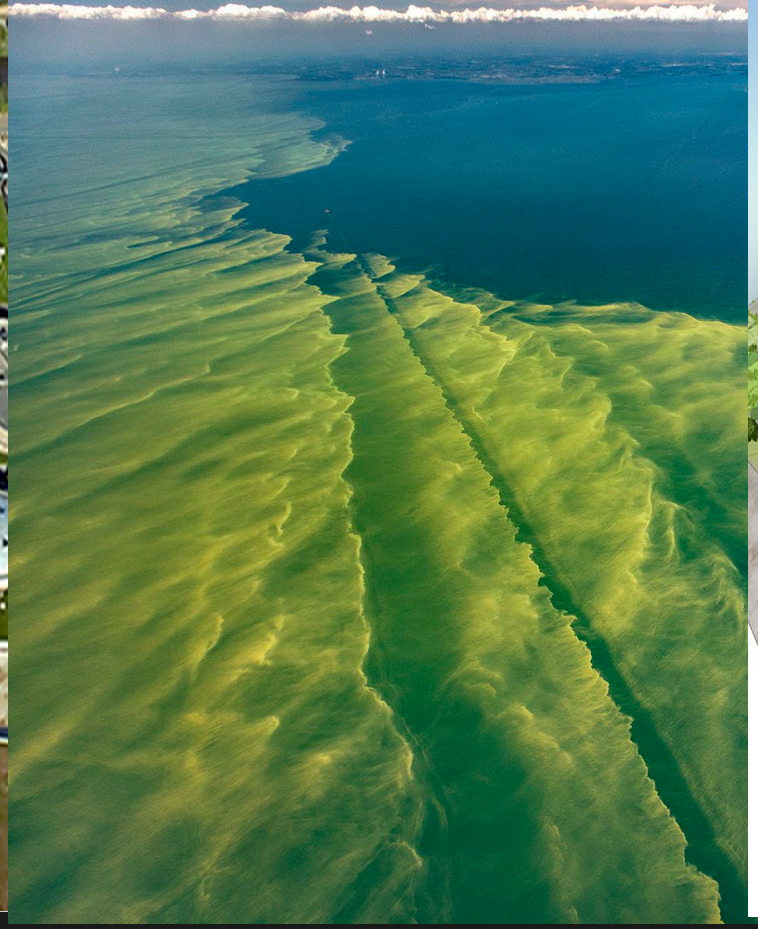

Pushing the Envelope on Phosphorus from WWTPs - Regulatory, Compliance and Sustainability Implications

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Aashirwad Sangal, M. Eng. – Process Engineer

November 14, 2023

RVA

Presentation Outline

- Phosphorus in wastewater
- Phosphorus species
- Wastewater Treatment for P removal
- Conventional approach and practices – critical review
- P offsetting and trading
- Conclusions, future direction

Phosphorus – Sources and Water Pollution

- Naturally present in soil and water
- Urban sources
  - Household Cleaners
  - Phosphorous from Human waste
  - Synthetic Detergents
- Eutrophication (Nutrient for Plants)
  - Algal blooms – Lakes, Rivers, Coasts
  - Starts at very low P-PO_4 concentrations
  - 0.1-0.2 mg/L in flowing waters
  - 0.005-0.01 mg/L in stagnant water

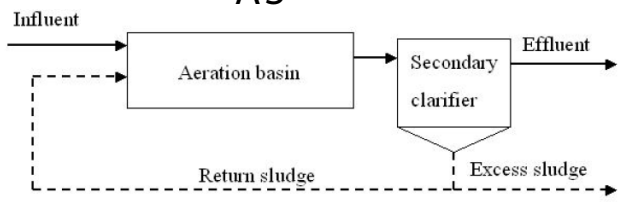
Phosphorus Species in Wastewater

<table>
<tr><td colspan="4">Total Phosphorus</td></tr>
<tr><td colspan="2">Particulate P</td><td colspan="2">Dissolved or Soluble P</td></tr>
<tr><td>Particulate Reactive P</td><td>Particulate Organic P Digestible</td><td>Particulate Acid Hydrolyzable P</td><td>Ortho P Reactive P Soluble Reactive P</td><td>Soluble Organic P Digestible</td><td>Inorganic Condensed P Acid Hydrolyzable P</td></tr>
<tr><td>PRP</td><td colspan="2">Part. Non-Reactive P (PNRP)</td><td>SRP</td><td colspan="2">Soluble Non-Reactive P (SNRP)</td></tr>
</table>

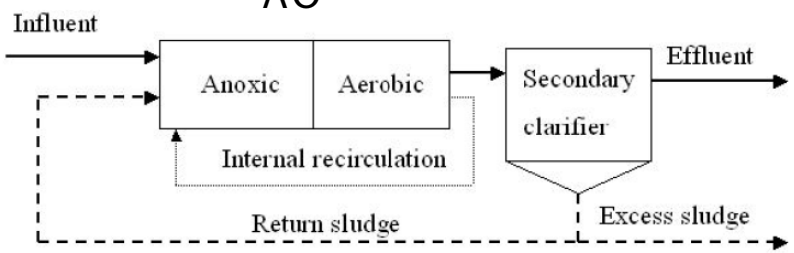
Source: Phosphorus Reduction In Wastewater Treatment, Low Phosphorus (neowatertreatment.com)

Wastewater Treatment for P Removal

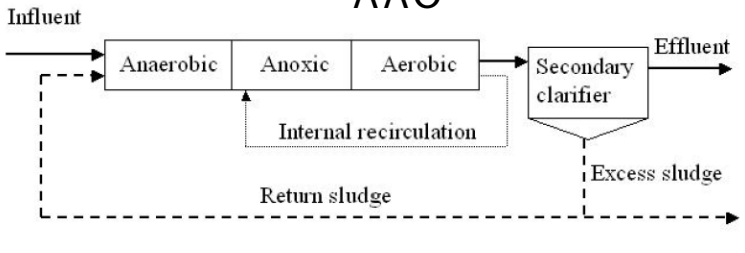
AS



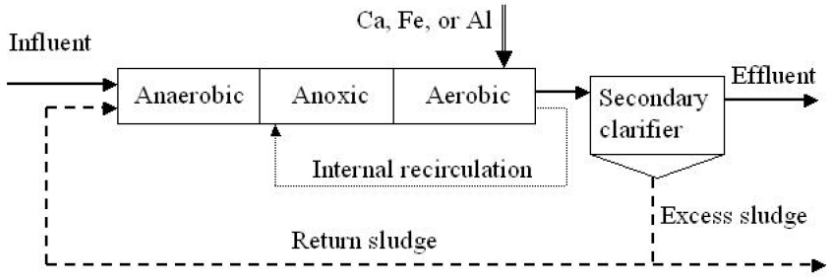
AO



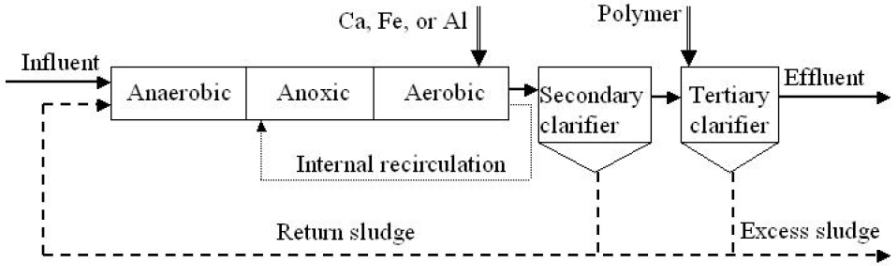
AAO



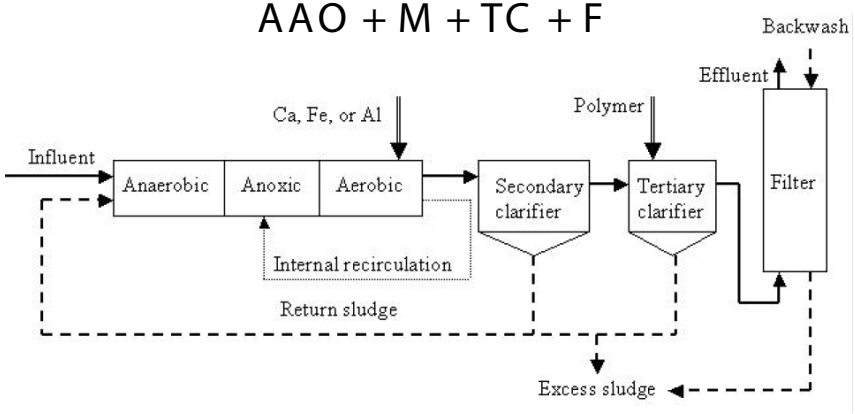
AAO + M



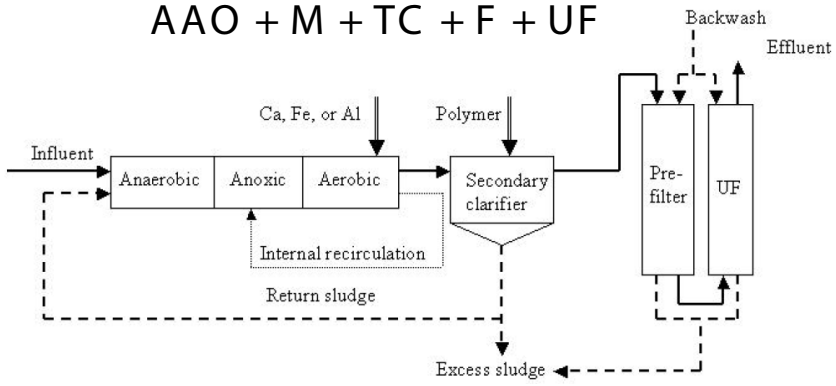
AAO + M + TC



AAO + M + TC + F



AAO + M + TC + F + UF

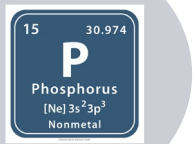


Wastewater Treatment for P Removal

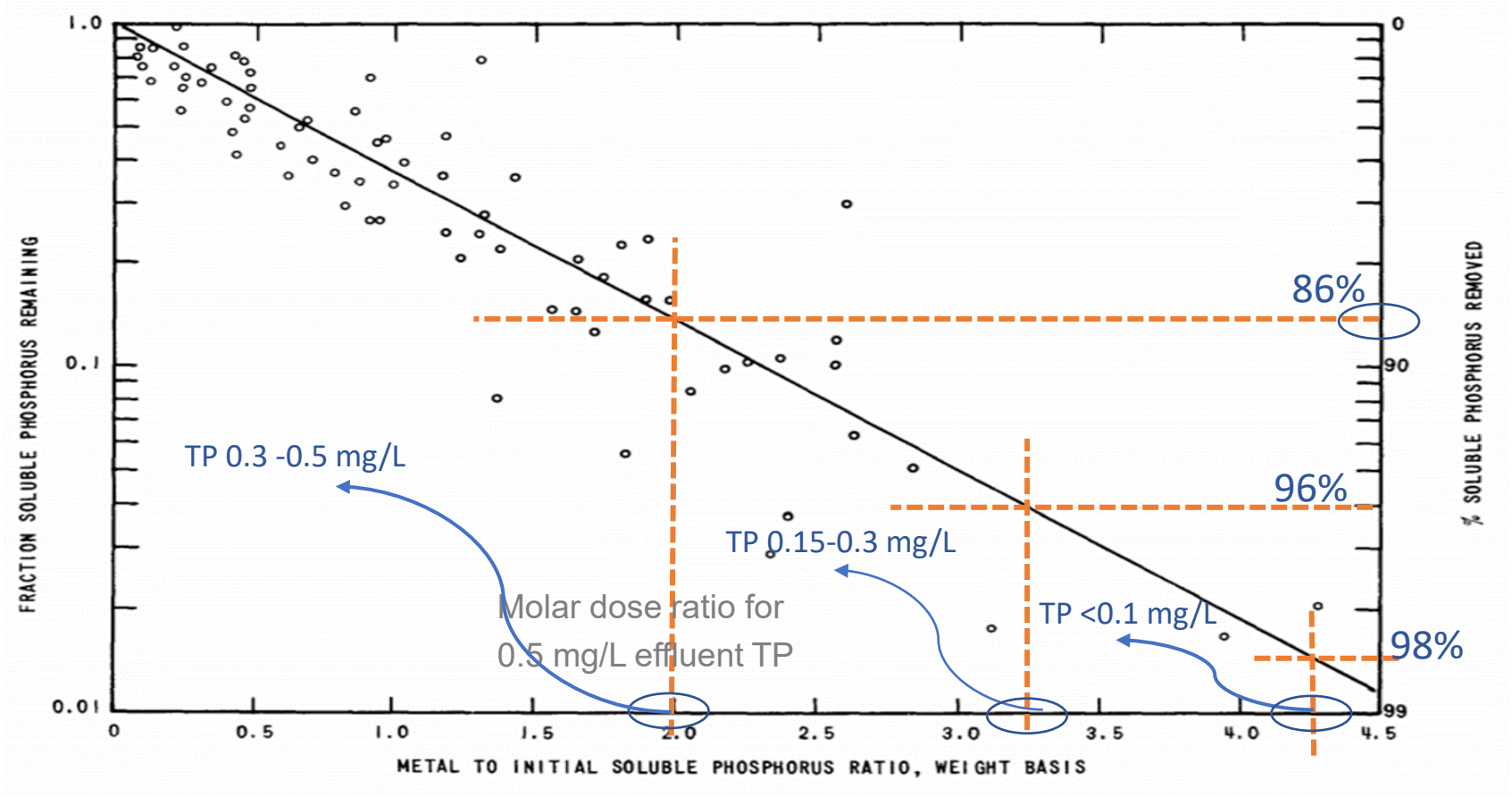
Process	TBOD mg/L	TSS mg/L	TP mg/L	P removal %
Influent	174	172	7.5	-
Effluent of AS	22	20	5.86	21.8
Effluent of AO	11-20	20	4.12	45.1
Effluent of AAO	11	20	2.95	60.7
Effluent of AAO + M	10	20	1	86.7
Effluent of AAO + M+ TC	5-10	5	0.325	95.7
Effluent of AAO + M+ TC + F	5	1	0.145	98.1
Effluent of AAO + M+ TC + AF	<1	<1	0.10	98.7
Effluent of AAO + M + F + UF	<1	<1	0.05	99.3

Conventional Approach Issues

- Chemical consumption – diminishing returns
- Capital costs
- Non-reactive P fraction
- Bioavailability of effluent P species
- Other P sources

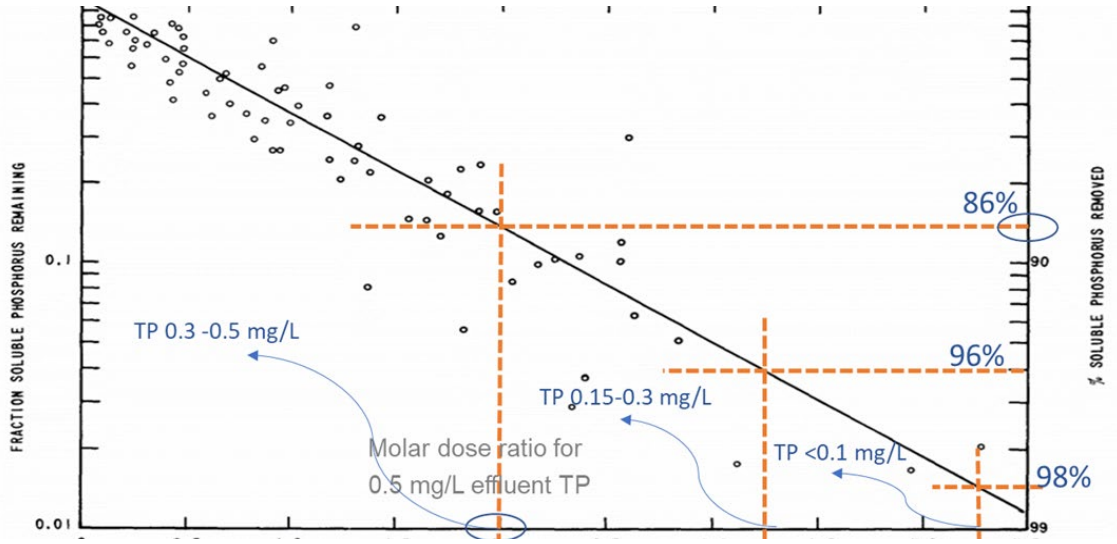


Conventional Approach Issues – Chemical Consumption



Conventional Approach Issues – Chemical Consumption

- Increased operational cost
- Alkalinity depletion, nitrification issues
- Increased metals in biosolids
- Stringent biosolids regulations

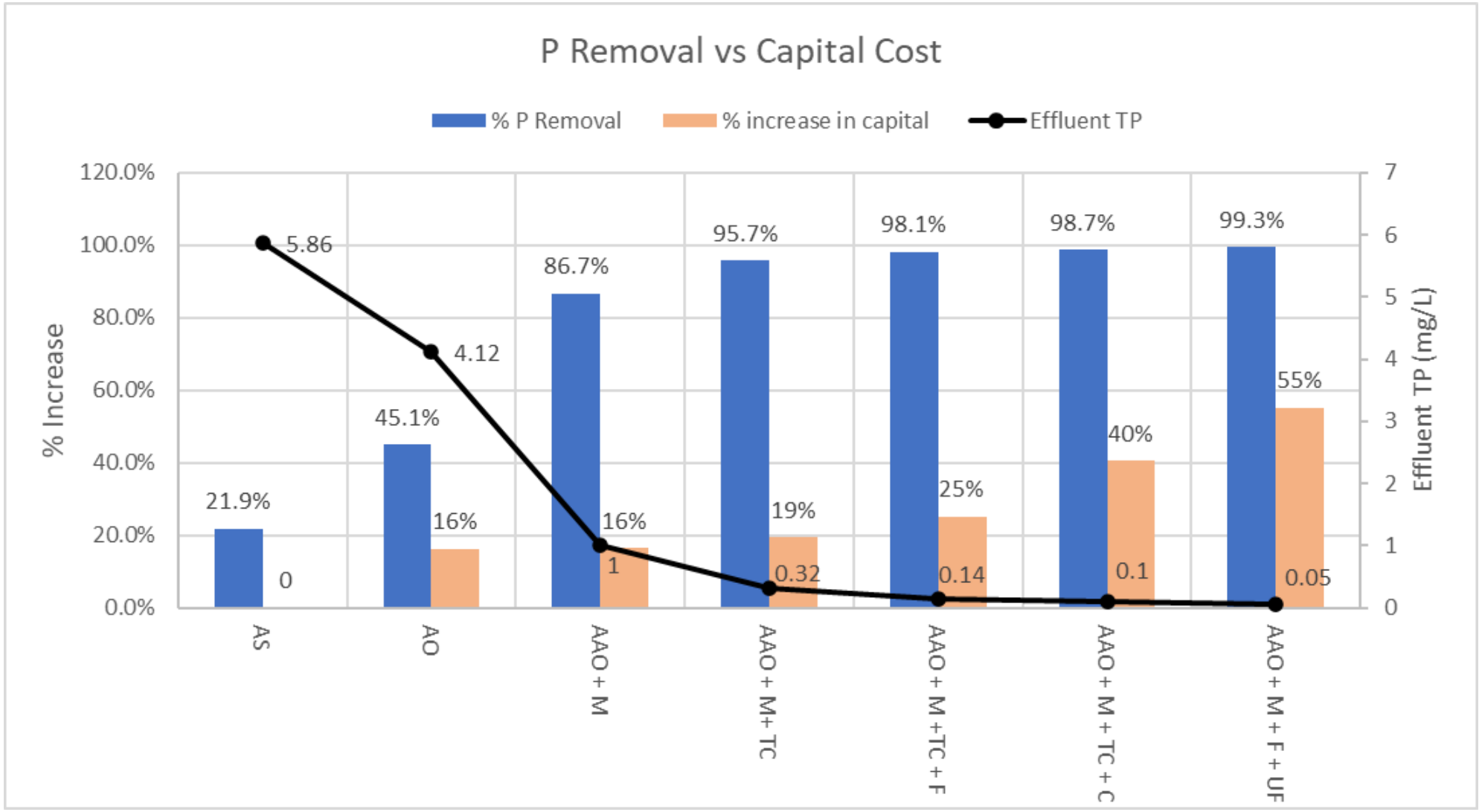


Conventional Approach Issues – Capital Cost

PROCESS	TBOD mg/L	TSS mg/L	TP mg/L	P removal %	Total capital (2004$*10^6)	Total O&M (2004$*10^6)
Influent	174	172	7.5	-	39.53	4.13
Effluent of AO	11-20	20	4.12	45.1	54.52	5.43
Effluent of AAO + M	10	20	1.00	86.7	54.56	7.1
Effluent of AAO + M + TC	5-10	5	0.325	95.7	56.03	7.5
Effluent of AAO + M + TC + F	5	1	0.145	98.1	58.72	7.82
Effluent of AAO +M + F + UF	<1	<1	0.05	99.3	72.79	9.18

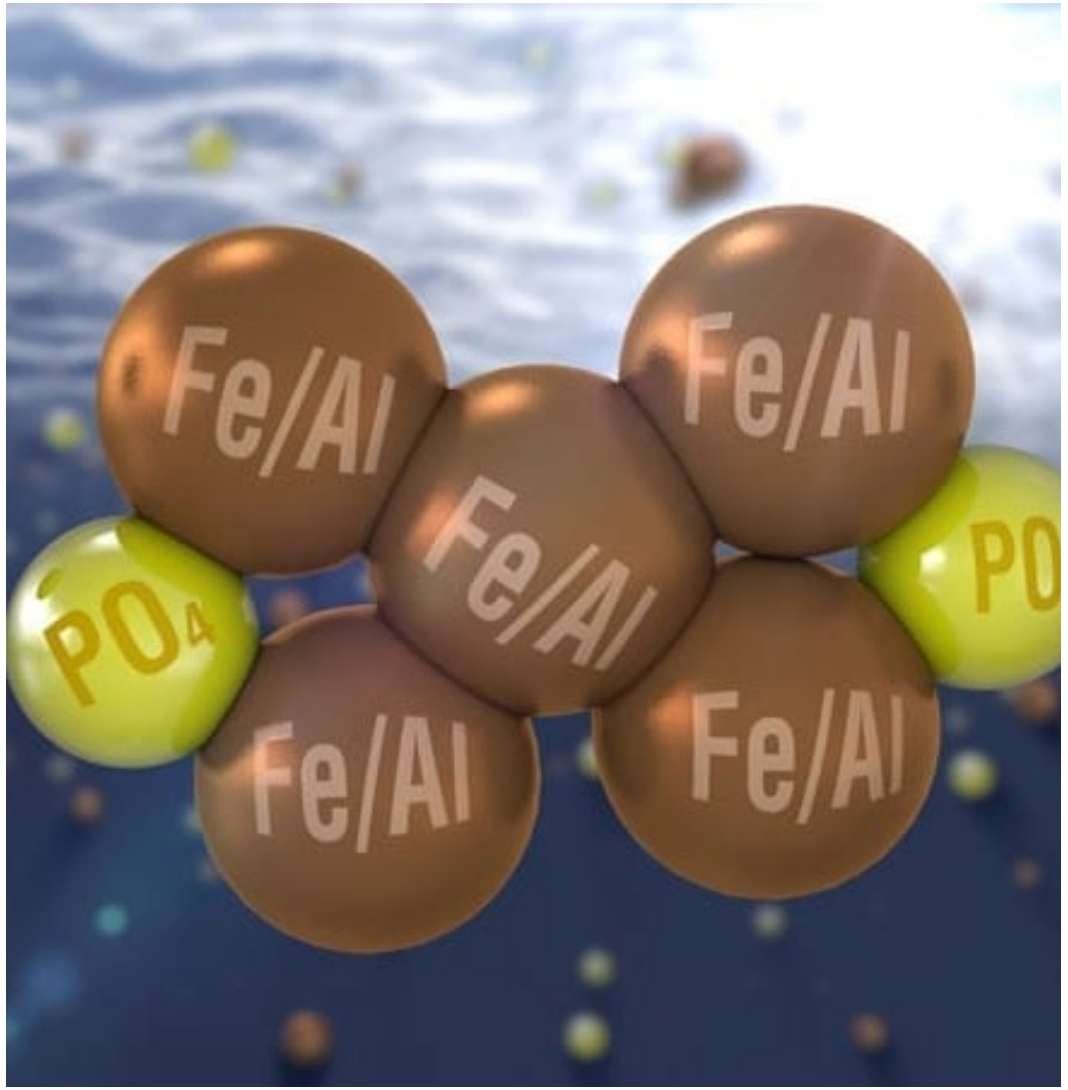
Source: Estimation of Cost of Phosphorous Removal in Wastewater Treatment Facilities by F.Jiang, M.B. Beck, R.G. Cummings, K Rowles, D. Russel

Conventional Approach Issues – Capital Cost



Conventional Approach Issues – Non-Reactive P

- Treatability and Compliance Issues
  - Recalcitrant sNRP
  - Less amenable to removal
  - Challenge for ultra-low TP levels
  - Typical range - 0.01 - 0.03 mg /L
  - Up to 0.5 mg/L with industrial loads
  - Can lead to non-compliance
- Bioavailability
  - Poor bioavailability in general
  - Some species slowly bioavailable
  - Others completely unavailable



Conventional Approach Issues – sNRP Bioavailability

Table 4 - Summary of Speciation Reactivity and Bioavailability Measurements for Inorganic and Organic Phosphorus
(Containing Compounds that May Be Present in Nutrient Removal Facilities)

Chemical Category	Speciation Category	Bioavailability	Example Compounds
Inorganic	Reactive	Bioavailable	Ca-P
Inorganic	Nonreactive	Nonbioavailable	Al-P, Pyro-P
Inorganic	Reactive	Nonbioavailable	Apatite, Ca-hydroxyapatite
Inorganic	Nonreactive	Mostly Bioavailable	Tripoly-P
Organic	Nonreactive	Bioavailable	ATP, DNA, RNA
Organic	Nonreactive	Nonbioavailable	Phytic Acid
Humic	Nonreactive	Nonbioavailable	Humic Complexes

Source: Brett and Li 2015

Total Phosphorus Management (TPM) – P off-setting

- Flexible watershed-based program
- Pollutant discharge "offset" by reductions elsewhere
- Offsetting ratio applied to reduction targets
- Viable alternative to point-source solutions

- Often more economical than point-source control
- Cost-effective controls at non-point sources
- Explored as part of WWTP design or EAs

TPM – Nonpoint Sources

- Caused by Rainfall or Snowmelt moving over and through the ground
- Leading source of water quality impacts on Rivers, and Lakes
- Agricultural activities that cause NPS pollution include:
  - Poorly located agriculture land
  - Poorly animal feeding operations
  - Overgrazing
  - Plowing too often or at the wrong time
  - Improper, excessive or poorly timed application of Irrigation Water, and Fertilizer

Current TPM Programs – Canada and USA

- South Nation River Watershed – 1999
- Nottawasaga Valley Conservation Authority (with New Tecumseth) – 2013
- Halton Region P offsetting program
- Lake Simcoe Region Conservation Authority (2008)
- Chesapeake Bay (2010)
- Mississippi River Basin (2009)

TPM Success – SNC River Watershed

Delayed community support

- Initial resistance from Rural landowners
- Perception of being biased towards industry
- Putting agriculture in poor light

Three years of extensive consultations with program partners

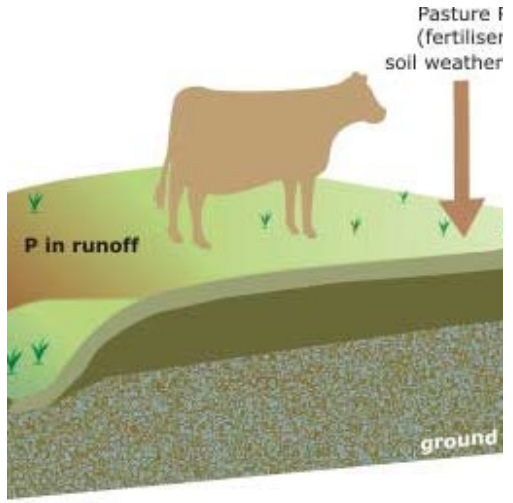
Spearheaded by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)

- Statement of Roles and Responsibilities
- Absolved farmers from any legal liability
- WWTPs responsible for required P reductions
- Community support for the program
- Local farmers as field representatives

South Nation Conservation TPM

Best Management Practices

- Manure storage – non application periods
- Clean water diversion away from manure
- Milkhouse Washwater treatment
- Livestock access restriction to watercourse
- Buffer strips – planted or natural vegetation
- Nutrient management
  - efficient use of nutrients
  - fertilizers, manure, biosolids
  - yearly plans
  - soil tests-based application
- Fragile land retirement prone to
  - water or wind erosion
  - sloped lands
  - flood plains
- Septic systems Improvement



South Nation Conservation TPM

Best Management Practice	Calculation of kg phosphorus controlled
Manure Storage	# animals x days x phosphorus excreted x 0.30 (beef cattle) # animals x days x P excreted x 0.07 (dairy cattle)
Milkhouse Washwater	# cows x 0.69 kg/cow/yr (excluding manure) # cows x 2.76 kg/cow/yr (including manure)
Clean Water Diversion	# animals x days x phosphorus excreted x 0.30 x (reduced feedlot runoff volume/ original feedlot runoff volume) (phosphorus leached = 0.30 for beef cattle manure and 0.07 for dairy cattle manure)
Livestock Access	# animals x days x phosphorus excreted x 0.03 (multiply by 0.5 if animals have half day access to watercourse)
Cropping Practices	0.5 kg x hectares (no-till) 0.4 kg x hectares (cover cropping)
Buffer Strips	0.67 kg x hectares buffered (for 6-10 m wide buffer)

TPM Success – SNC River Watershed

TPM widely accepted by farmers, WWTPs

2015 Status - 287 trades completed

Over 12,000 kg of P removed from the watershed

Off-setting cost - $300 per kg of P removed

At 4:1 ratio, $1200/kg through TPM program

Traditional WWTP approach - $2000 per kg P removed

Conclusions and Lessons Learnt

- Conventional solutions
  - Unsustainable for sensitive watershed with low TP limits
  - Poor return on investment
  - High operational costs
  - Operational concerns
  - Environmental risks
- Regulatory changes
  - Integrating sNRP species in low TP limits
  - Identification of non-bioavailable P species
- Total phosphorus management
  - Often more cost-effective, better P reduction
  - Conservation of important resource
  - Needs inclusion in engineering thought process
  - Collaborative, sustained effort for successful programs
  - Engineering community needs to champion

Questions, Thoughts?

THANK YOU!