Phosphorus Removal Technologies and Cost Information Presentation

Presentation By:
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Indiana Lake & Reservoir Nutrients External Workgroup Meeting
IDEM Shadeland Office
June 26, 2012
1:00 p.m.

Presentation Outline

- Introduction – Impacted Permittees & P Removal
- Current WWTP Phosphorus (P) Removal Practices
- Available Removal Technologies & Costs
  - No chemical P Removal or BNR, Level 1
  - 1 to >0.3 mg/l Effluent P, Level 2
  - 0.3 to >0.1 mg/l Effluent P, Level 3
  - 0.1 to >0.05 mg/l Effluent P, Level 4
  - 0.05 to 0.035 mg/l Effluent P, Level 5
- P Fractions, Fate, Removal Limitations & Bioavailability
- Sustainability Implications
- Policy/Rule Implications

Impacted Permittees

- 176 Point Source Contributors - 7 of which are Industrial Facilities
  - 90 of the 176 have NPDES permit limit(s) for P
  - 86 may receive permit limit(s)

Impacted Permittees

- A Look at the Numbers:
  - 83 of the 176 (47%) have discharges at less than 0.1 MGD
  - 66 of the 176 (38%) have discharges between 0.1 MGD and 1 MGD
  - 27 of the 176 (15%) have discharges greater than 1 MGD

Current P Removal Practices in Indiana

- Current NPDES Permit Limit(s) – 90 of the 176 Dischargers Upstream of a Lake or Reservoir
- Effluent Limit at ≤ 1 mg/L – Monthly Average (Monitoring 3 to 5X/Week) Sliding Scale for % Removal, dependant on Influent Concentration

In accordance with 327 IAC 5-10-2(b), the facility must produce an effluent containing no more than 1.0 mg/L total phosphorous (P) any month the average phosphorous level in the raw sewage is greater than 5 mg/L. Otherwise, a degree of reduction, as prescribed below, must be achieved. Such reduction is to be calculated based on monthly average raw and final concentrations.

Phosphorous (P) Level in Raw Sewage (mg/L)	Required Removal (%)
greater than or equal to 4	80%
less than 4, greater than or equal to 3	75%
less than 3, greater than or equal to 2	70%
less than 2, greater than or equal to 1	65%
less than 1	60%

Biological P Removal

- IDEM data indicates majority of WWTPs with P limit(s) employ some modification of the Activated Sludge Process

  (Note: WWTP description did not always identify specific treatment method for meeting P limit(s))

- There are a few facilities with Trickling Filters

- There are a few with Lagoons

Chemical Treatment for P Removal

- IDEM data indicates WWTPs with P Limits primarily use an iron salt as a coagulant
  - Ferric chloride most prevalent
  - Alum also used
- Data inconclusive to make an complete assessment

P Removal for Plants with Tertiary Filters

- **No Data Available!**

P Removal Data Summary

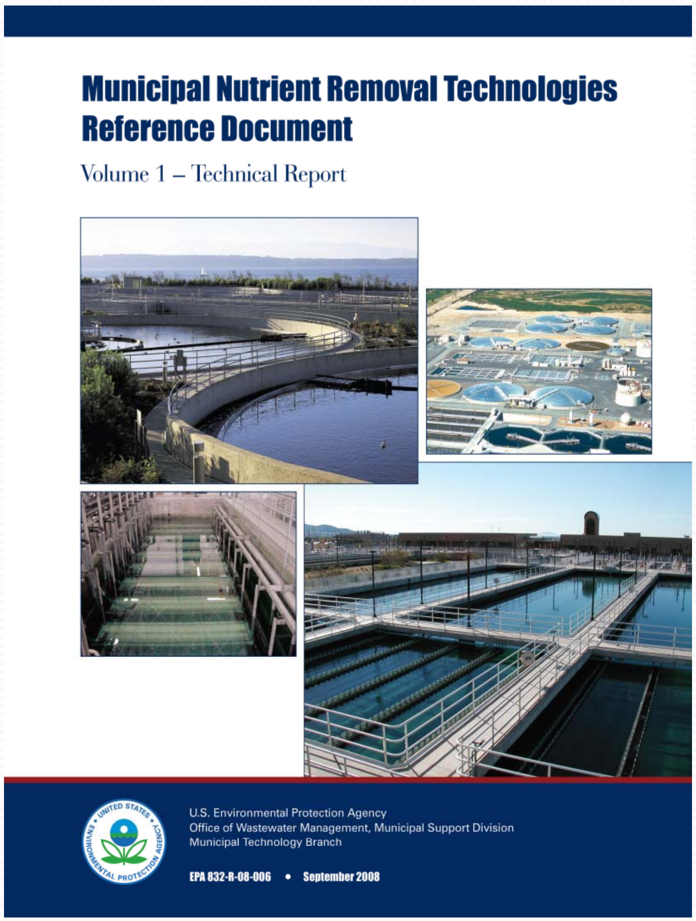
A Look at 32 Municipal WWTPs with P Limits:

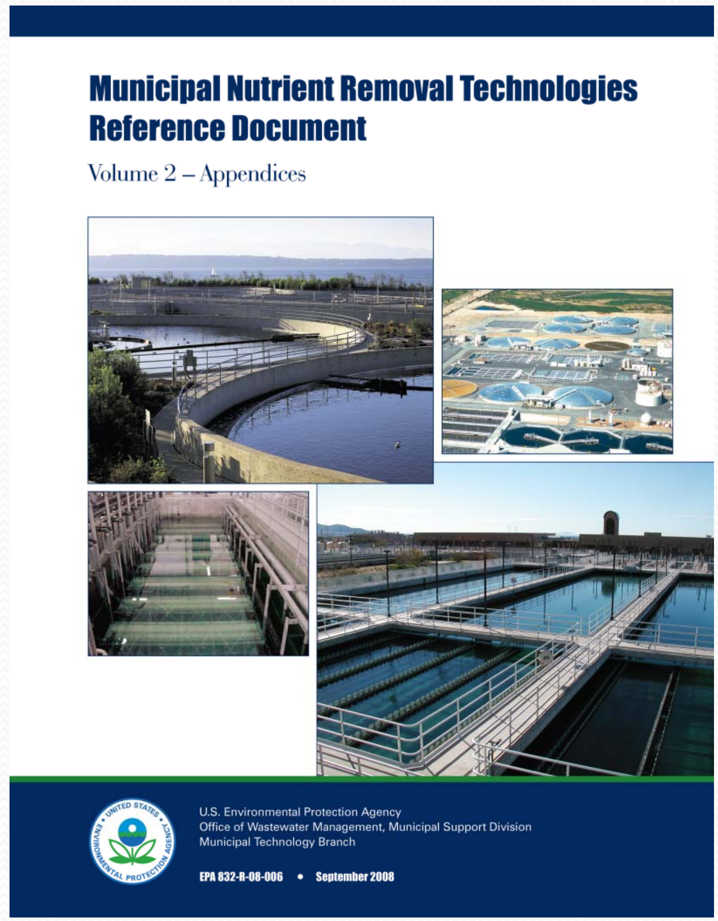
Average Daily Discharge of 32 WWTPs at <u>0.985 MGD</u>

- Flows ranged from 0.128 MGD to 9.167 MGD
- 20 WWTPs from 0.128 MGD to 0.99 MGD
- 12 WWTPs at greater than 1 MGD

- Average Monthly Average P Discharge at <u>0.67 mg/L</u>
  - P ranged from 0.17 mg/L to 4.45 mg/L
  - Total average P discharge from 32 WWTPs = 176 lb/day

EPA Reference Manual, 2008



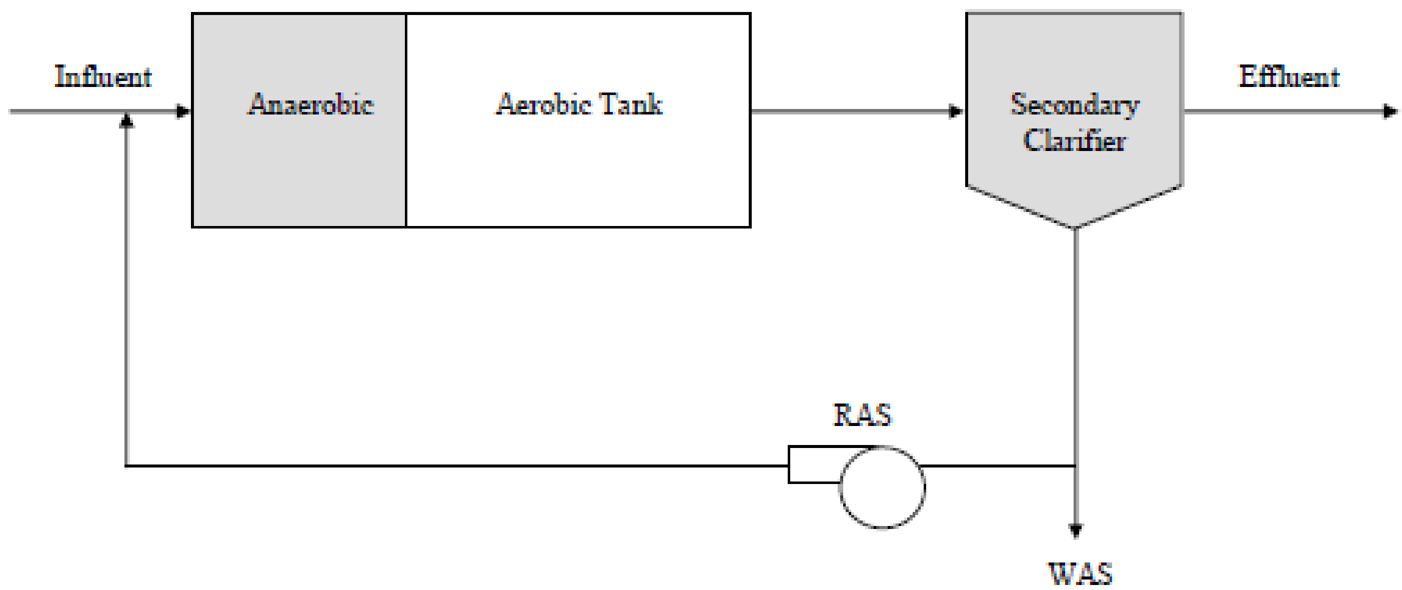


Available Technologies
1 to > 0.3 mg/l Effluent P – Level 2

Conventional Secondary Treatment, plus:

- Chemical Precipitation without Filtration
- Biological Nutrient Removal (BNR)
  - A/O (Anoxic/Oxic) process
  - VFA (Volatile Fatty Acid) addition

A/O Process



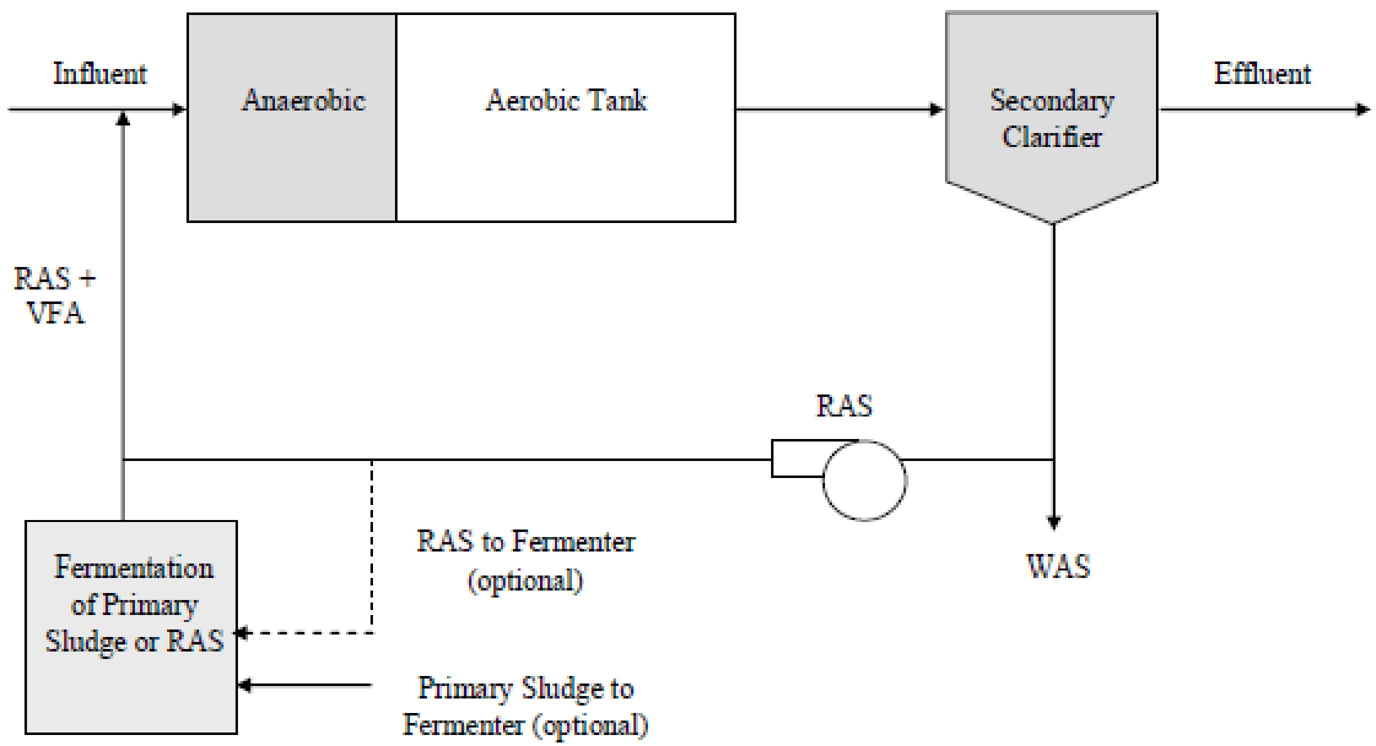
Influent
Anaerobic
Aerobic Tank
Secondary Clarifier
Effluent
RAS
WAS

Available Technologies:
0.3 to > 0.1 mg/l Effluent P – Level 3

Effluent from 1.0 to > 0.3 mg/l effluent P, plus:

- Enhanced BNR
  - Sludge fermentation
  - A^2O (Anaerobic/Anoxic/Oxic) Process
- Chemical processes: Alum or $FeCl_3$ addition
  - Increased usage – increasing P reduction from 75 % to 95% increases typical Al:P molar dosage from 1.4:1 to 2.3:1 (64% increase)
  - Multiple points of application
- Effluent filtration
- Tertiary clarifier

Process with Fermentation



A²O Process

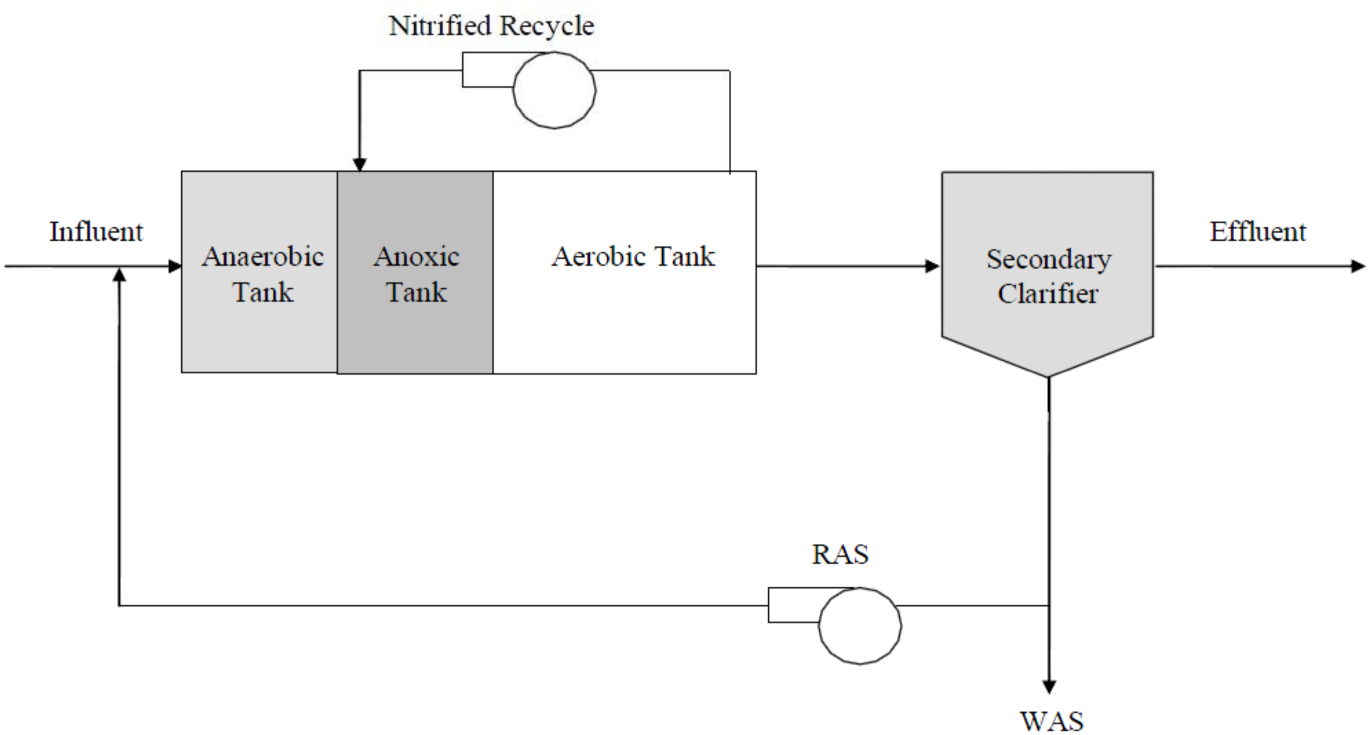
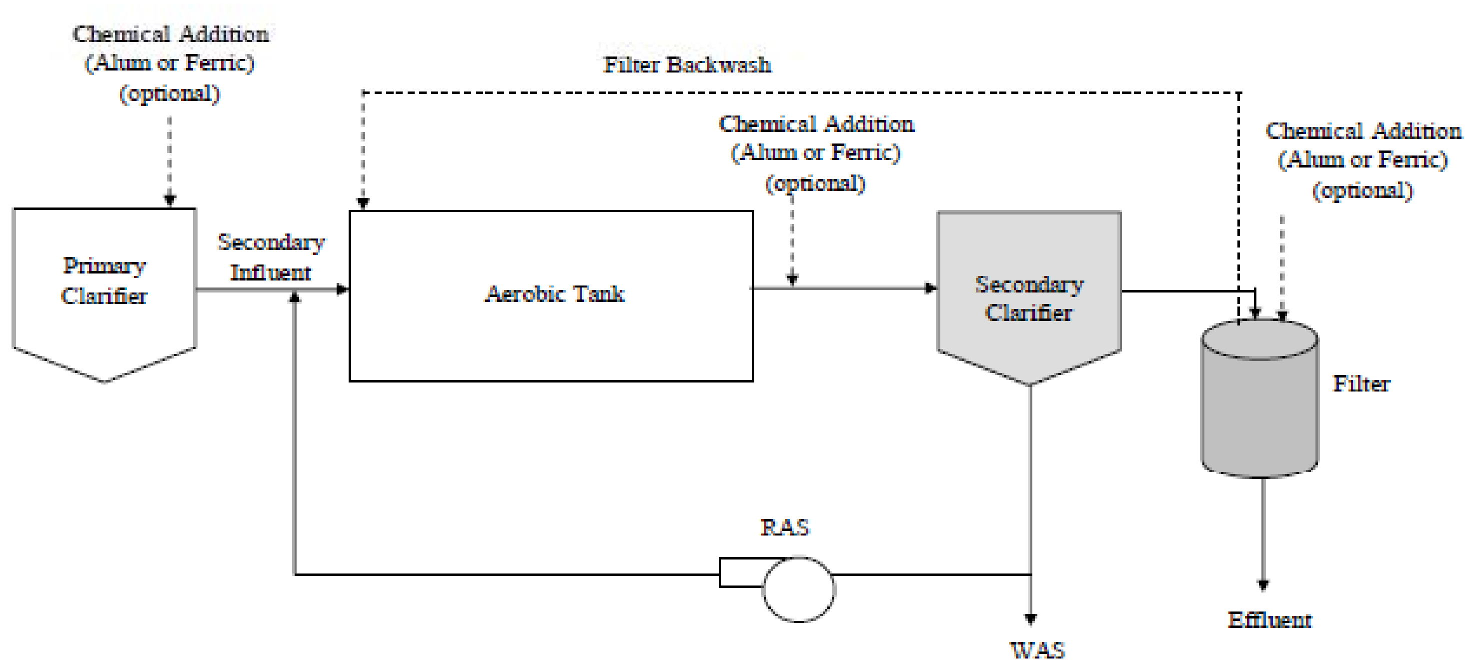


Figure 2-22. A^2O process.

Chemical/Filter Process



Available Technologies: 0.1 to > 0.05 mg/l Effluent P – Level 4

Secondary Effluent from 0.3 to > 0.1 mg/l effluent P, plus:

- Membrane (micro) filtration, or
- High-performance filters
  - Blue PRO®
  - CoMag®
  - DynaSand D2®
  - Trident™ Filters

Blue PRO® Advanced Filtration Process

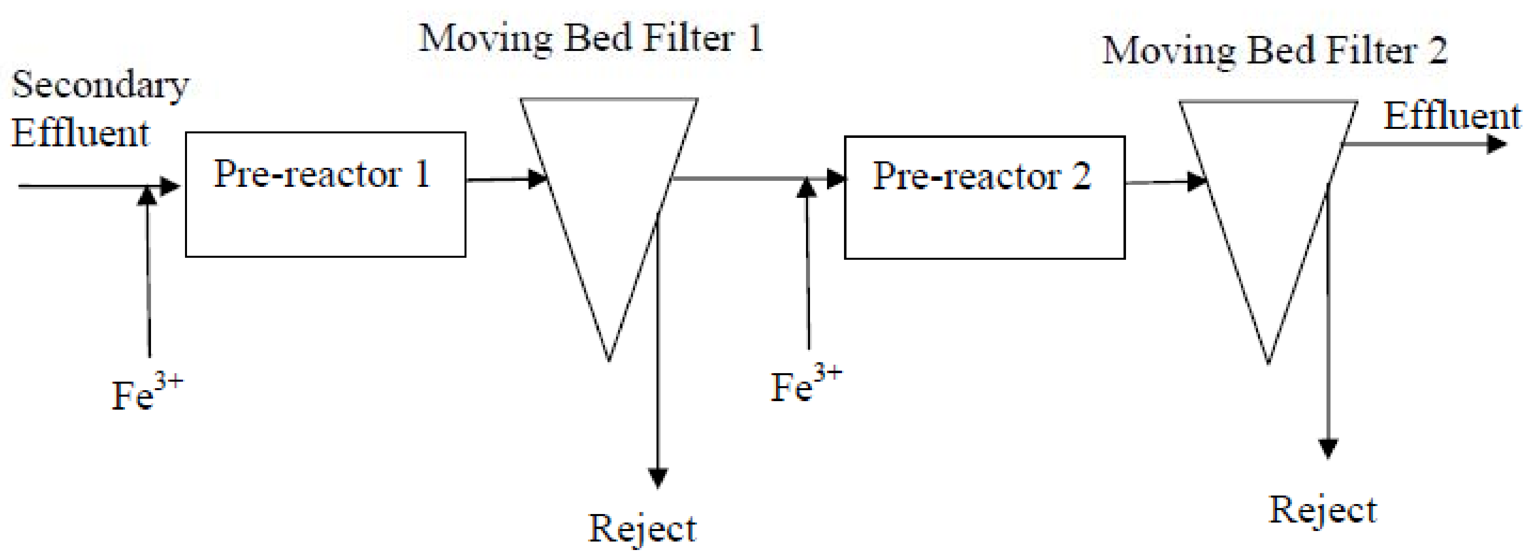


Figure 2-20. Blue-PRO process.

CoMag® Advanced Filtration Process

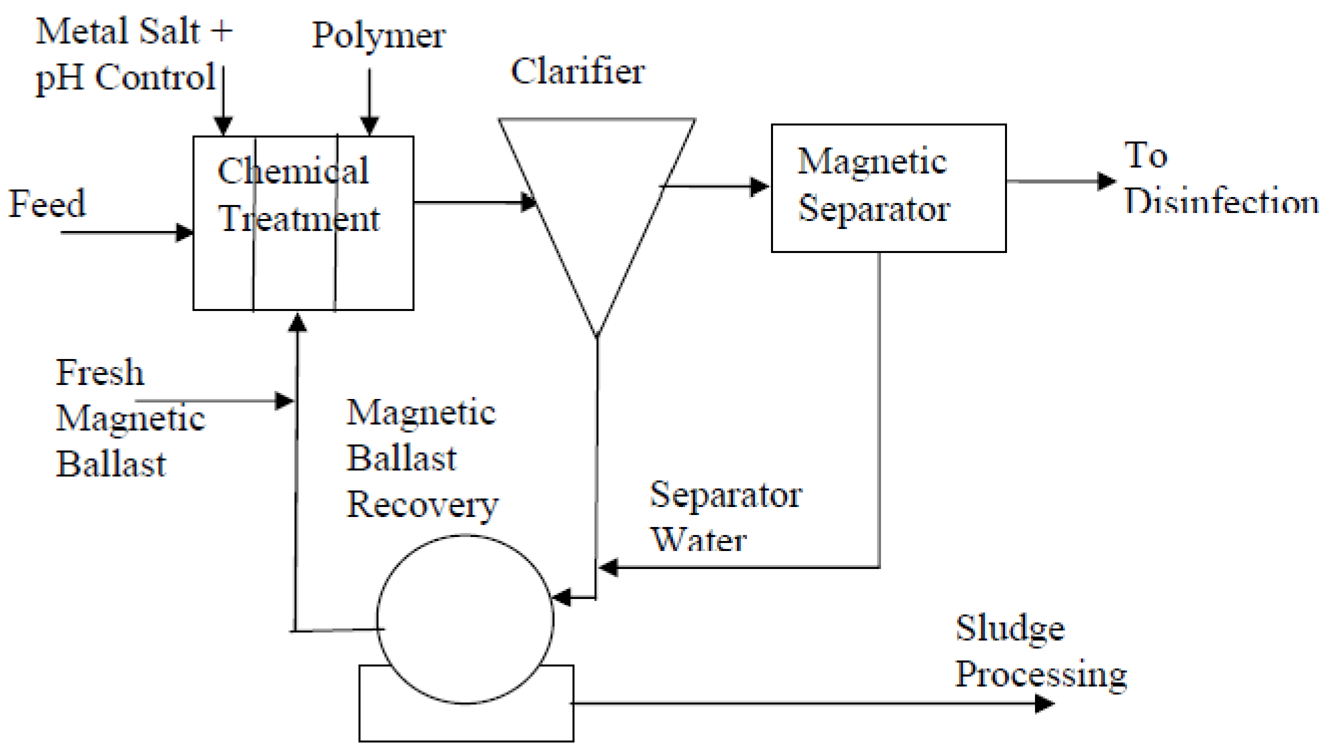


Figure 2-19. CoMag process.

Dynasand D2® Advanced Filtration

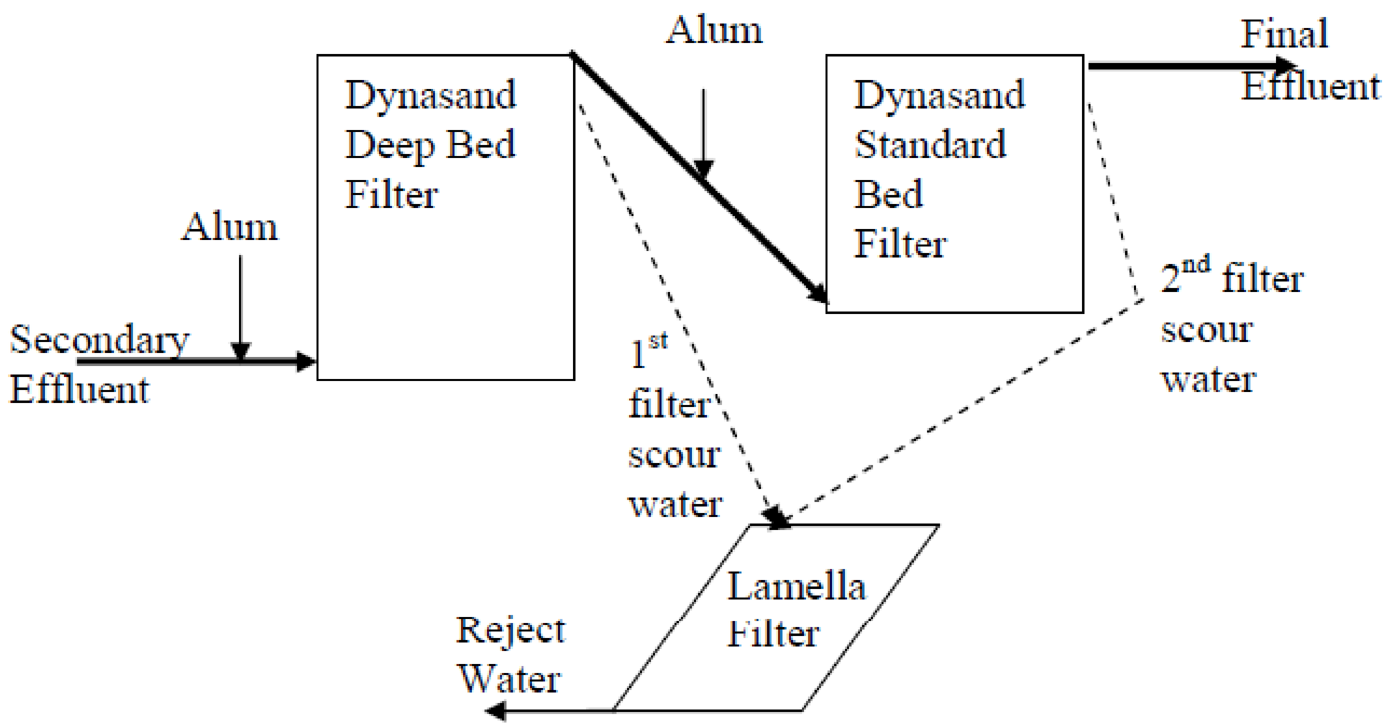


Figure 2-18. Parkson Dynasand D2 advanced filter system.

Trident™ HS Advanced Filtration Process

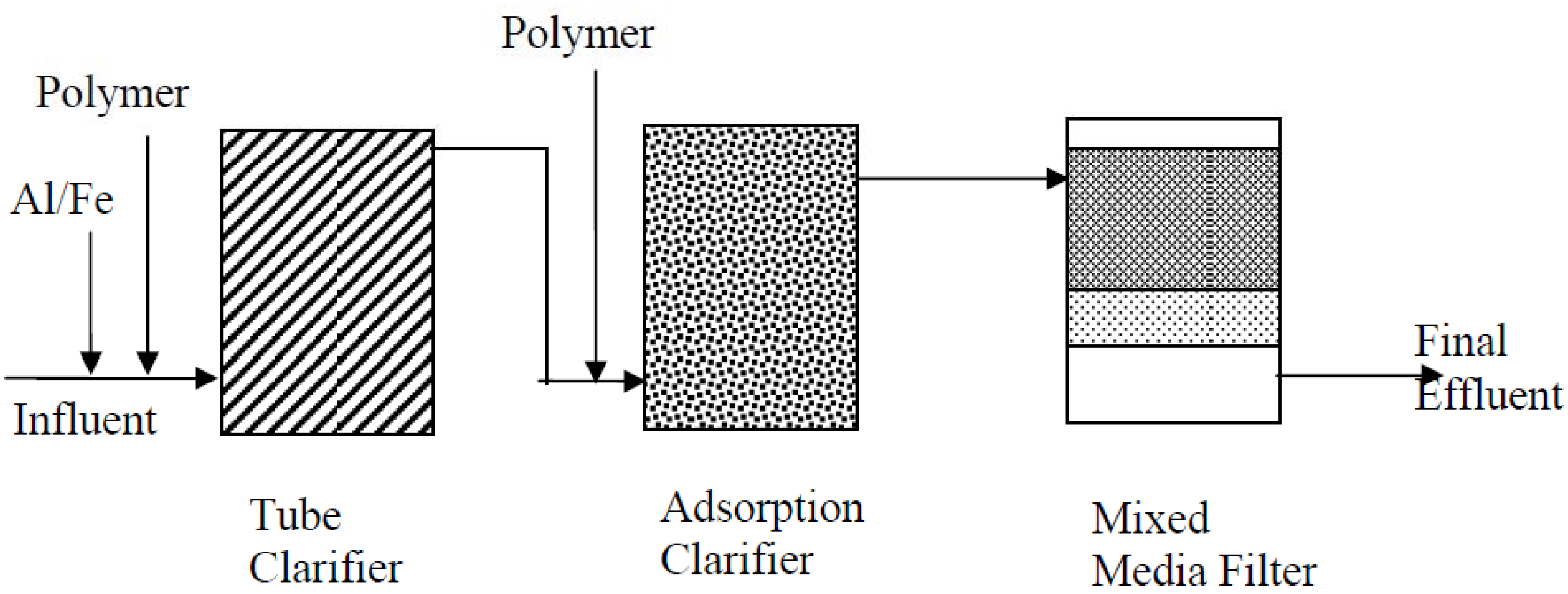


Figure 2-21. U.S. Filter Trident process.

Available Technologies:
less than 0.05 mg/l Effluent P – Level 5

Effluent from 0.1 to > 0.05 mg/l effluent P, plus:

- Reverse Osmosis (including microfiltration stage)
  - Approximate 20% reject water waste
- Ultrafiltration
- Soil infiltration (limited applicability)

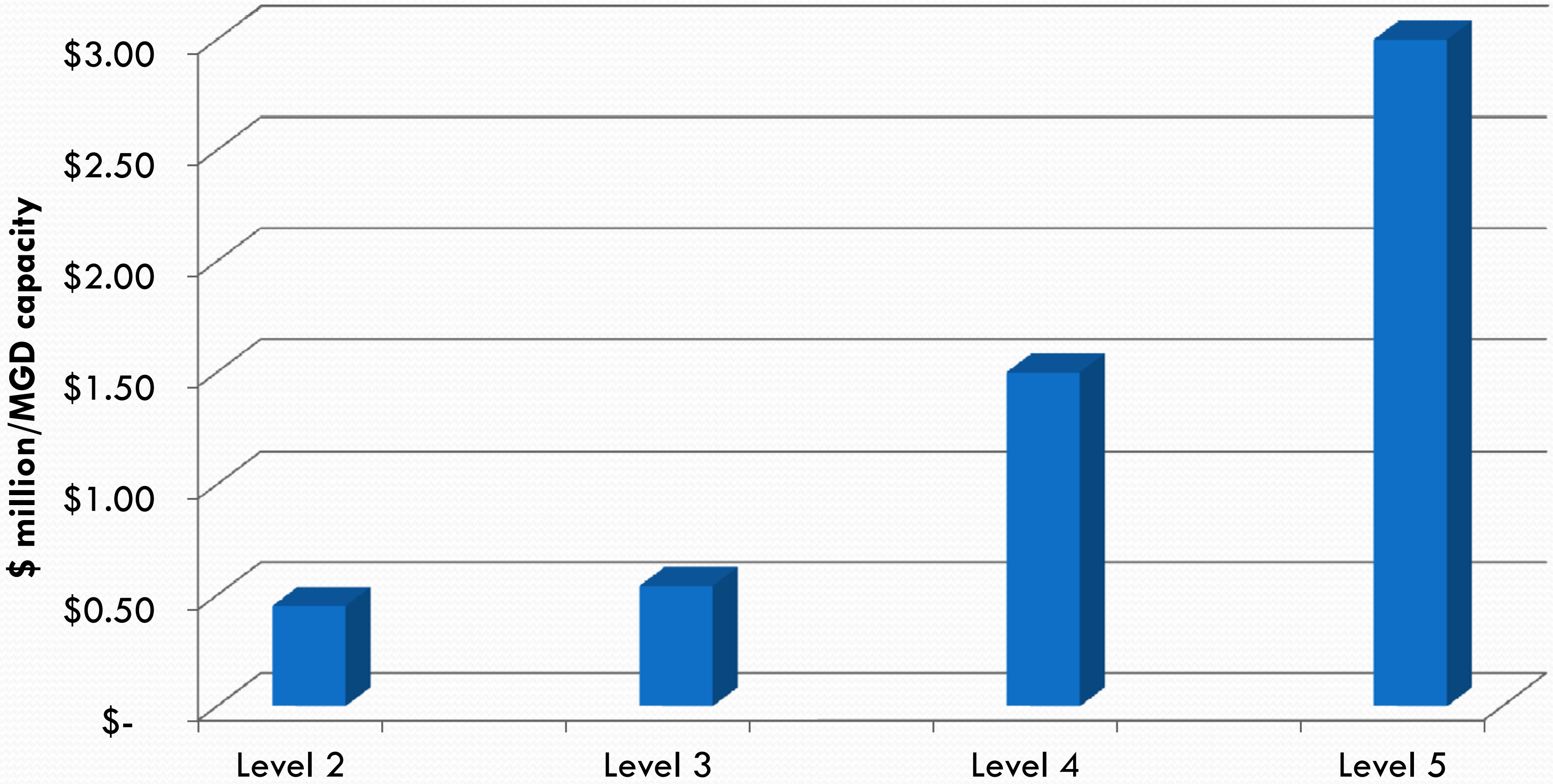
Reverse Osmosis System

Associated Costs

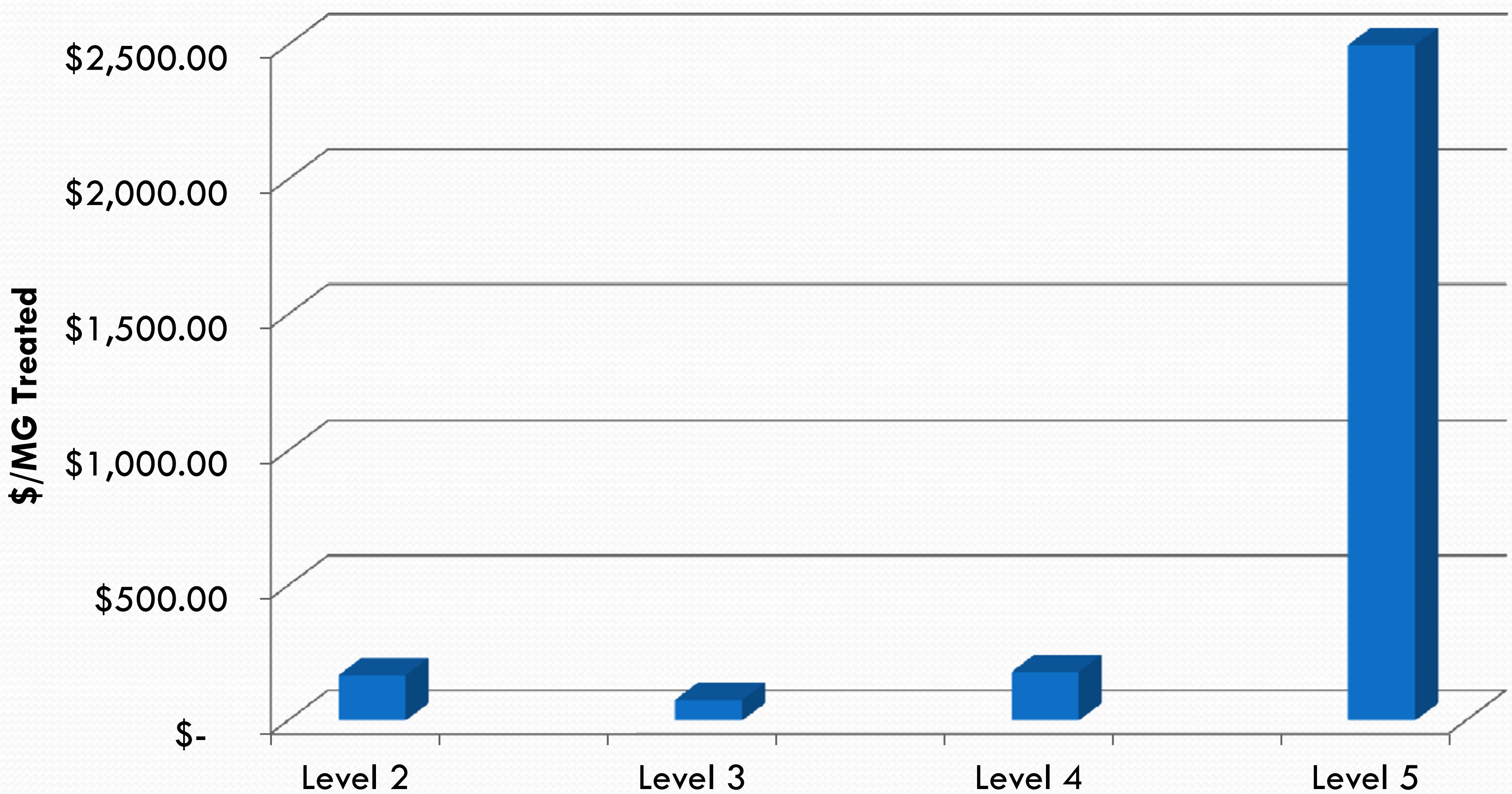
	Incremental O&M $/MG treated	Incremental Capital ENRCCI=9291 $ million/MGD capacity
Level 2 (1.0 - 0.3 mg/L P)		
Biological Nutrient Reduction	$ 215.00	$ 0.56
Chemical precipitation w/o filtration	$ 120.00	$ 0.34
Level 3 (0.3 - 0.1 mg/L P)		
Enhanced BNR	$ 25.00	$ 0.37
Advanced Chemical Processes	$ 120.00	$ 0.33
Effluent Filter	$ 30.00	$ 0.35
Tertiary Clarification	$ 130.00	$ 1.11
Level 4 (0.1 - 0.05 mg/L P)		
Membrane (Micro) Filtration	$ 190.00 [1]	$ 1.50 [1]
High-Performance Filter	$ 170.00 [1]	$ 1.50 [1]
Level 5 (0.05 - 0.035 mg/L P)		
Reverse Osmosis/Ultrafiltration	$ 2,500.00 [2]	$ 3.00 [1]

*All costs are taken from the EPA Reference Manual (2008) except as noted.
*Process costs for each level of control are in addition to the cost of achieving the prior level(s) of control.
*Capital costs have been extrapolated from ENRCCI=7940 (2007) to ENRCCI=9291 (2012).
*Except where noted, all values are based on a WWTP with a 1 MGD average annual design flow capacity
[1] Capital and O&M cost data provided by Siemens. Costs of proprietary systems vary.
[2] Falk, et. al, Striking a Balance Between Nutrient Removal and Sustainability, Nutrient Recovery and Management 2011. page 633 (assumes all flow treated through the RO/Ultrafiltration system)

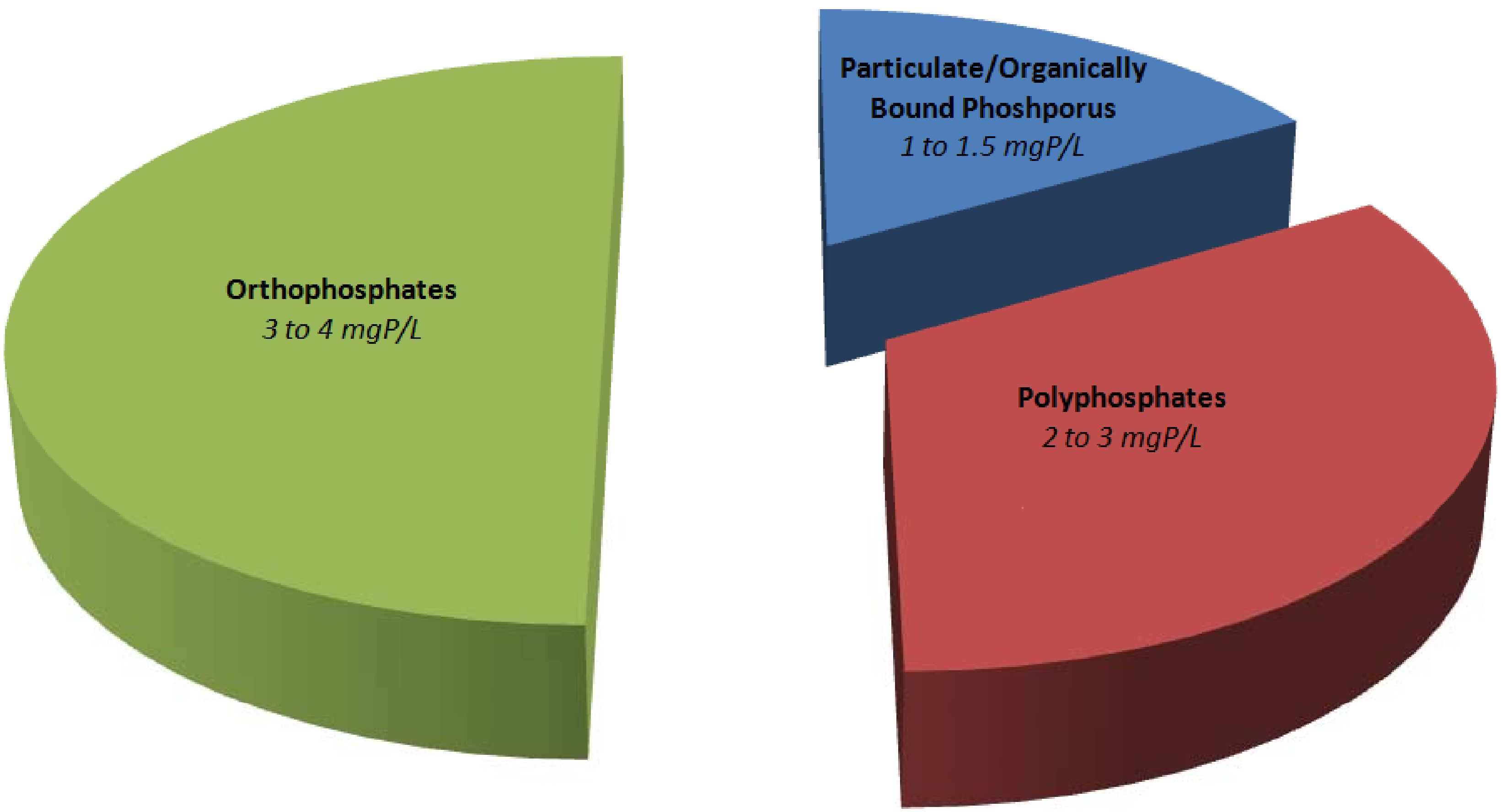
1 MGD Average Flow WWTP
(Incremental Capital Cost)



1 MGD Average Flow WWTP (Incremental Annual O&M Cost)



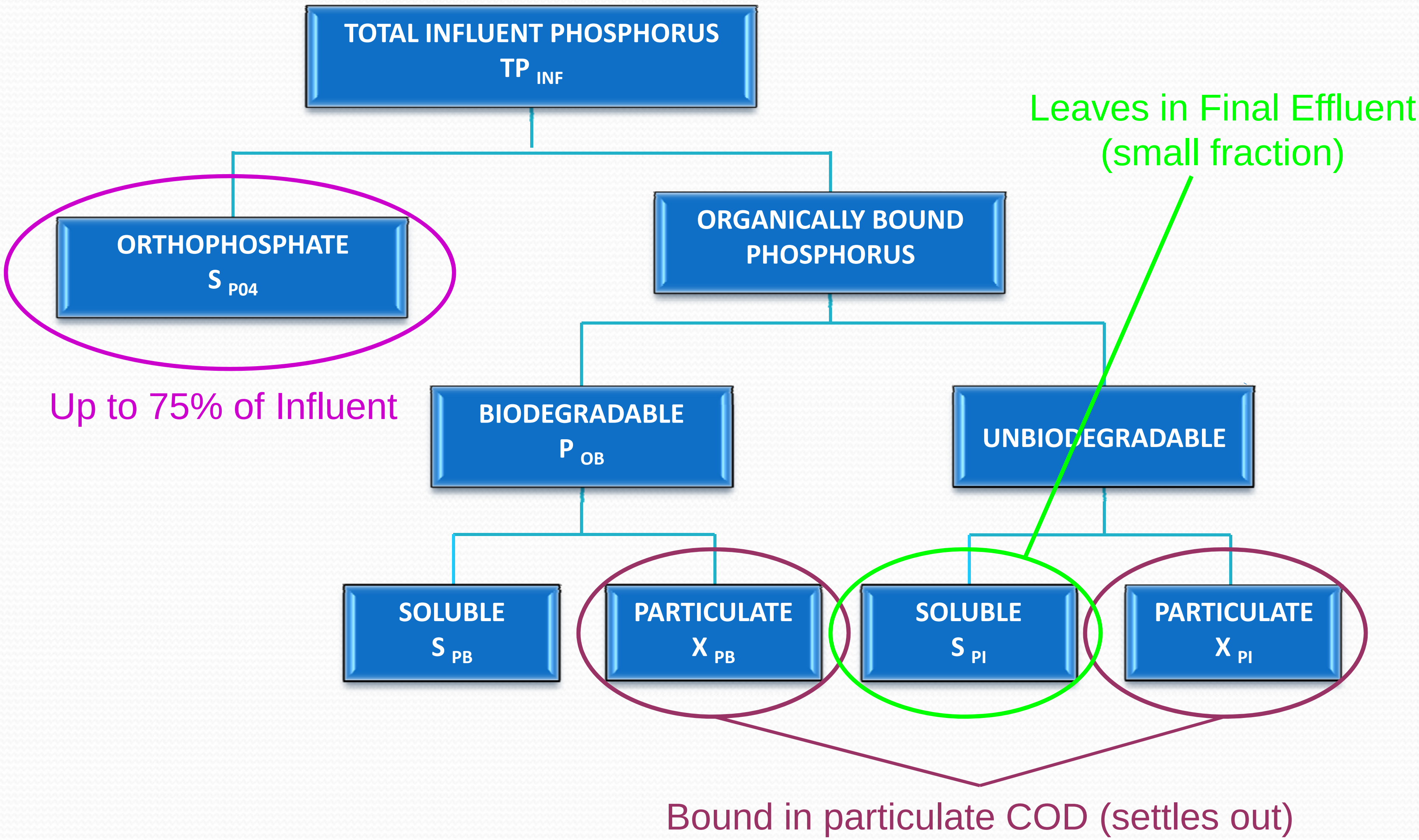
Phosphorus Fractions in Wastewater



Phosphorus Fractions in Wastewater

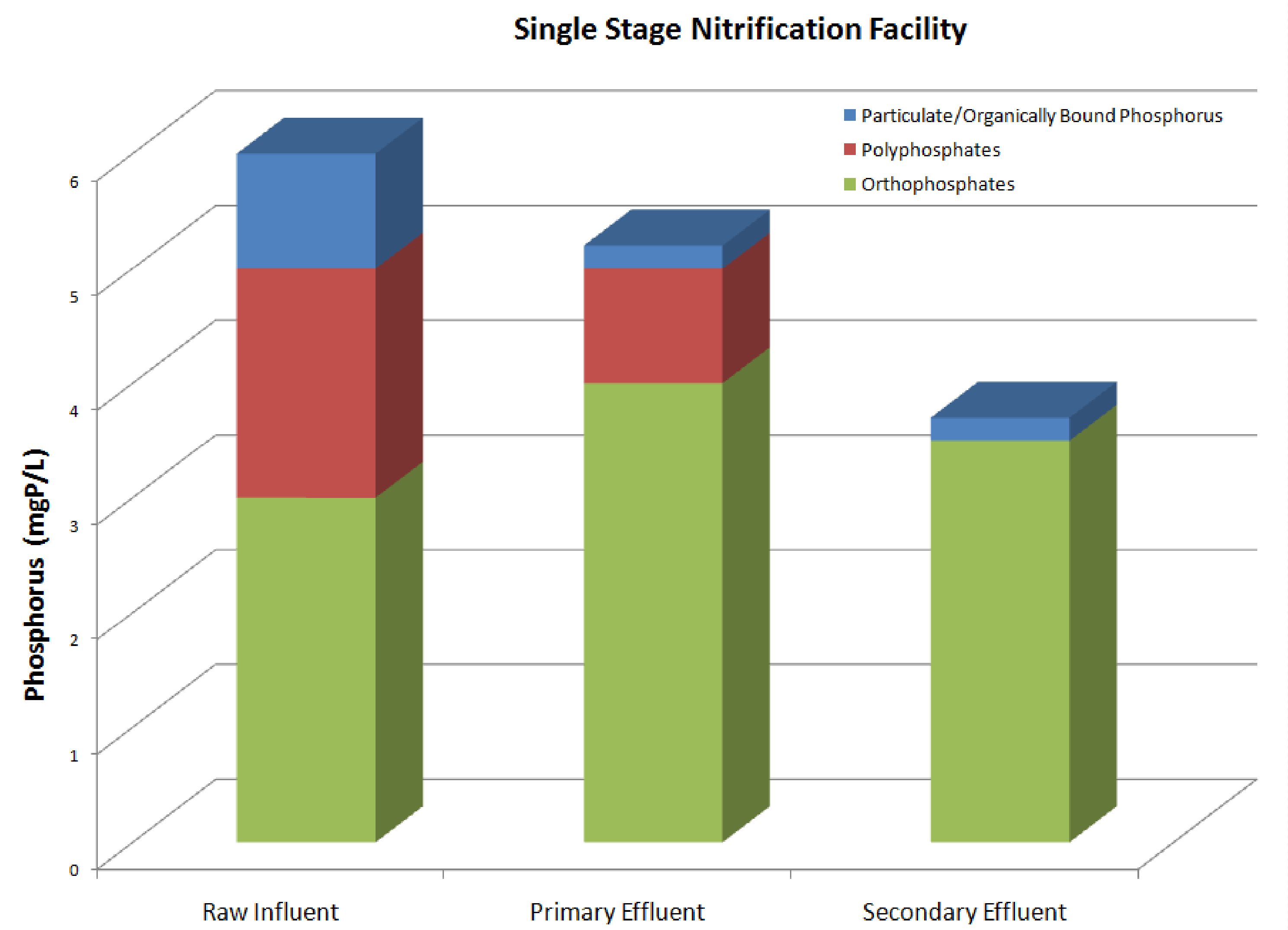
- Orthophosphates
  - available for biological processes
  - "Normal" biomass synthesis
  - Enhanced biological phosphorus removal (EBPR) in phosphate accumulating organisms (PAOs)
  - *This is also the fraction that is removed during chemical precipitation*
- Polyphosphates
  - Converted to orthophosphates during hydrolysis processes
- Particulate and Organically Bound Phosphorus
  - Bound to COD
  - Particulate settles in primary or secondary clarifiers

Phosphorus Fractions in Wastewater

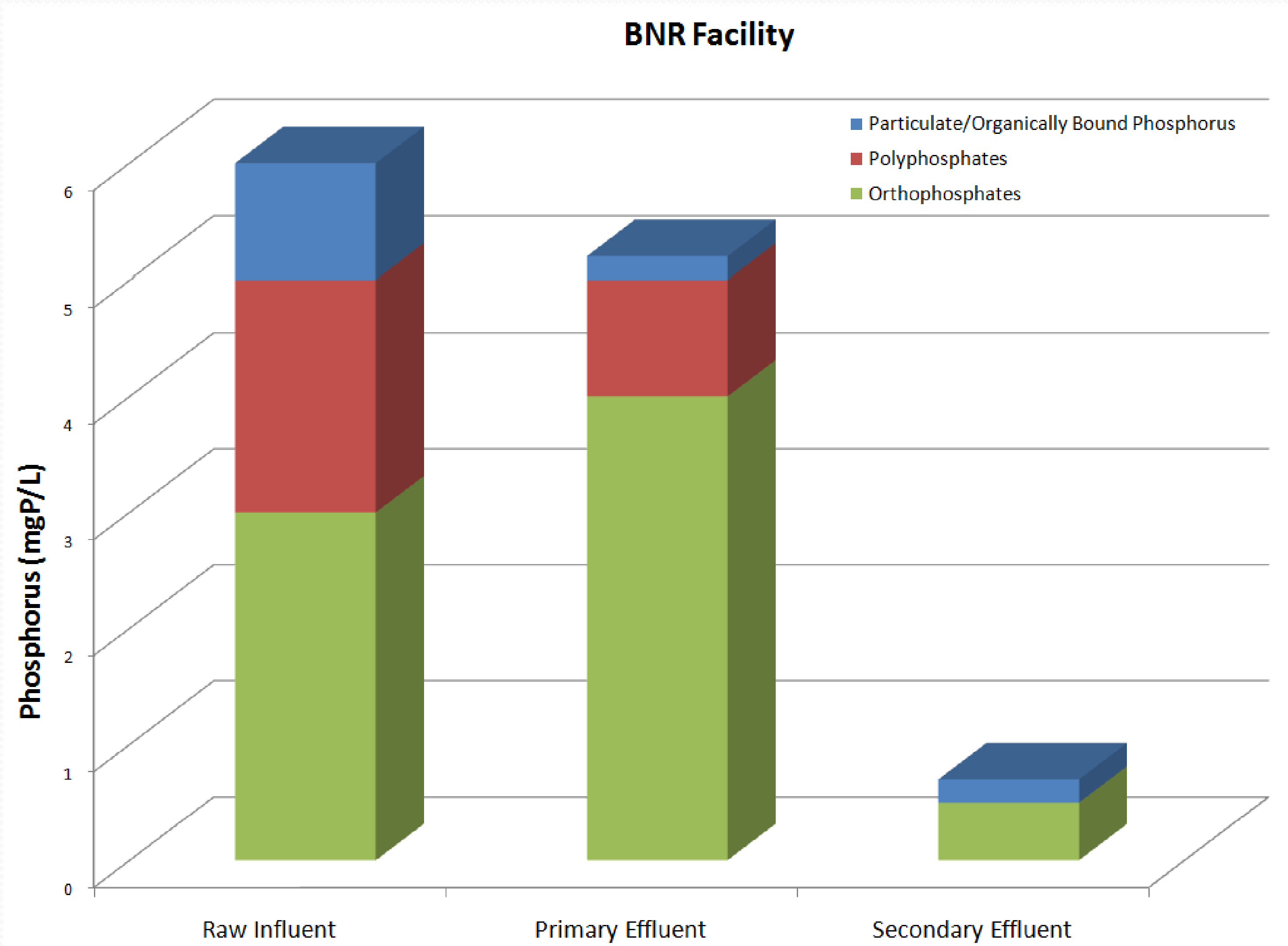


*Source: WERF Report No. 99-WWF-3:*Methods for Wastewater Characterization in Activated Sludge Modeling*

Phosphorus Fate w/o P Removal Process



Phosphorus Fate with P Removal Process



P Removal Limitations

- Soluble inert (non-reactive) P (S_{PI}) is normally on a minor component of P in wastewater, but
- S_{PI} can be dominant component in tertiary effluents (≤ 0.1 mg/l or level 4 removal), has been reported to be:
  - **0.02 mg/l** in 2011 IAWA Report "Evaluation of Practical Technology-Based Effluent Standards for P and N in Illinois"
  - **0.01 to 0.07 mg/l** in 2009 WEFTEC paper "Fractionation and Treatability Assessment of P in Wastewater Effluents – Implications on Meeting Stringent Limits"
  - **0.04 to 0.07 mg/l** in 2007 final thesis report "Pilot-Scale Investigation to Achieve Very Low N and P Effluents by Retrofitting a UCT Process" by Dae Wook Kang and Daniel R. Noguera to Madison Metropolitan Sewerage District

Bioavailable P

- Availability to support algae growth
  - Particulate P found to be nearly entirely unavailable
    - Needs to be converted to dissolved forms
  - Soluble reactive P (S_{PO4}) is considered to be immediately available
  - Soluble organic biodegradable P (S_{PB}) is available over longer time scale through enzymatic and mineralization processes
  - Soluble non-reactive P (S_{PI}) is generally perceived to not be readily available

Steve W. Effler, Martin T. Auer, Feng Peng, MaryGail Perkins, Susan M. O'Donnell, Anthony R. Prestigiacomo, David A. Matthews, Phillip A. DePetro, Renn S. Lambert, and Natalie M. Minott; Factors Diminishing the Effectiveness of P Loading from Municipal Effluent: Critical Information for TMDL Analyses of P; (March, 2011) *Water Environment Research*, p 254-264.

Sustainability Implications

- Sustainability Analysis
- GHG Production per P Treatment Level
- Point of Diminishing Returns for P Removal
- N Versus P Incremental GHG Comparison
- Ancillary Implications
- Sustainability Conclusions

Sustainability Implications

Green House Gas Emissions per P Treatment Level

Sustainability Analysis Includes:

- GHG emissions (aeration, polymer, mixing, external C sources, metal salts, and polymer)
- Water quality surrogate that reflects potential algal growth (7.2 lbs of N and 1.0 lbs P = 100 lbs of algae),
- Capital and operational costs,
- Energy demand (hp, kBTU/sf/yr), and
- Consumables (e.g. such as chemicals, gas, diesel, etc.)

Falk, Michael W., Reardon, David J., Neethling, JB., & Pramanick, Amit. (2011) Wastewater Treatment Nutrient Removal and Energy/GHG. *Water Environment Federation – Energy and Water*, 920-940.

Sustainability Implications

Green House Gas Emissions per P & N Treatment Level

- Level 1 – 30 mg/l BOD_5 and 30 mg/l TSS = 4,260 CO_2 eq mt tons/yr*
- Level 2 – 8 mg/l N and ≤1 mg/l P = 5,600 CO_2 eq mt tons/yr*
- Level 3 – 4-8 mg/l N and 0.3-0.1 mg/l P = 6,600 CO_2 eq mt tons/yr*
- Level 4 – 3 mg/l N and ≤0.1 mg/l P = 7,580 CO_2 eq mt tons/yr*
- Level 5 – < 2 mg/l N and <0.02 mg/l P = 12,950 CO_2 eq mt tons/yr*

*Estimation based on evaluation of 5 different hypothetical treatment trains at a nominal 10 mgd flow rate

Falk, Michael W., Reardon, David J., Neethling, JB., & Pramanick, Amit. (2011) Wastewater Treatment Nutrient Removal and Energy/GHG. *Water Environment Federation – Energy and Water*, 920-940.

Sustainability Implications

Green House Gas Emissions per P Treatment Level – continued

- Knee of the Curve – Diminishing Returns

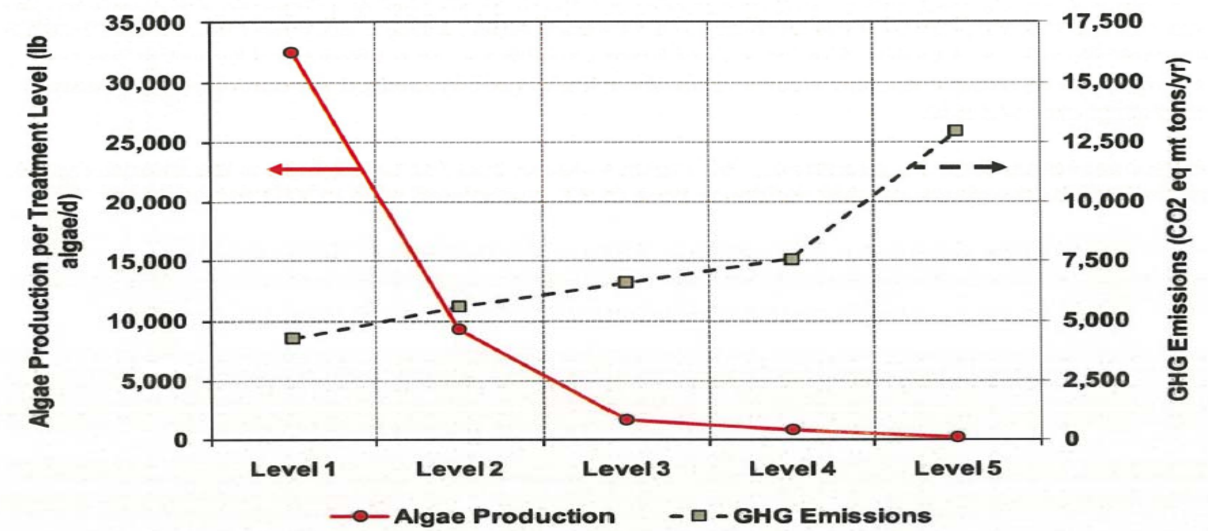


Figure 10 – GHG Emissions and Algae Production per Treatment Level

Falk, Michael W., Reardon, David J., Neethling, JB., & Pramanick, Amit. (2011) Wastewater Treatment Nutrient Removal and Energy/GHG. *Water Environment Federation – Energy and Water*, 920-940.

Sustainability Implications

Green House Gas Emissions per P Treatment Level – continued

- N Versus P Incremental GHG Comparison

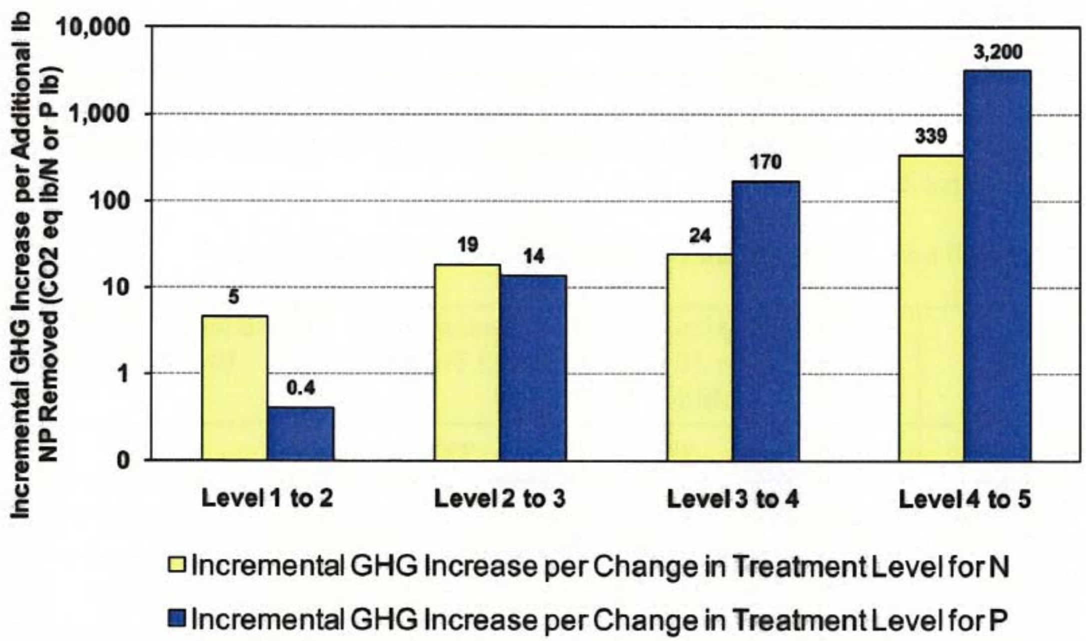


Figure 8 – Incremental GHG Increase per Additional lb N or lb P Removed

Falk, Michael W., Reardon, David J., Neethling, JB., & Pramanick, Amit. (2011) Wastewater Treatment Nutrient Removal and Energy/GHG. *Water Environment Federation – Energy and Water*, 920-940.

Sustainability Implications

Green House Gas Emissions per P Treatment Level – continued

- Conclusions:
  - Levels 4 and 5 result in negative sustainability impacts that far outweigh the potential improvements to water quality
  - RO (Level 5 - < 0.02 mg/l P) impractical due to high costs, GHG emissions, and RO reject disposal challenges
  - Recommended Holistic Approach = Level 3 (0.3 - 0.1 mg/l P) + Non-point source BMPs

Falk, Michael W., Reardon, David J., Neethling, JB., & Pramanick, Amit. (2011) Wastewater Treatment Nutrient Removal and Energy/GHG. *Water Environment Federation – Energy and Water*, 920-940.

Sustainability Implications

Treatment Level Byproduct Implications

- Chemical
  - May increase sludge production and disposal costs
  - May result in necessary solids processing expansion
  - May decrease sludge quality due to metals such as mercury causing land application problems
- Reverse Osmosis
  - Reject water disposal issues

Policy/Rule Implications

- Financial Capability Analysis
  - CSO Guidance for Financial Capability Assessment and Schedule Development (1997)
  - Interim Economic Guidance for Water Quality Standards (1995)
- Achieving Water Quality Through Municipal Stormwater and Wastewater Plans & Integrated Planning Frame Work
- Schedules of Compliance
  - Indiana Administrative Code
  - Is a Variance or Streamline Variance Feasible?

Questions?

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