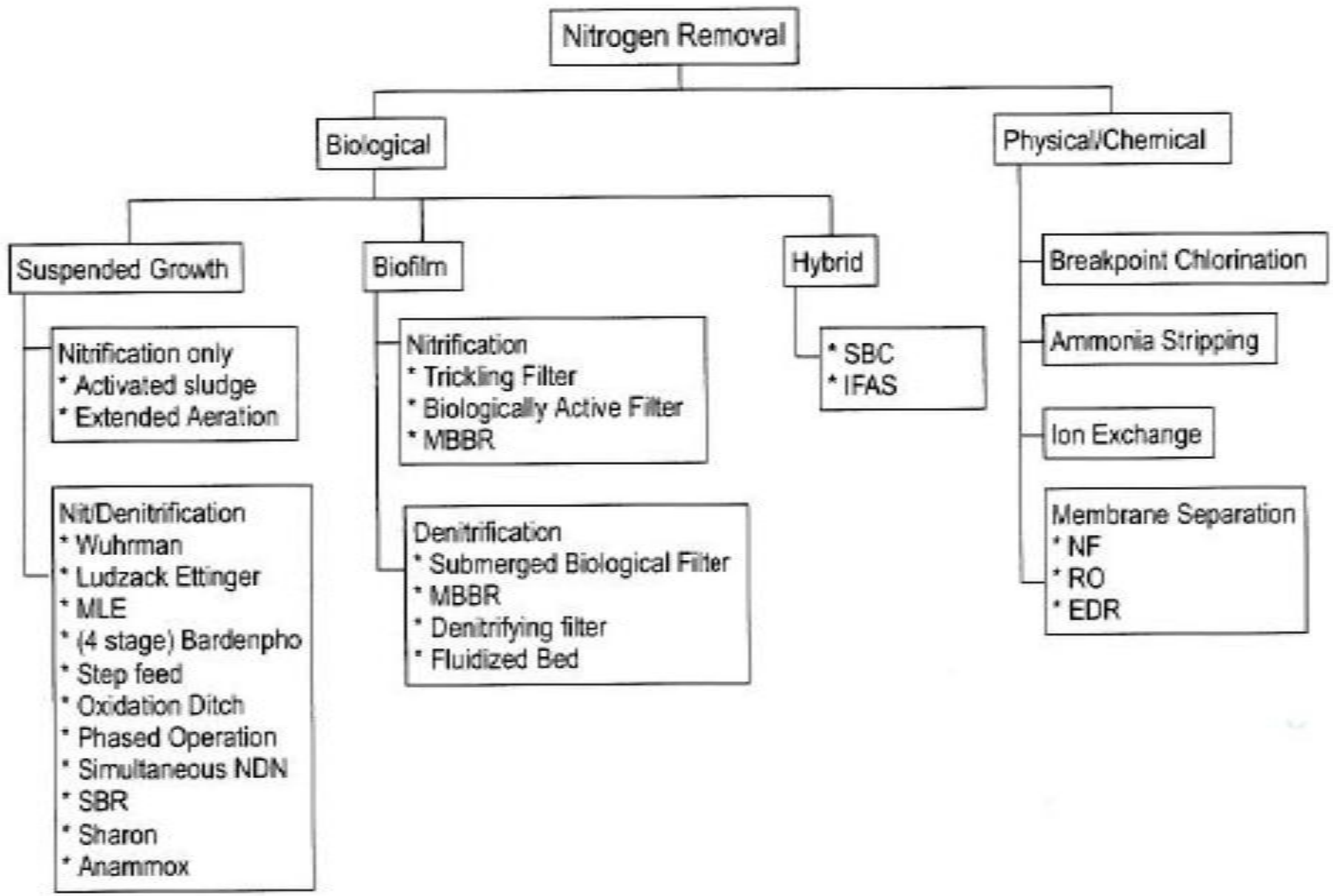
- Managing Wet Weather Flows in Nutrient Removal Facilities

Part III

Presentation Outline

- Why Remove Nutrients?
- Overview of Wastewater Treatment
- **Nutrient Removal**
  - Phosphorus Removal
  - **Nitrogen Removal**
- **Sustainability Considerations**
- **Design & Operational Considerations**
- Managing Wet Weather Flows in Nutrient Removal Facilities

Nitrogen Removal Alternatives



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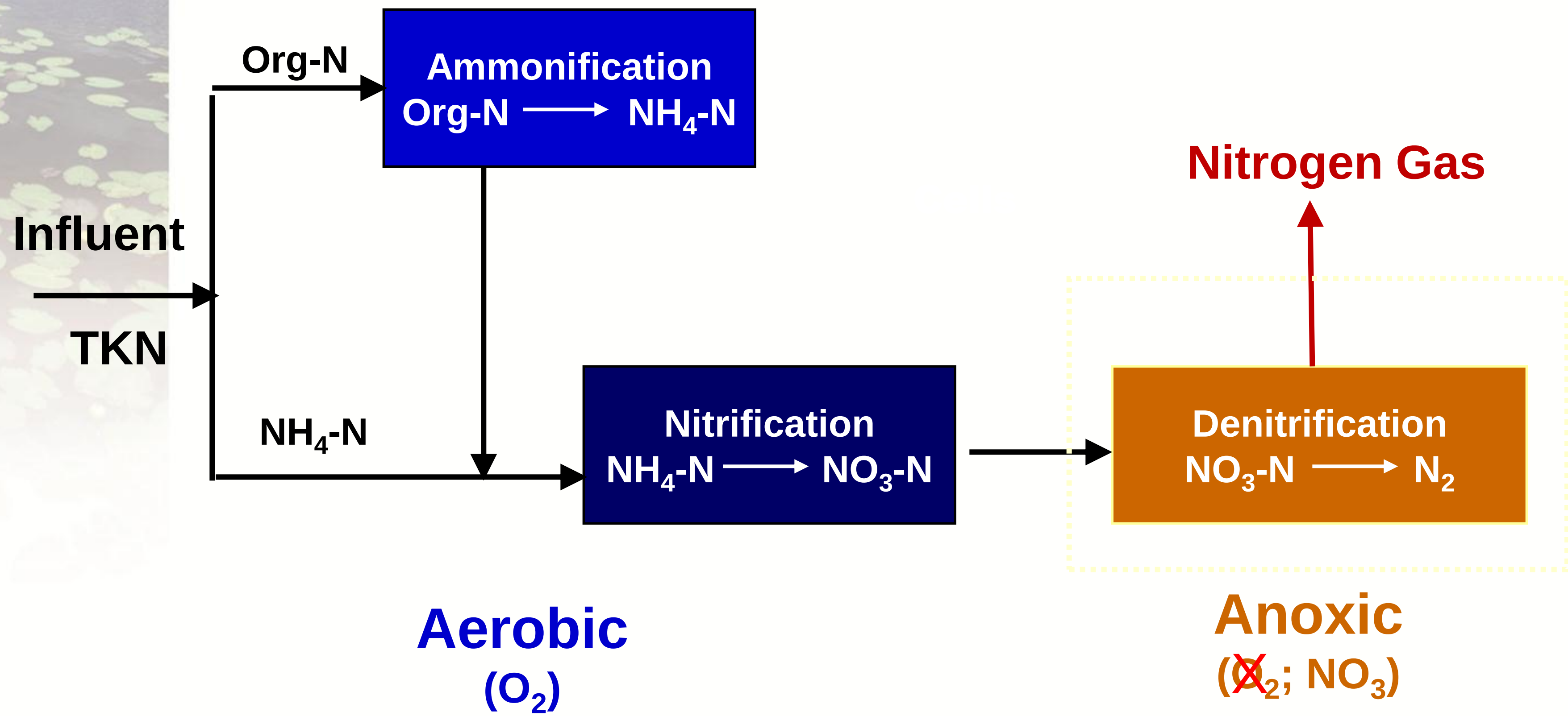
Nitrogen Removal Processes



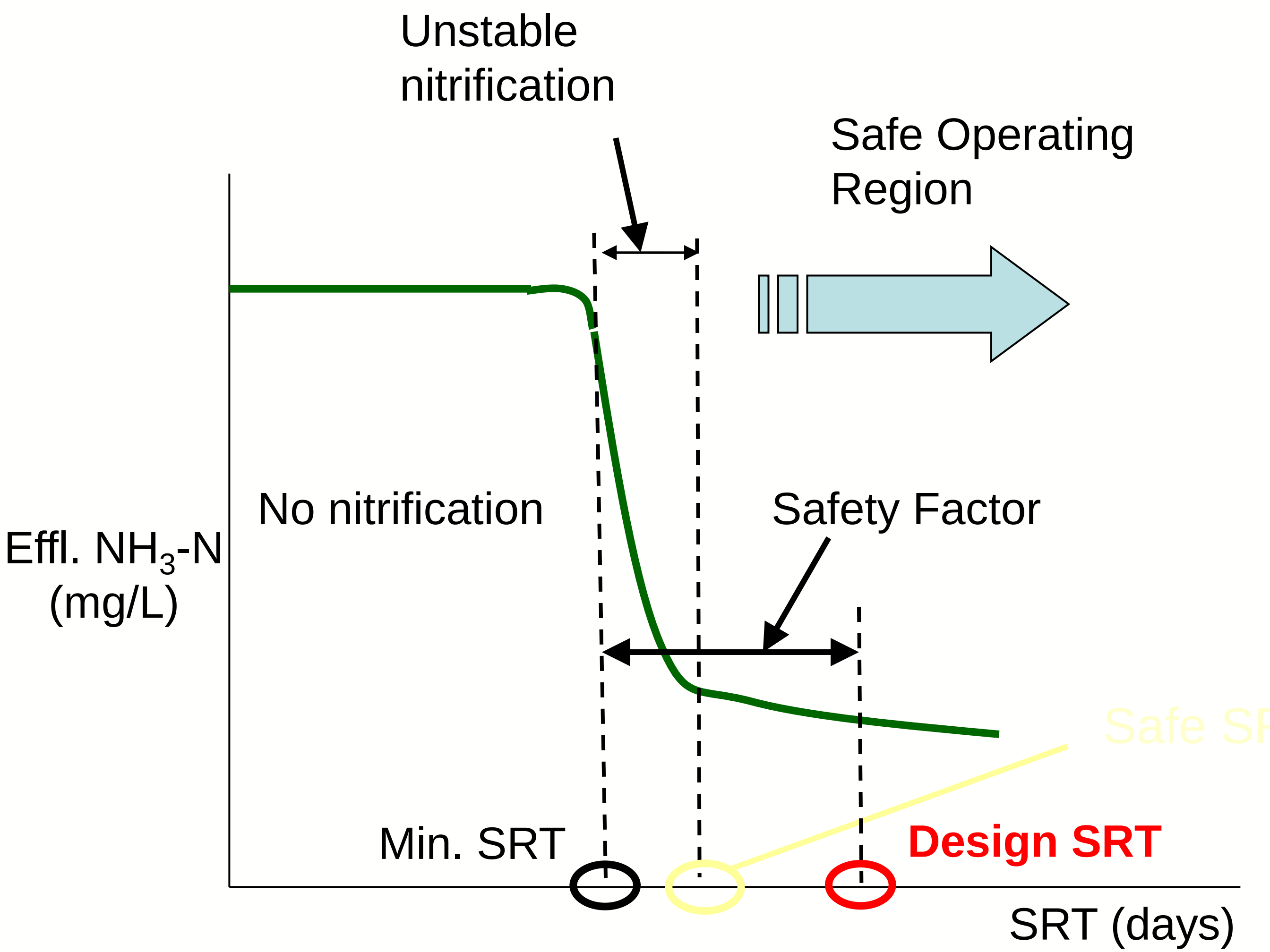
Nitrification

- Mediated by *Autotrophs*
- Conversion (oxidation) of ammonia to nitrate
- Does not result in significant nitrogen removal

Factors that impact nitrification

- Solids Retention Time (SRT)
- pH (Optimum: 6.5 - 8.0)
- DO (Optimum: 1.0 – 2.0 mg/L)
- Absence of inhibitory compounds
- Recycle load

Adequate SRT is Crucial for Reliable Nitrification



Denitrification

- Denitrification: Conversion (reduction) of nitrate to nitrogen gas

$$NO_3 \quad \Rightarrow \quad N_2\ (g)$$

- Facultative heterotrophic organisms
- Results in nitrogen removal

Factors impacting denitrification

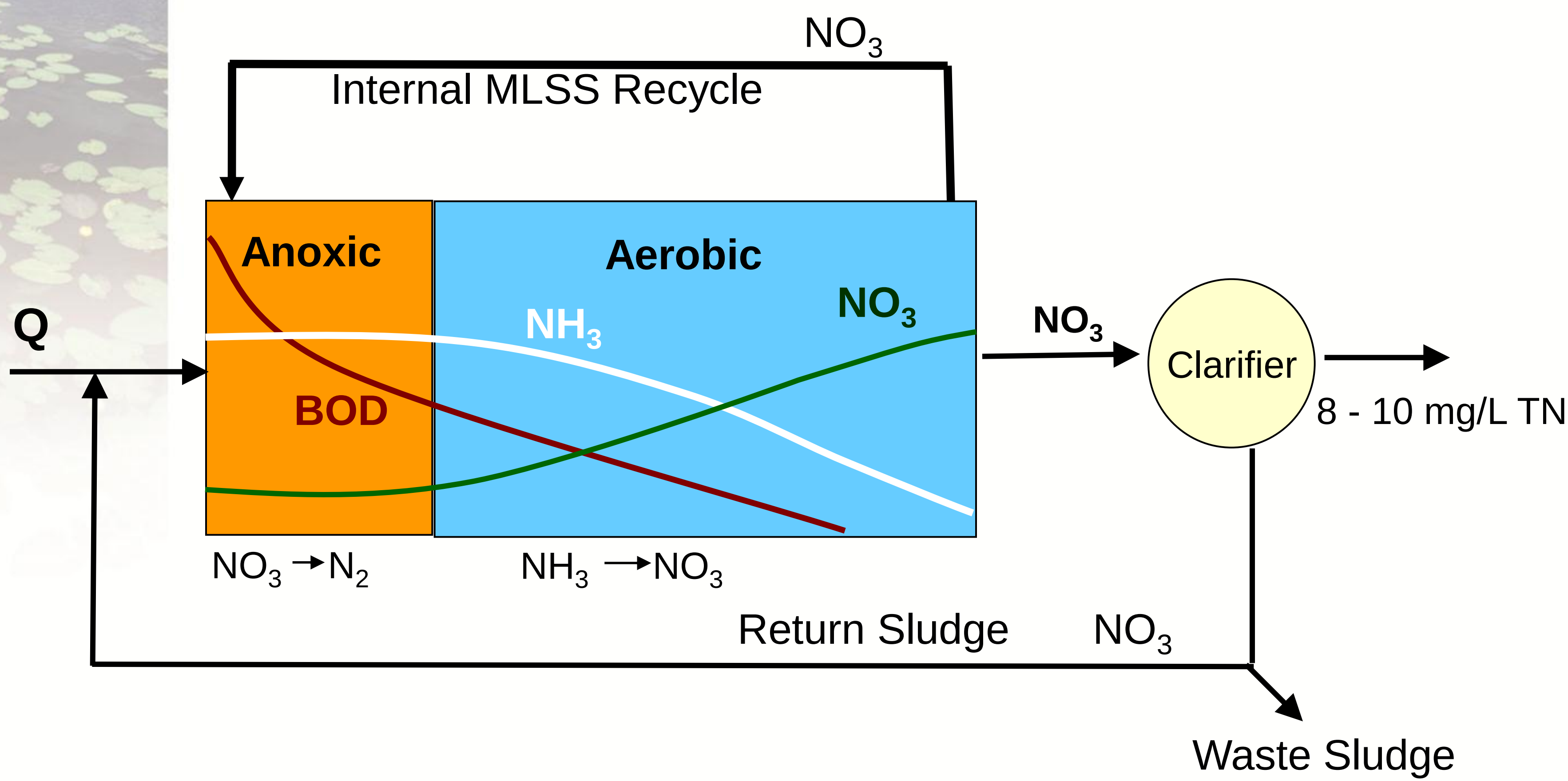
- Anoxic condition (Sufficient NO_3)
- Carbon source
- Adequate anoxic SRT
- Temperature

Nitrification vs. Denitrification

Factor	Nitrification	Denitrification
Environment	Aerobic	Anoxic
Oxygen source (Electron Acceptor)	Dissolved oxygen (DO)	Combined Oxygen (NO_3)
Type of Organism	Autotrophs	Heterotrophs
Energy (food) source Electron Donner)	Ammonia-N	Organic Matter
Carbon Source	Organic Matter	Inorganic (CO_2)
Oxygen	Demand (4.6 lb O_2 / lb NH_4 oxidized)	Credit (2.9 lb O_2 / lb NO_3 reduced)
Alkalinity (as $CaCO_3$)	Consumed (7.1 lb /lb NH_4 oxidized)	Produced (3.6 lb /lb NO_3 reduced)

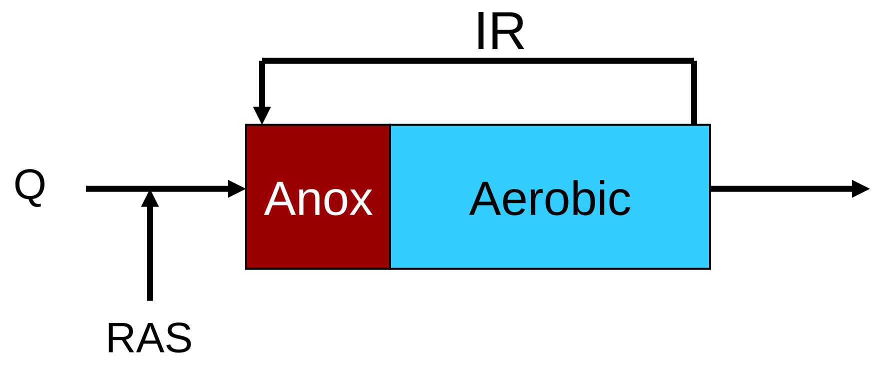
How is Nitrogen Removal Achieved in Practice?

Modified Ludzack-Ettinger (MLE) Process

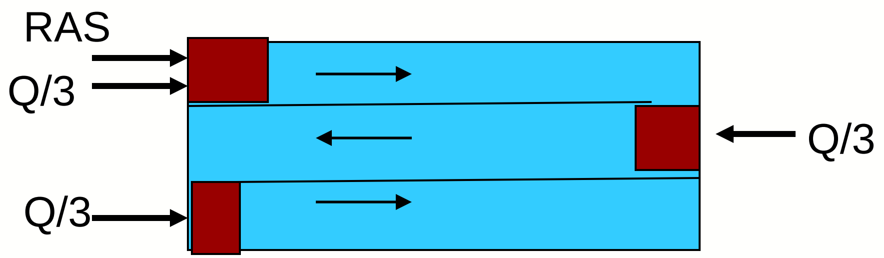


Nitrogen Removal Capability of Various Processes

MLE Process
TN = 8 - 10 mg/L

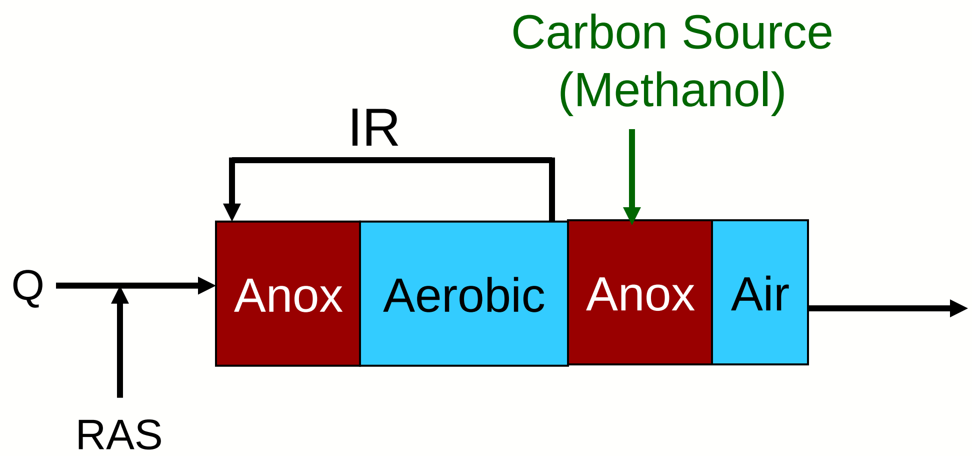


Step-Feed
TN = 8-10 mg/L

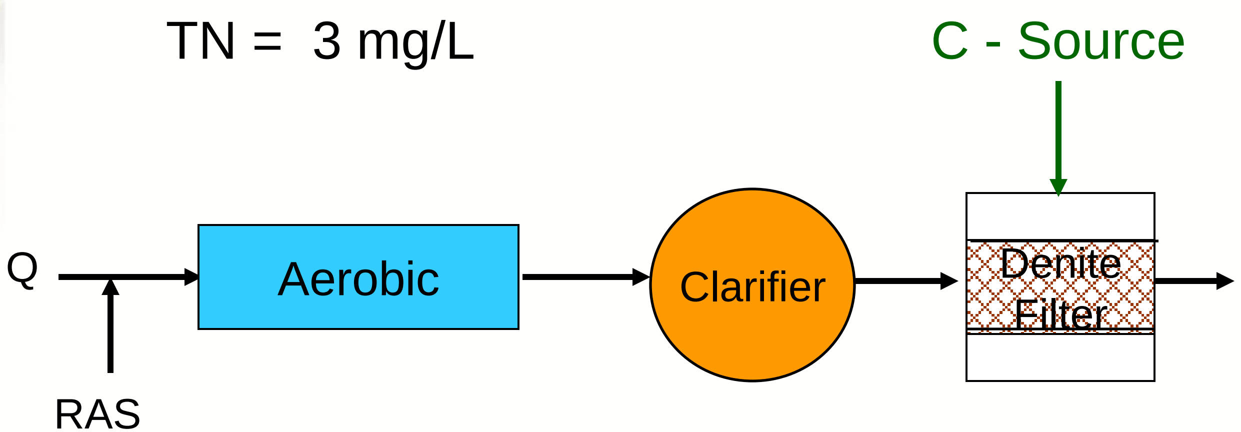


Nitrogen Removal Capability of Various Processes

4-Stage Bardenpho
TN = 3 mg/L

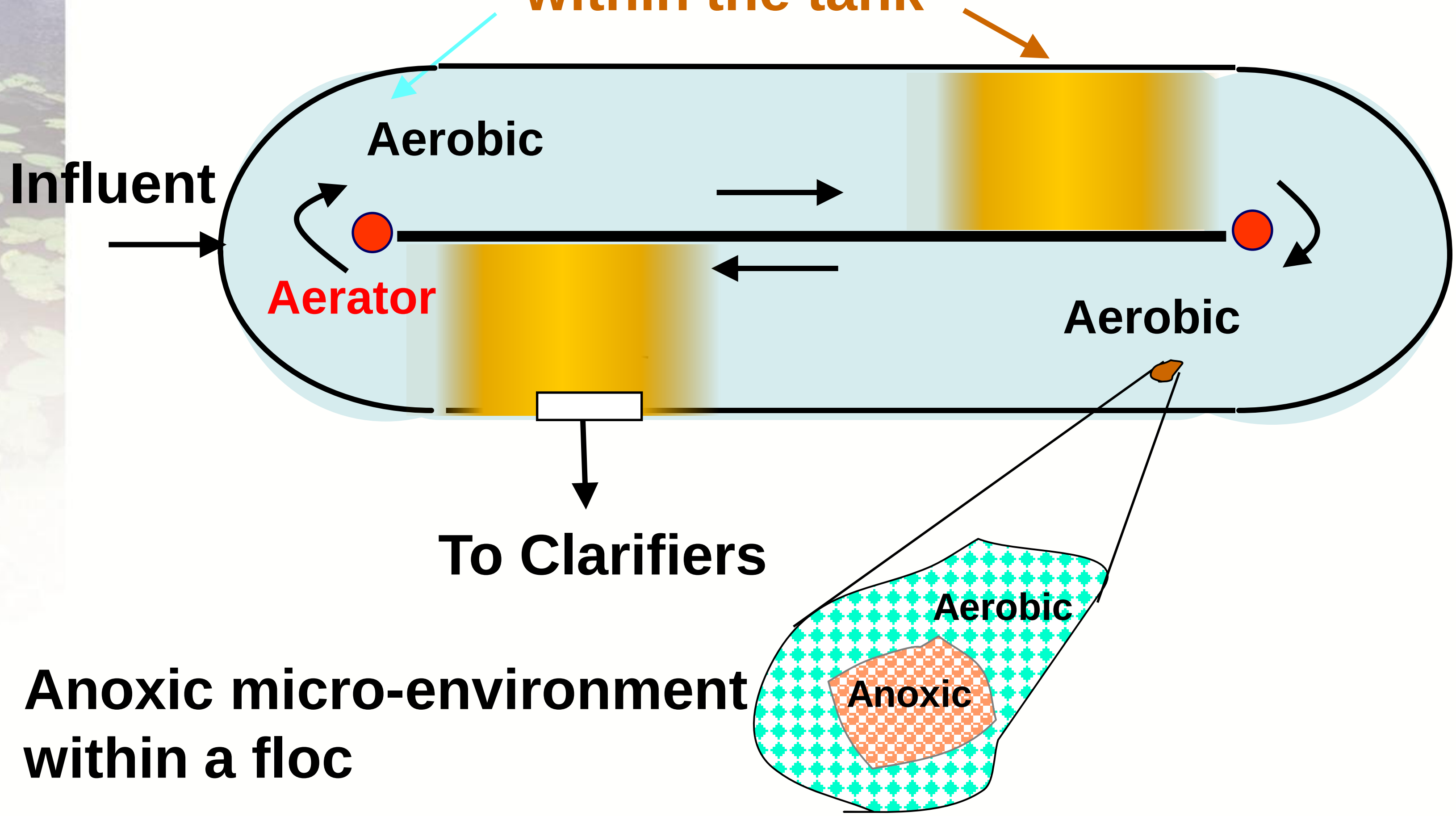


Denitrification Filter
TN = 3 mg/L



Informal Anoxic Zones Cause Simultaneous Nitrification/Denitrification

Anoxic macro-environment within the tank



Anoxic micro-environment within a floc

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Striking a Balance

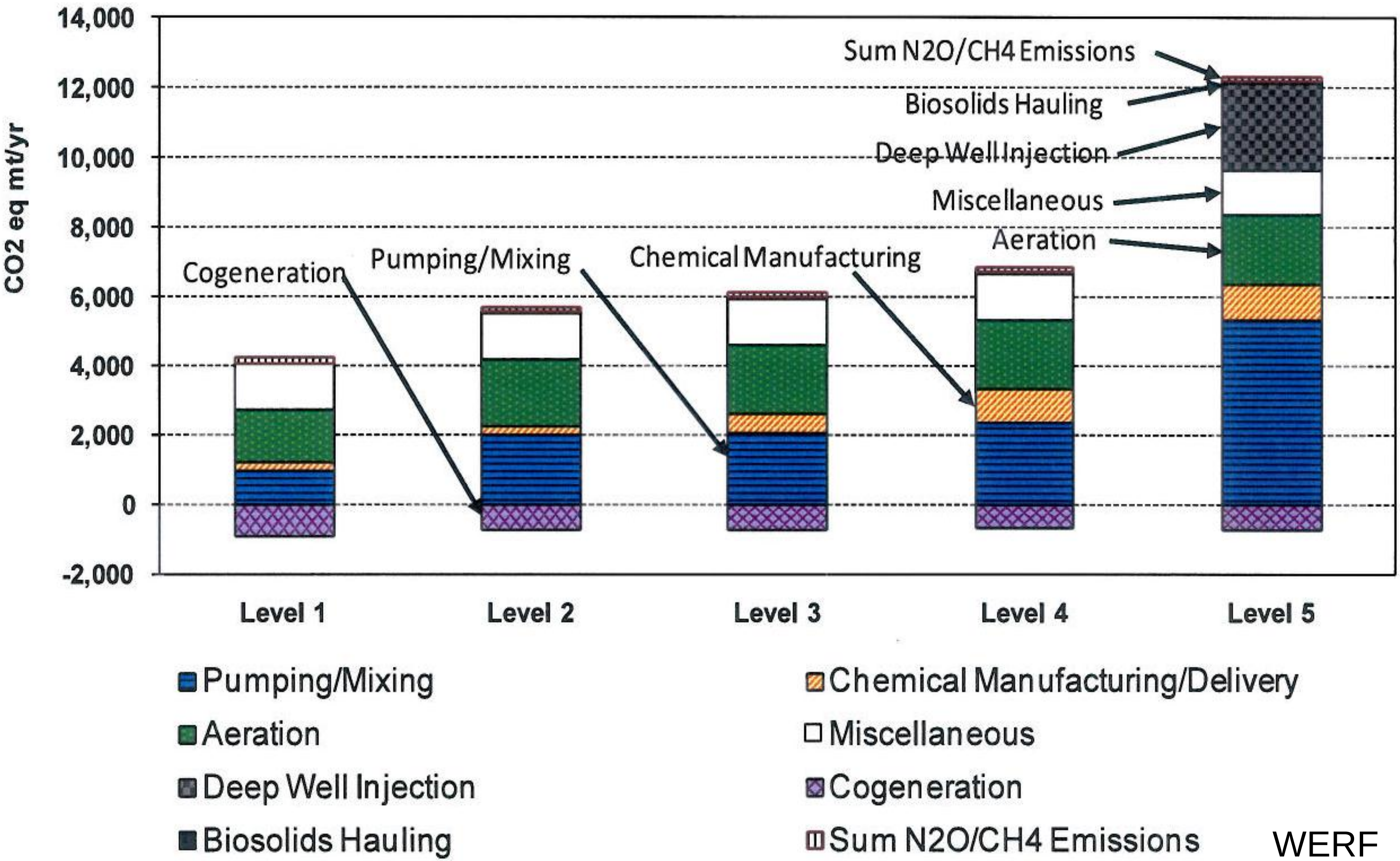
- Removing nutrients to very low levels:
  - ➢ Incur significant capital and O&M costs
  - ➢ Have larger carbon footprint
    - Increased use of chemicals & energy
    - Increased GHG emissions
  - ➢ Can result in lower ‘net’ environmental benefits - meaningless

Summary of WERF Sustainability Study

- 10 mgd plant with following effluent objectives

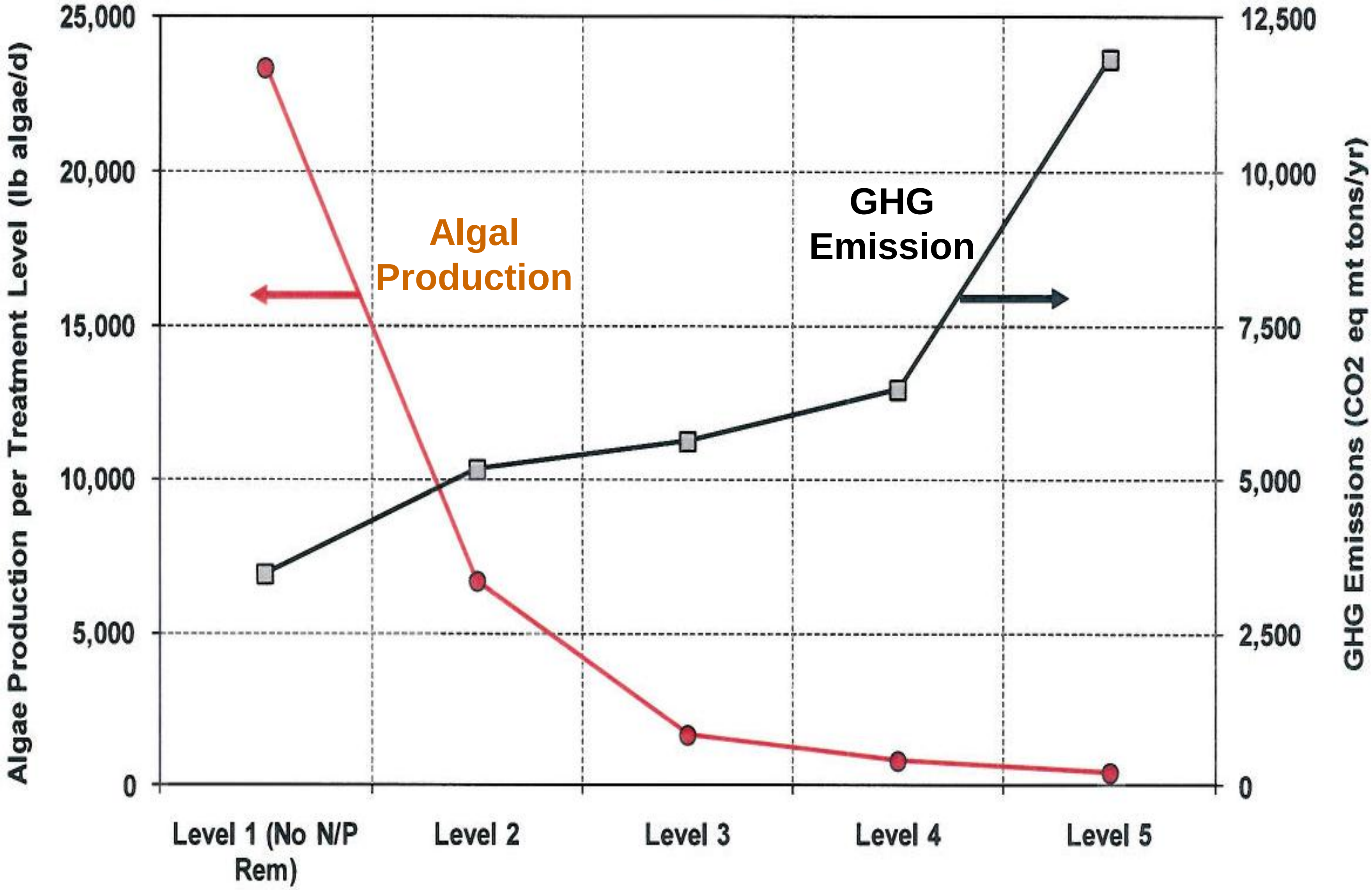
Level	BOD (mg/L)	TSS (mg/L)	TN (mg/L)	TP (mg/L)
1 (Secondary)	**30**	**30**	**-**	**-**
2	**-**	**-**	**8**	**1**
3	**-**	**-**	**4-8**	**0.1 – 0.3**
4	**-**	**-**	**3**	**0.1**
5	**-**	**-**	**<2**	**<0.05**

Total GHG Emission Burden



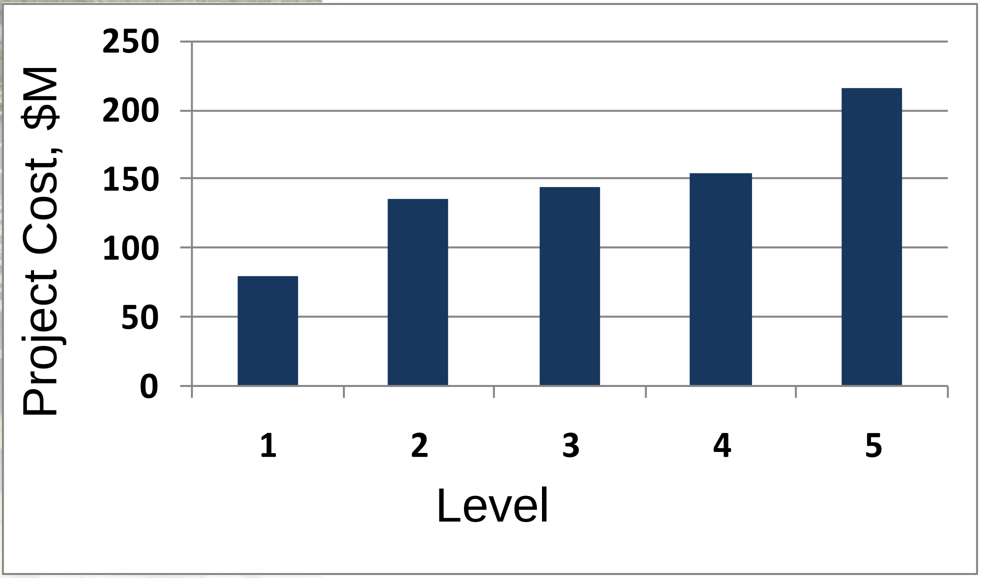
WERF

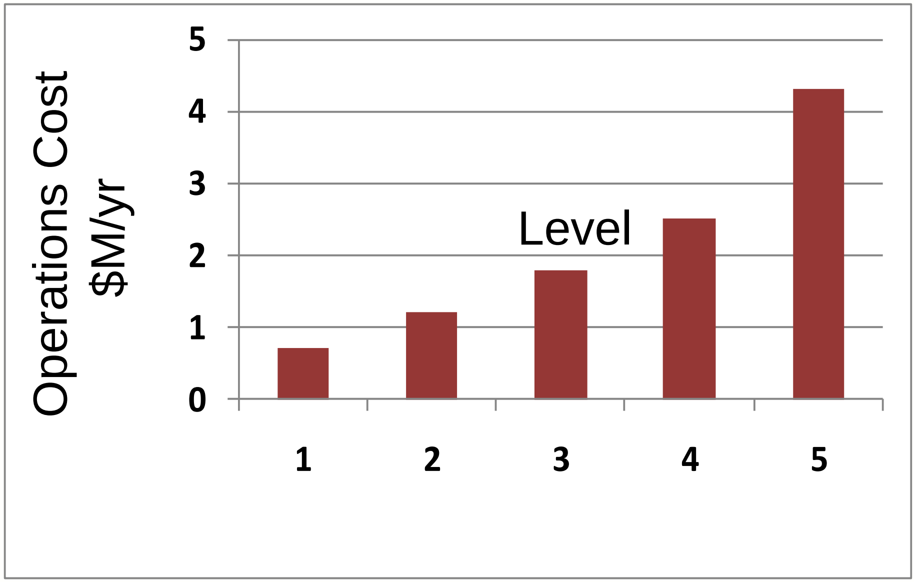
GHGs versus Algal Production



WERF

Capital & Operations Costs



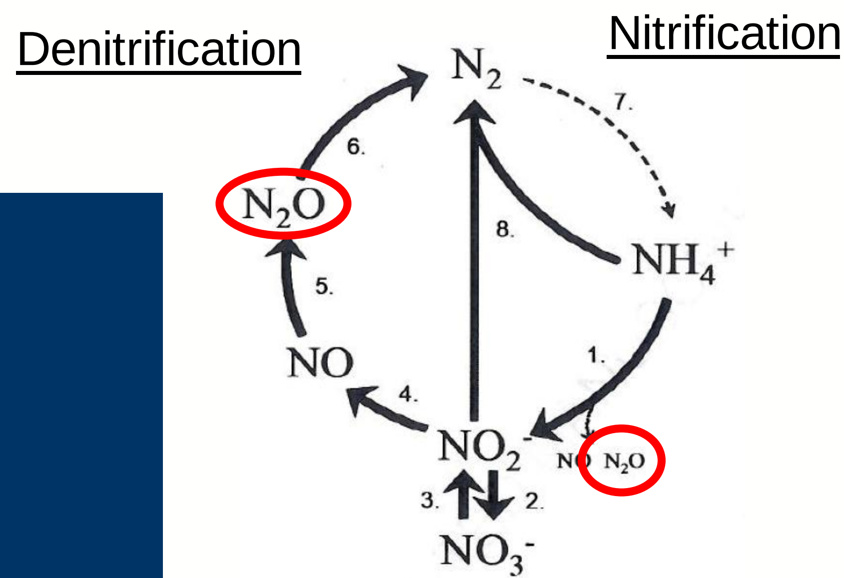


Excludes labor, maintenance, & membrane replacement costs

WERF

New Information on Nitrous Oxide Generation at WWTPs

- N_2O potentially produced during nitrification & always during denitrification.
- Potentially more during nitrification. Occurs due to:
  - Intermittent or incomplete nitrification
  - Repeated switching between aerobic & anoxic + high DO & NH_3-N
- But lower N_2O production in ox. ditches due to more uniform spatial DO profile



WERF

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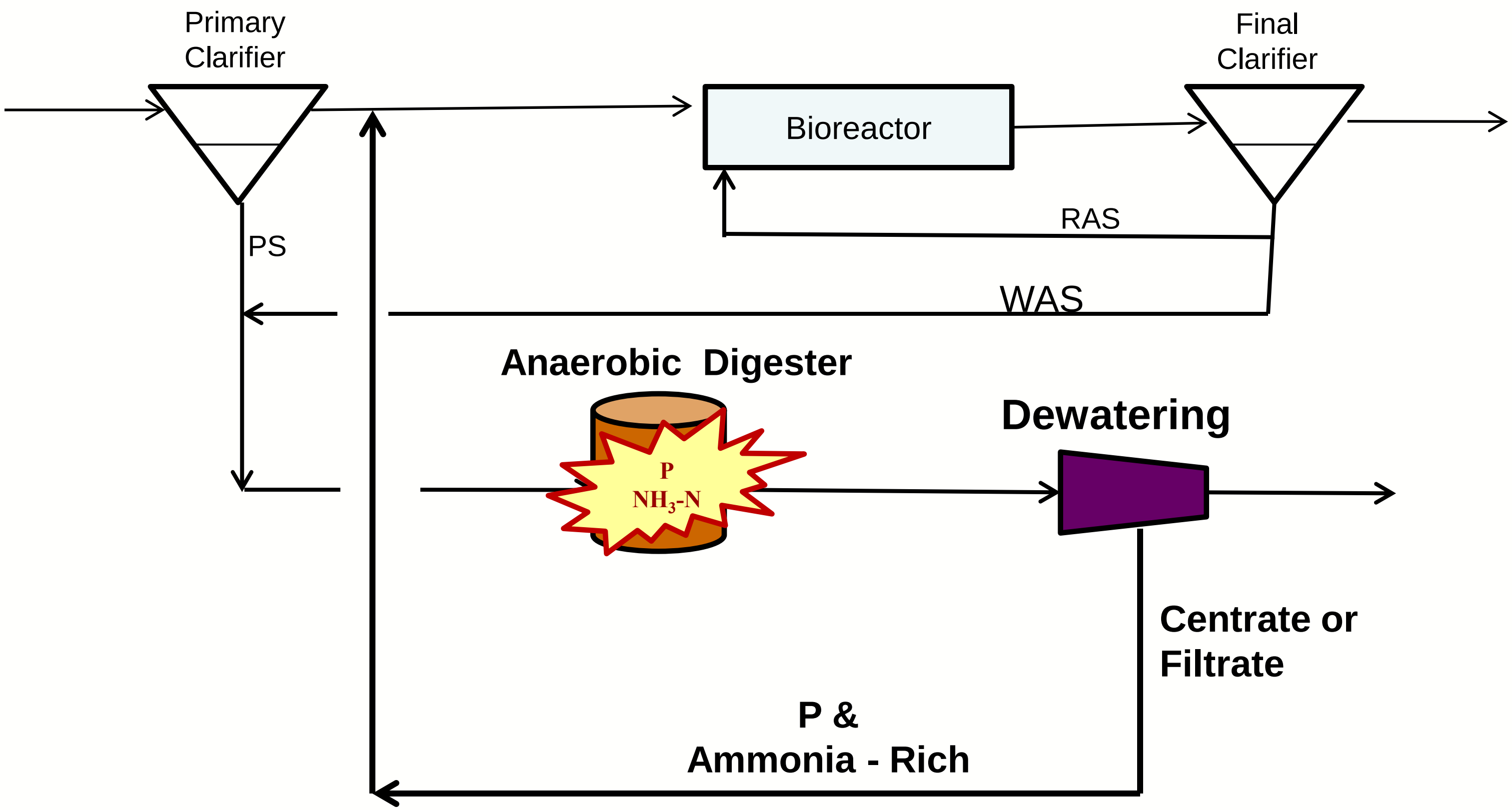
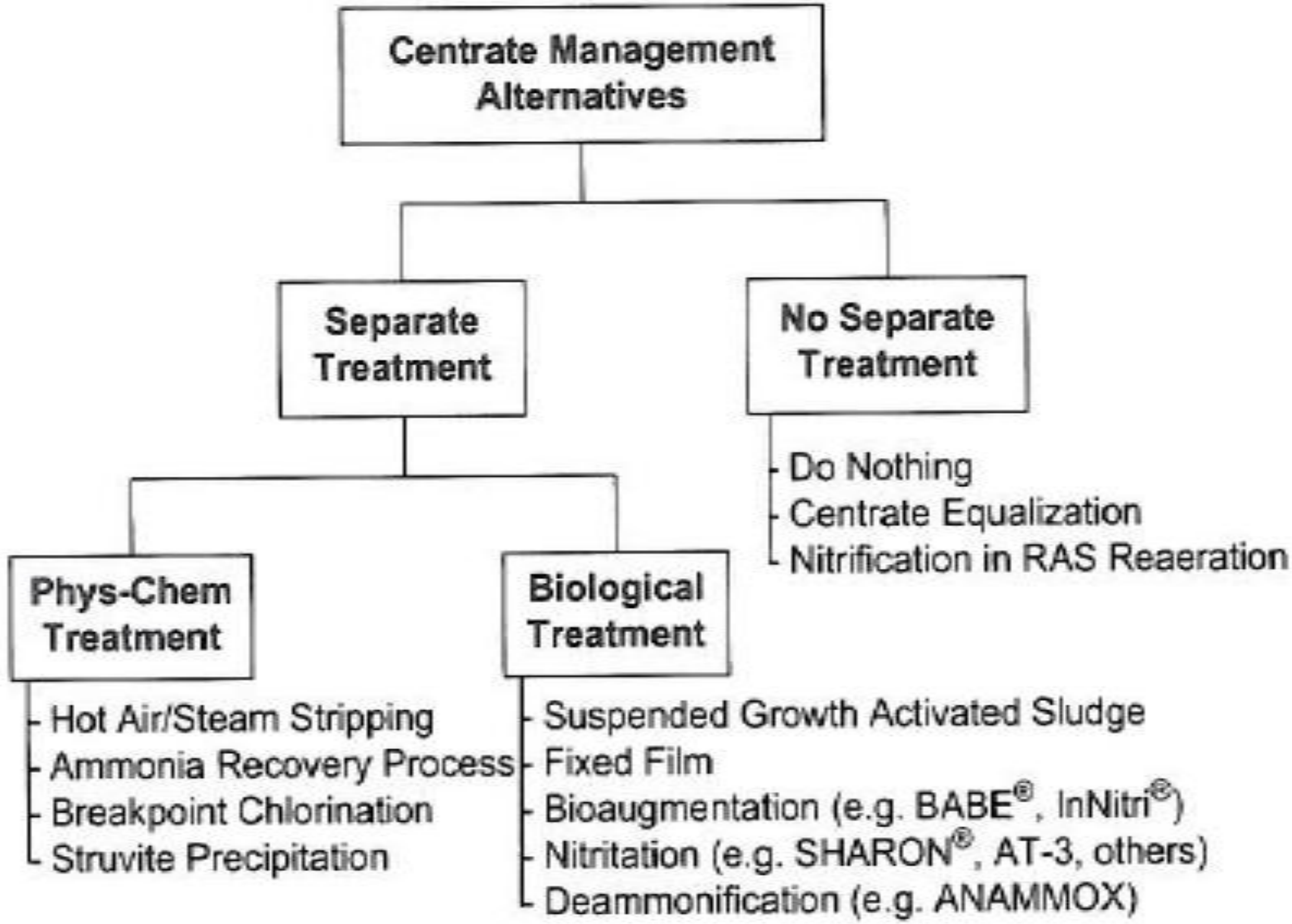
Recycle Management is Crucial for Meeting TP & TN Limits



- Anaerobic digestion releases P & ammonia.
- Dewatering centrate/filtrate can impose additional load on the main process

Sidestream Management Alternatives



The Dreaded Foam

Most Common Filaments in Wastewater Treatment in the US

Dominant Filament	Percentage of the Plants
Nocardioforms	31
Type 1701*	29
Type 021N *	19
Type 0041*	16
Thiotrix spp	12
S. natans	12
Microthrix parvicella *	10

525 samples from 270 plants

* Also commonly found in other countries

Jenkins et al & WERF

Factors Impacting Filamentous Growth

- Wastewater Characteristics
- Process Configuration (design)
- Operational Conditions

Wastewater Characteristics Associated with Some of the Common Filaments

Dominant Filament	rbCOD	sbCOD	Sulfide	Nutrient Deficiency
Nocardioforms	√	√		
Type 1701*	√			
Type 021N *	√		√	√ (N)
Type 0041*		√		
Thiotrix spp	√		√	√ (N)
S. natans	√			√ (P)
Microthrix parvicella *		√		

rbCOD – Rapidly Biodegradable COD (VFAs)
sbCOD – Slowly Biodegradable COD (LCVA)

Summary of Operational Conditions Associated with Some of the Common Filaments

Dominant Filament	Low DO	Long MCRT	Modest MCRT	Short MCRT
Nocardioforms		√	√	
Type 1701*	√		√	
Type 021N *		√	√	
Type 0041*		√		
Thiotrix spp			√	√
S. natans	√		√	√
Microthrix parvicella *	√	√		

WERF

More Design & Operational Considerations

- General design approach:
  - Influent characteristics
  - Effluent limits
  - The box in-between
  - SRT is paramount

- General process optimization approach:
  - First, nitrification & denitrification
  - Then, EBPR; add supplemental chemical, if required

- Judicious use of automation
- Data is not information

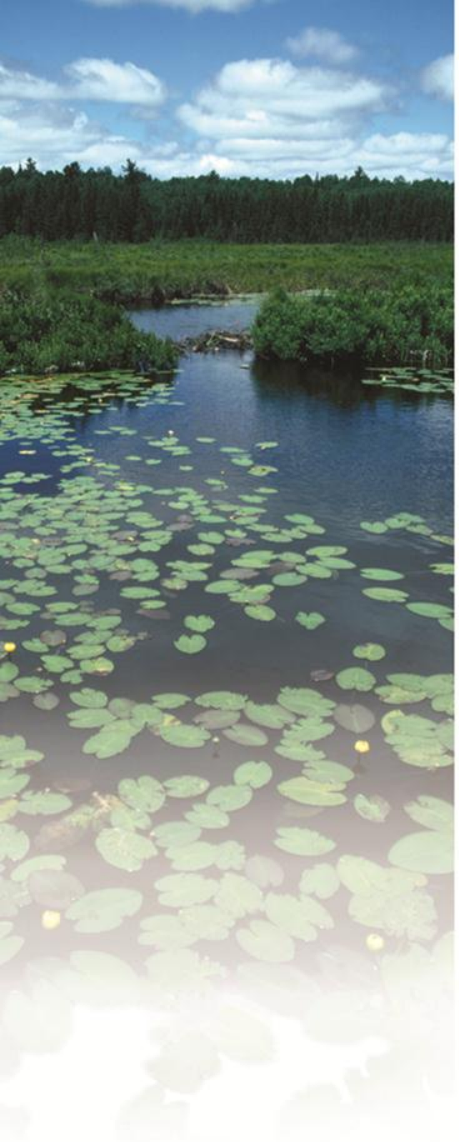
More Design & Operational Considerations

- Even flow splitting
  - Underloaded units often can not compensate for overloaded units
- Provision to control problem children of the activated sludge system - filaments
- Keep the bugs in the aeration basin- maintain low sludge blanket
- Maintain close as possible to SRT required for process reliability.
- It takes two to tango!
  - Designers: provide operational flexibility.
  - Operators: use operational flexibility provided.

Life with Nutrient Removal Requirements Will be more “Exciting”

- Little time left for crossword puzzles and/or web surfing!
- Dust your microbiology books
- Buy lunch for your lab tech: they will be running many more tests
- Provide tighter DO control for both N & P removal systems
- High flow conditions (RAS; IMLR) often result in higher DO; keep as low as possible
- DO & Nitrates are the enemy in BioP anaerobic zones
- Readily biodegradable carbon sources are your friend in unaerated zones
- Consider early retirement….


Questions?



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