South Texas Chapter

San Antonio Section

Summer Seminar

Emerging Issues in the Water/Wastewater Industry

Preparing for Nutrient Removal at Your Treatment Plant

Rajendra P. Bhattarai, P.E., BCEE
Austin Water Utility
Ana J. Peña-Tijerina, Ph.D., P.E., BCEE
Fort Worth Water Department

July 26, 2013

Presentation Outline

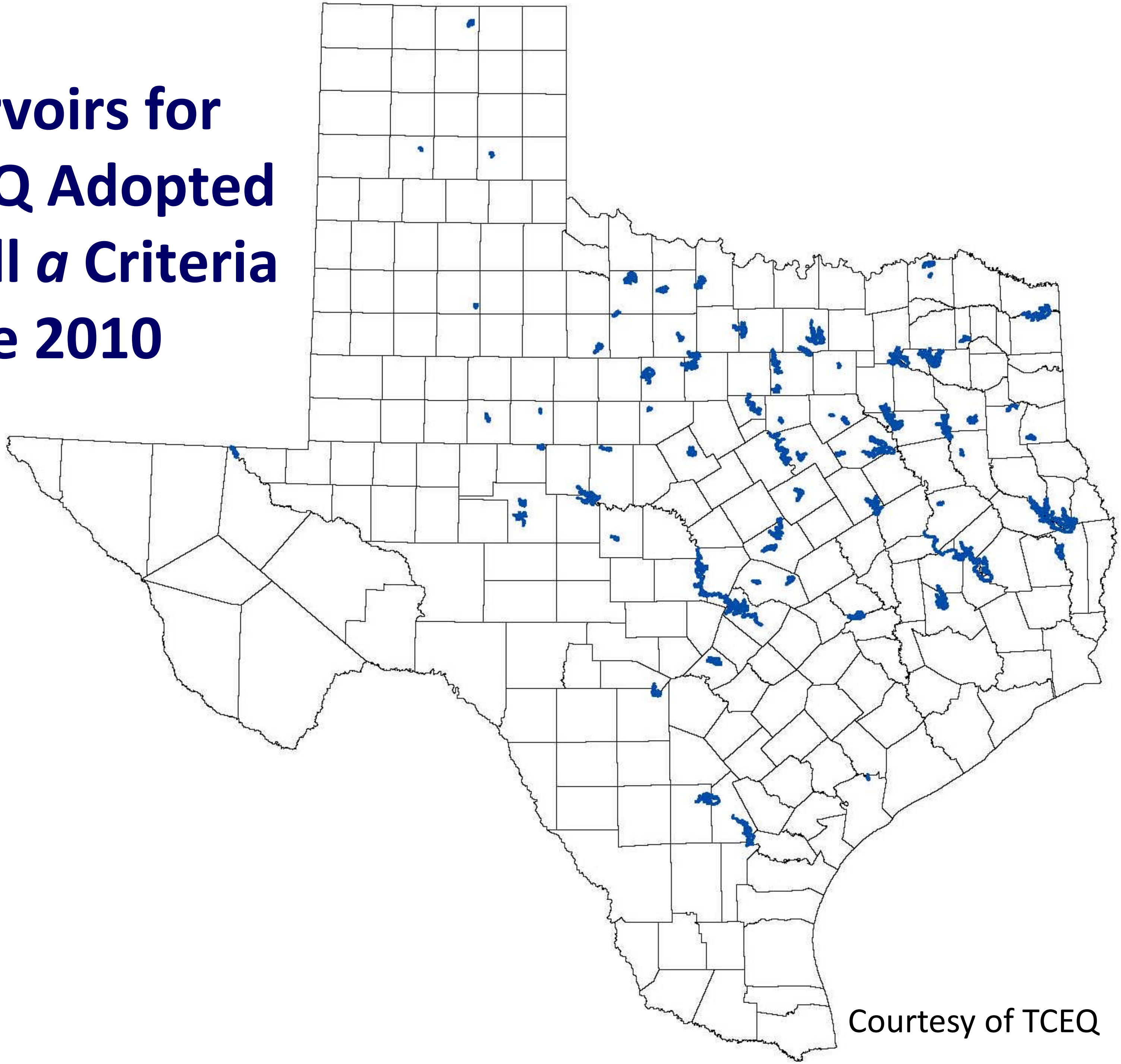
- Nutrient Regulations in Texas
  - When will I get nutrient limits in my permit?
  - What will it be?
- Quick Overview of Nutrient Removal
- Existing Treatment Plant Capacity Evaluation
  - TCEQ Design Criteria
- Wastewater Characterization
- Chemical or Biological Nutrient Removal (BNR)?
  - Process Configurations
- Nutrient Recovery

Current Permits with Nutrient Limits in Texas

Total Phosphorus (TP) Limit, mg/L	Number of Permits
>1.0	10
0.5 to 1.0	43
≤0.5	10
0.15	1

*** There are two facilities with 6 mg/L and two with 8 mg/L Total Nitrogen limits.**

75 Reservoirs for which TCEQ Adopted Chlorophyll *a* Criteria in June 2010



Courtesy of TCEQ

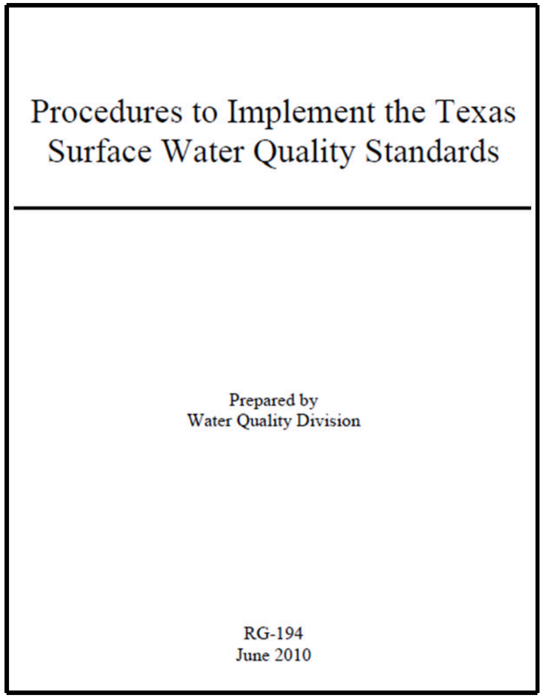
Proposed Total Phosphorus (TP) Limits in Texas

Permitted Flow, MGD	Typical TP Limit, mg/L
<0.5	1.0
0.5 – 3.0	0.5 to 1.0
>3.0	0.5

- More stringent limits may be recommended to protect unusually sensitive aquatic environments.
- Less stringent limits may be recommended when there are unusual mitigating factors.

Status of Nutrient Criteria

- July 2, 2013: EPA approved TCEQ's chlorophyll *a* criteria for 39 reservoirs and disapproved for 36
- July 12, 2013: EPA approved TCEQ's 2010 Implementation Procedures
- New and amended permits that authorize discharges to the 39 reservoirs will now start receiving TP limits
- TCEQ adoption of estuaries, rivers and streams nutrient criteria in 2017 onward


Procedures to Implement the Texas Surface Water Quality Standards

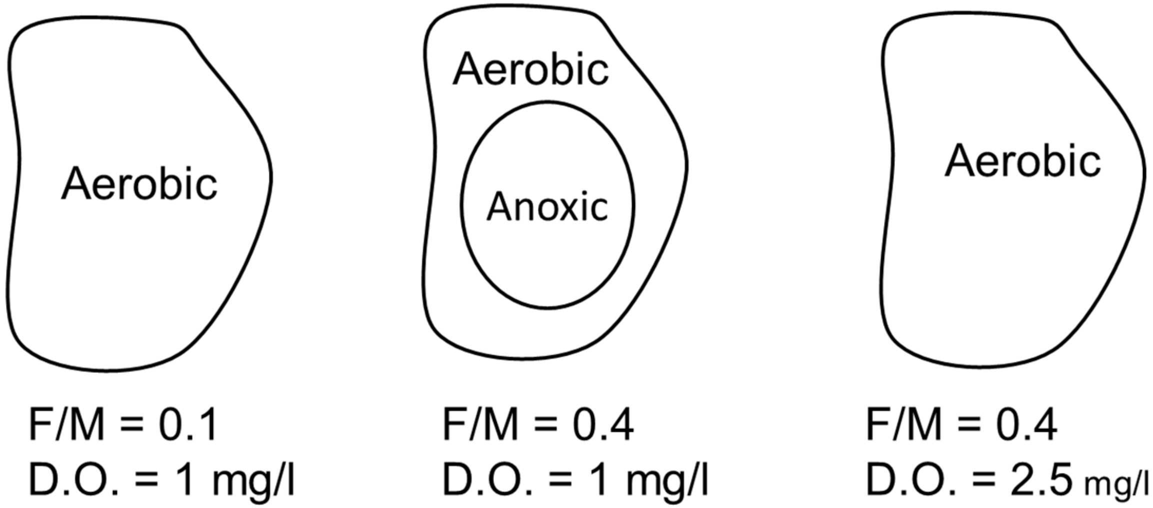
Prepared by
Water Quality Division

RG-194
June 2010

NMT
Nutrient Modeling Toolbox
Your Link to Site-Specific Nutrient Criteria

Aerobic, Anoxic or Anaerobic?

- Aerobic – dissolved oxygen (D.O.) present
- Anoxic – No D.O., but nitrate is present
- Anaerobic – No D.O. and no nitrate
- Relative terms, not to be taken absolutely, especially in biological reactors



P Removal by Chemical Addition

Phosphate is removed by precipitation

$PO_4^{\equiv} + FeCl_3 \rightarrow Fe\ PO_4\downarrow + 3\ Cl^-$

More chemical needed than predicted by equation due to other competing reactions

Alkalinity is consumed by metal salts and vice versa

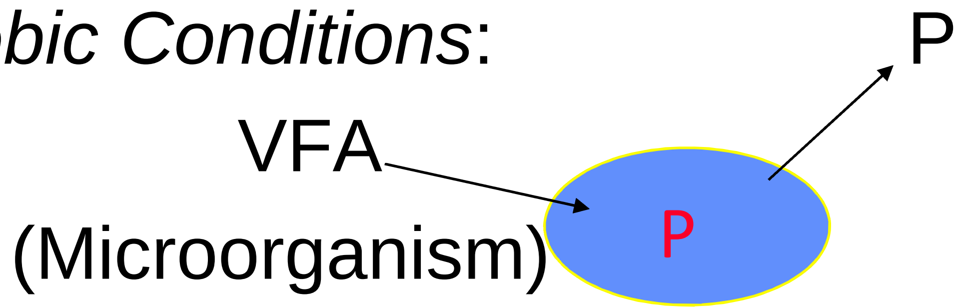
$3\ OH^- + FeCl_3 \rightarrow Fe(OH)_3\downarrow + 3\ Cl^-$

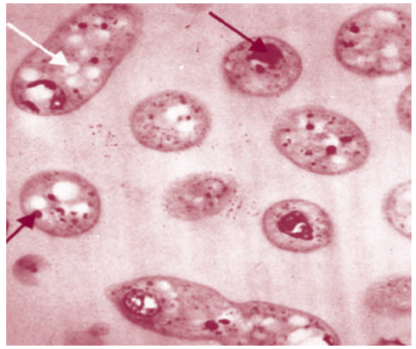
$3\ HCO_3^- + FeCl_3 \rightarrow Fe(OH)_3\downarrow + 3\ CO_2 + 3\ Cl^-$

Biological Phosphorus Removal

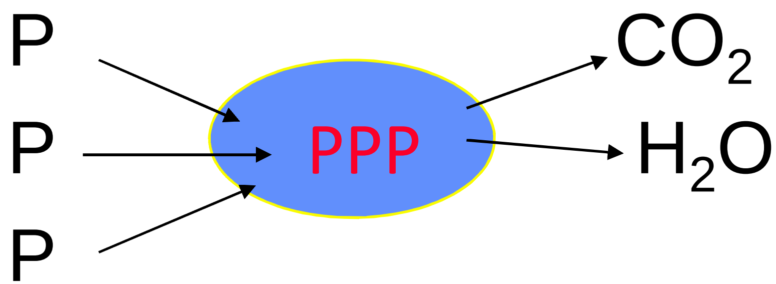
Requires Volatile Fatty Acids (VFAs) and alternating anaerobic/aerobic conditions

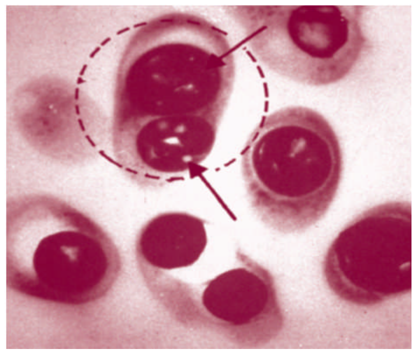
Anaerobic Conditions:





Aerobic Conditions:





Biological Nitrogen (N) Removal

Nitrification: Ammonium ion (NH_4^+) oxidized in two steps – first to Nitrite (NO_2^-), then to Nitrate (NO_3^-)

$$NH_4^+ + 1.5\ O_2 + 2\ HCO_3^- \rightarrow NO_2^- + 3\ H_2O + 2\ CO_2\uparrow$$

$$NO_2^- + 0.5\ O_2 \rightarrow NO_3^-$$

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

7.14 parts of **alkalinity** and **4.57** parts of **oxygen** consumed for every part of NH_4^+ oxidized to NO_3^-

Biological Nitrogen (N) Removal (continued…)

Denitrification: Nitrate ($NO3^-$) reduced to nitrogen gas in the absence of oxygen (anoxic condition)

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

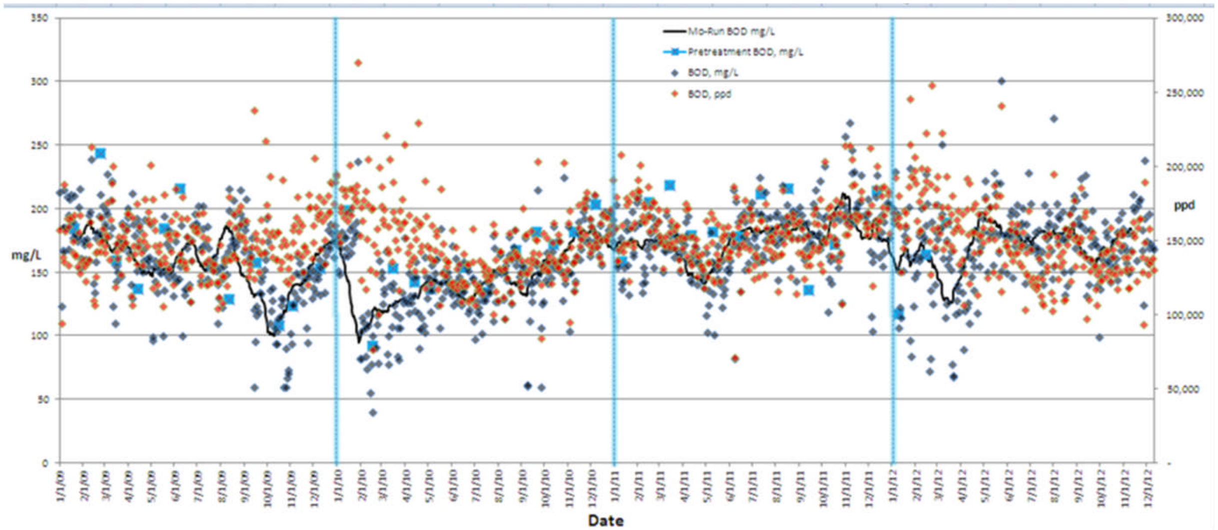
3.57 parts of **alkalinity** formed and **2.86** parts of **oxygen** "recovered" (or BOD consumed) for every part of NO_3^- denitrified

Existing
Treatment Plant Capacity Evaluation

- Check design and peak flows and load capacities for each treatment unit
- TCEQ "Design Criteria"
- Historical data analysis and actual treatment capability to meet permit limits
- Excess aeration basins capacity available?
- Can your basins sustain more SRT?
- Room for expansion?
- Hydraulic Head?
- Room for Filters? (for stringent limits)

Wastewater Characterization

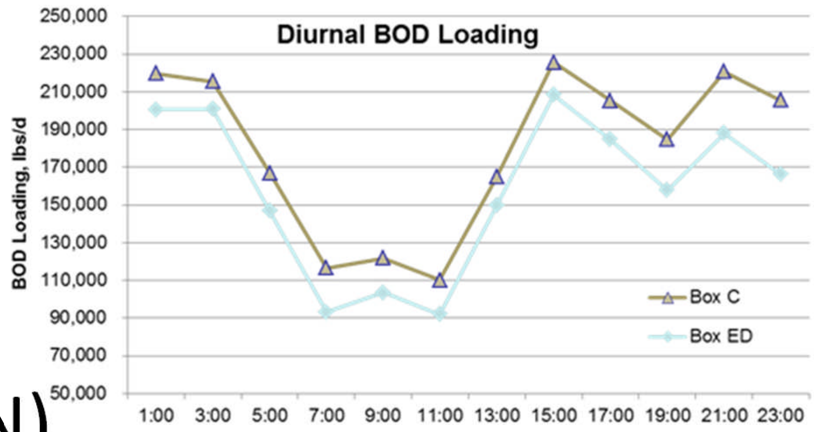
- Effluent data (for regulatory reporting)
  - BOD_5
  - TSS
  - NH_3-N
  - pH
  - TP



- Measurement Frequency
  - Large Plants: More frequent
  - Small Plants: Less frequent
  - May want targeted and intensive sampling

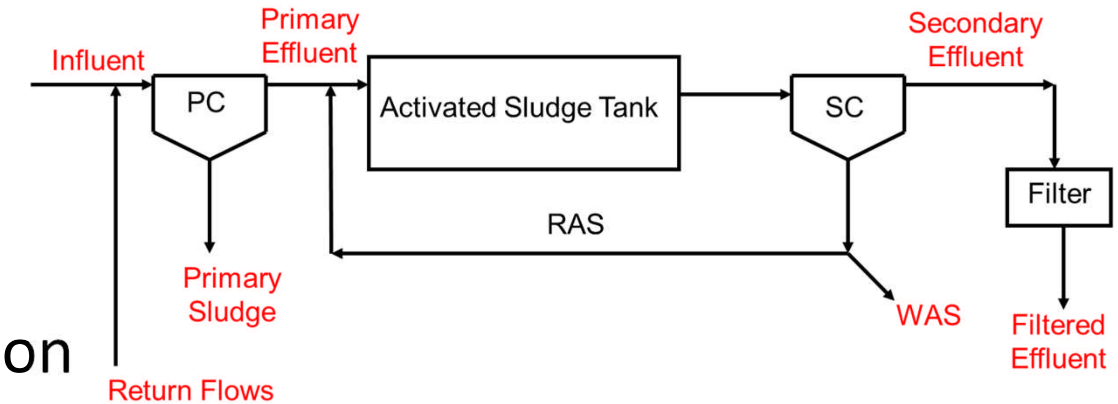
Wastewater Characterization (continued…)

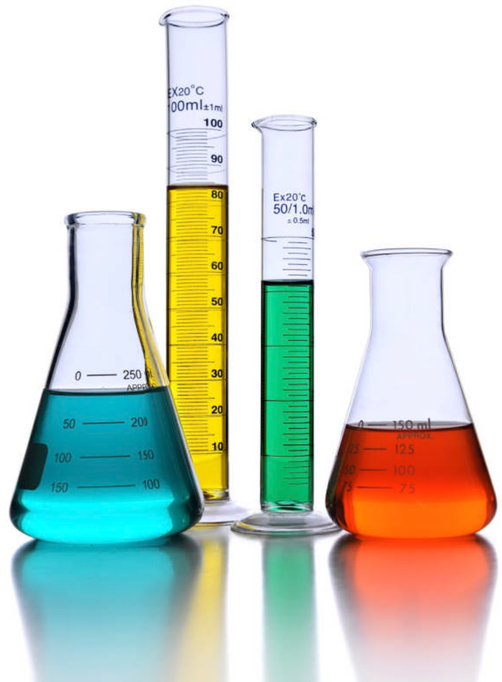
- BOD_5 – Total and Soluble
- COD – Total and Soluble
- NH_3-N
- Total Kjeldahl Nitrogen (TKN)
- Nitrate (NO_3^-) and Nitrite (NO_2^-)
- pH
- Alkalinity
- TP
- Ortho-Phosphorus (OP)



Wastewater Characterization (continued…)

- Influent
- Primary Effluent
- Secondary Effluent
  - Pre- and post-filtration
- Primary Sludge
- Waste Activated Sludge
- Sidestreams: Filter backwash, Thickener return flows, digester supernatant, Dewatering return flows





Wastewater Characterization (continued…)

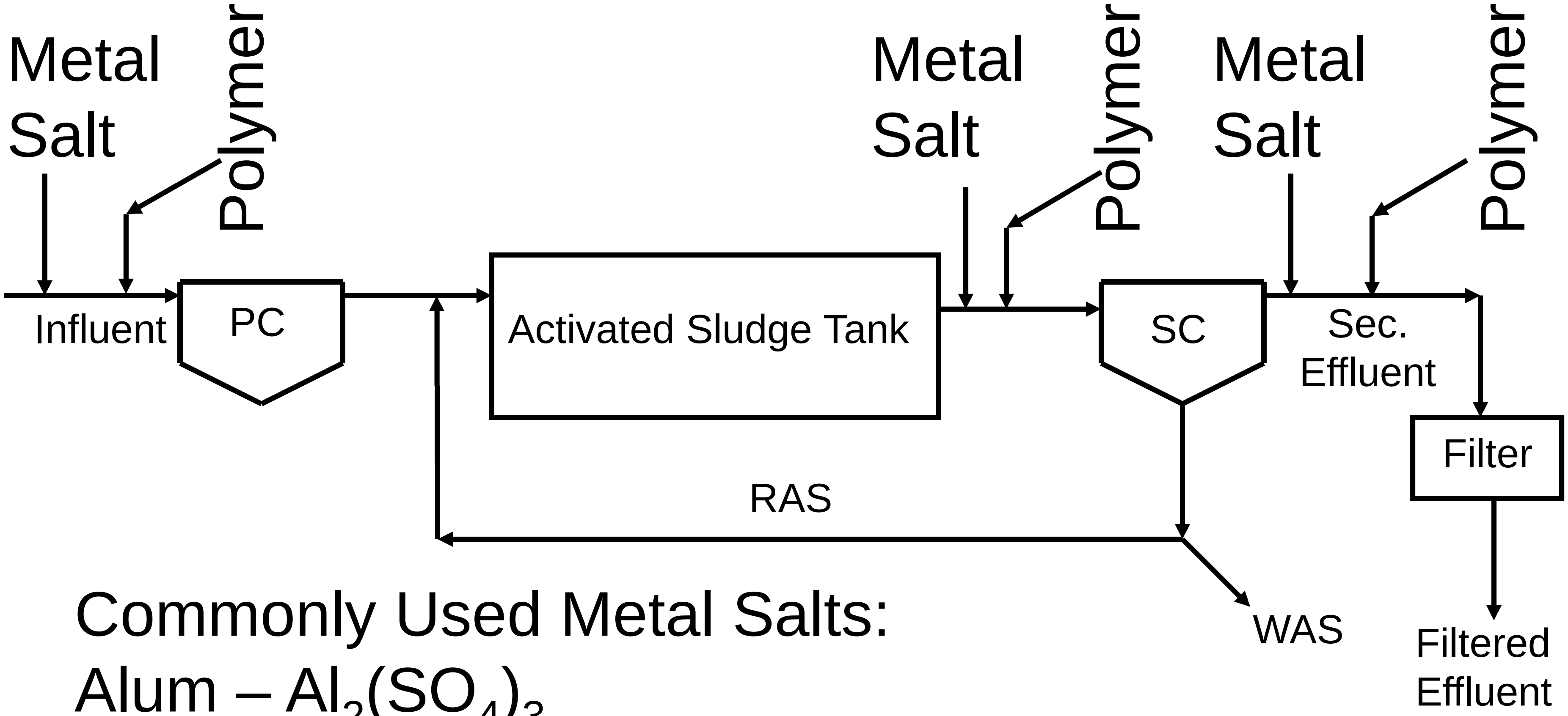
- Volatile Fatty Acids (VFAs)
  - Critical for BNR, especially for biological P removal
  - Difficult to measure
- Surrogate for VFAs
  - Readily Biodegradable COD (RBCOD)
    - Biological batch feed test method – time consuming
  - Truly Soluble COD (TSCOD) – Faster physical-chemical method* using flocculation

* Mamais, D., Jenkins, D., and Pitt, P. (1993): "A rapid physical-chemical method for the determination of readily biodegradable soluble COD in municipal wastewater." *Water Research*, **27** (1), pp 195 - 197.

TP Limits and Reasonably Achievable Technology

TP Limit (mg/L)	Biological	Chemical	Biological & Chemical	Filtration	Membranes
>1.0	✓	✓			
1.0	✓	✓	✓		
0.5			✓	✓	
<0.2					✓

P Removal by Chemical Addition
Dosing Options



Commonly Used Metal Salts:

Alum – $Al_2(SO_4)_3$

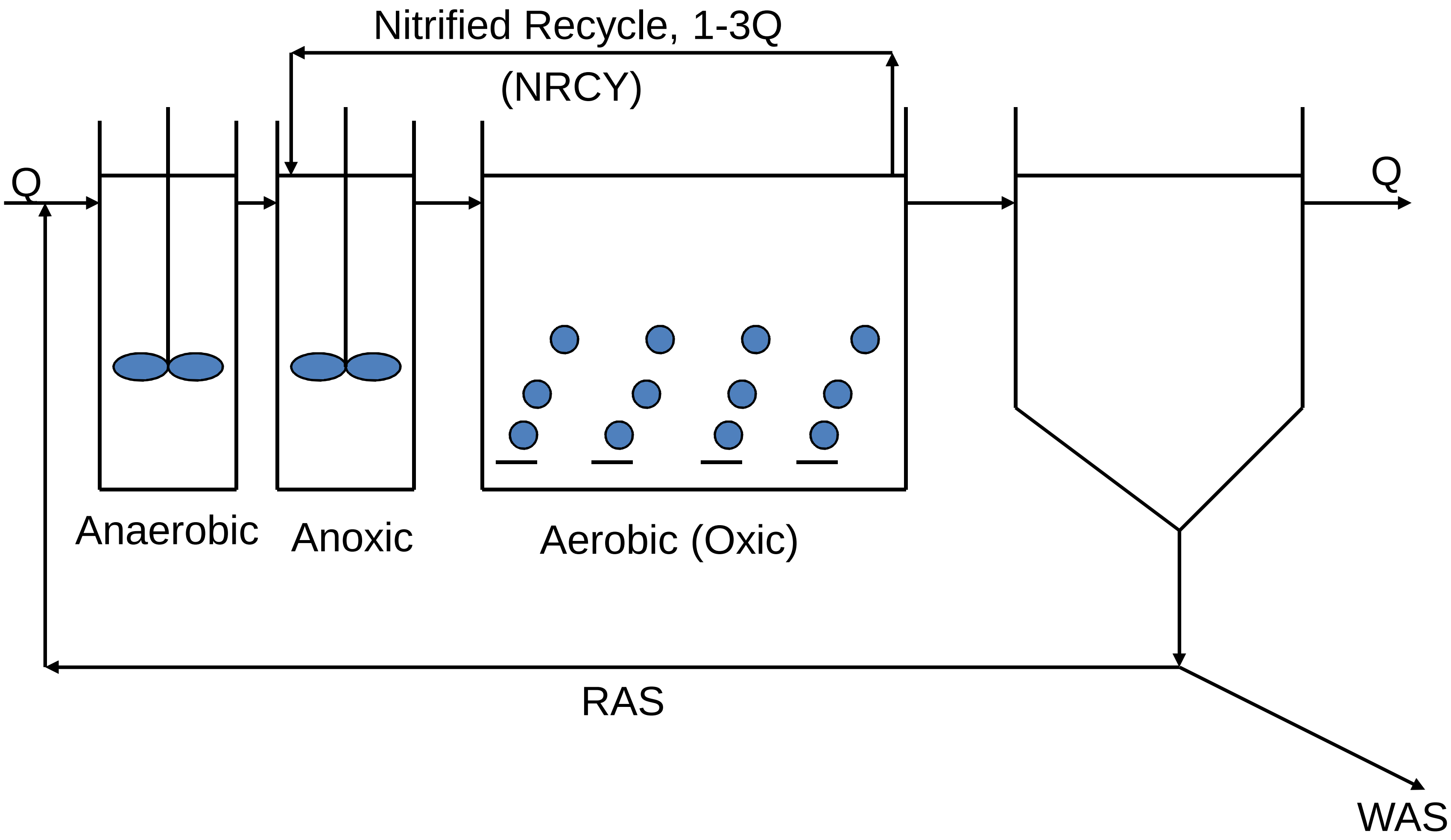
Ferric Sulfate – $Fe_2(SO_4)_3$

Ferric Chloride – $Fe\ Cl_3$

Chemical Dose Point Issues

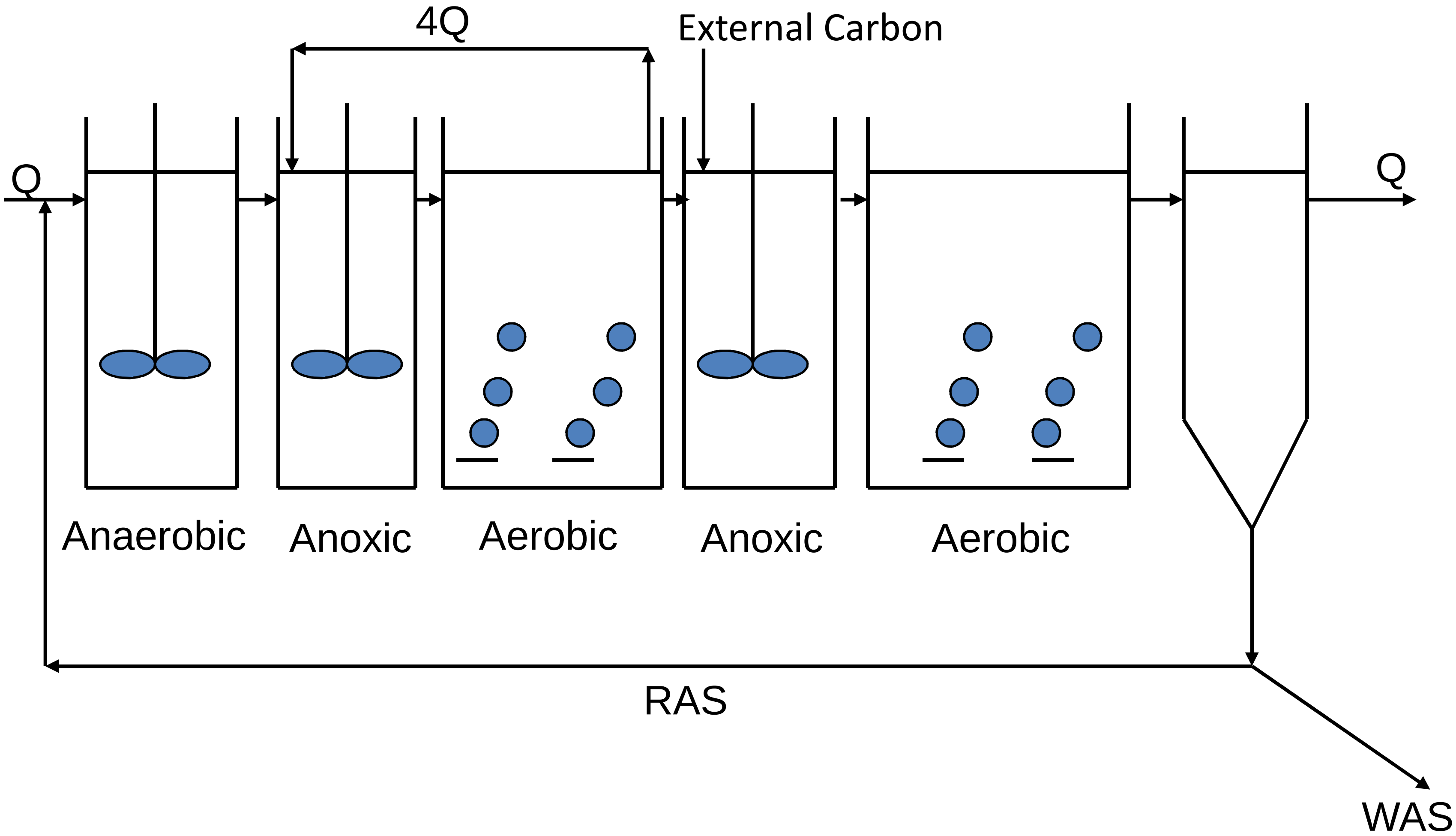
Dose Point	Expected Effluent TP	Issues
Primary	≥ 1 mg/L	Enhanced BOD and TSS removal; efficient chemical use; reduces P loading on downstream processes; may require polymer for flocculation
Secondary	≥ 1 mg/L	Less Efficient Chemical use; additional inert solids in MLSS
Primary and Secondary	0.5 – 1 mg/L	Combines advantages of above; slightly increased cost
Tertiary	≤ 0.5 mg/L	Required to meet stringent limits; significant increased cost

A2/O Process

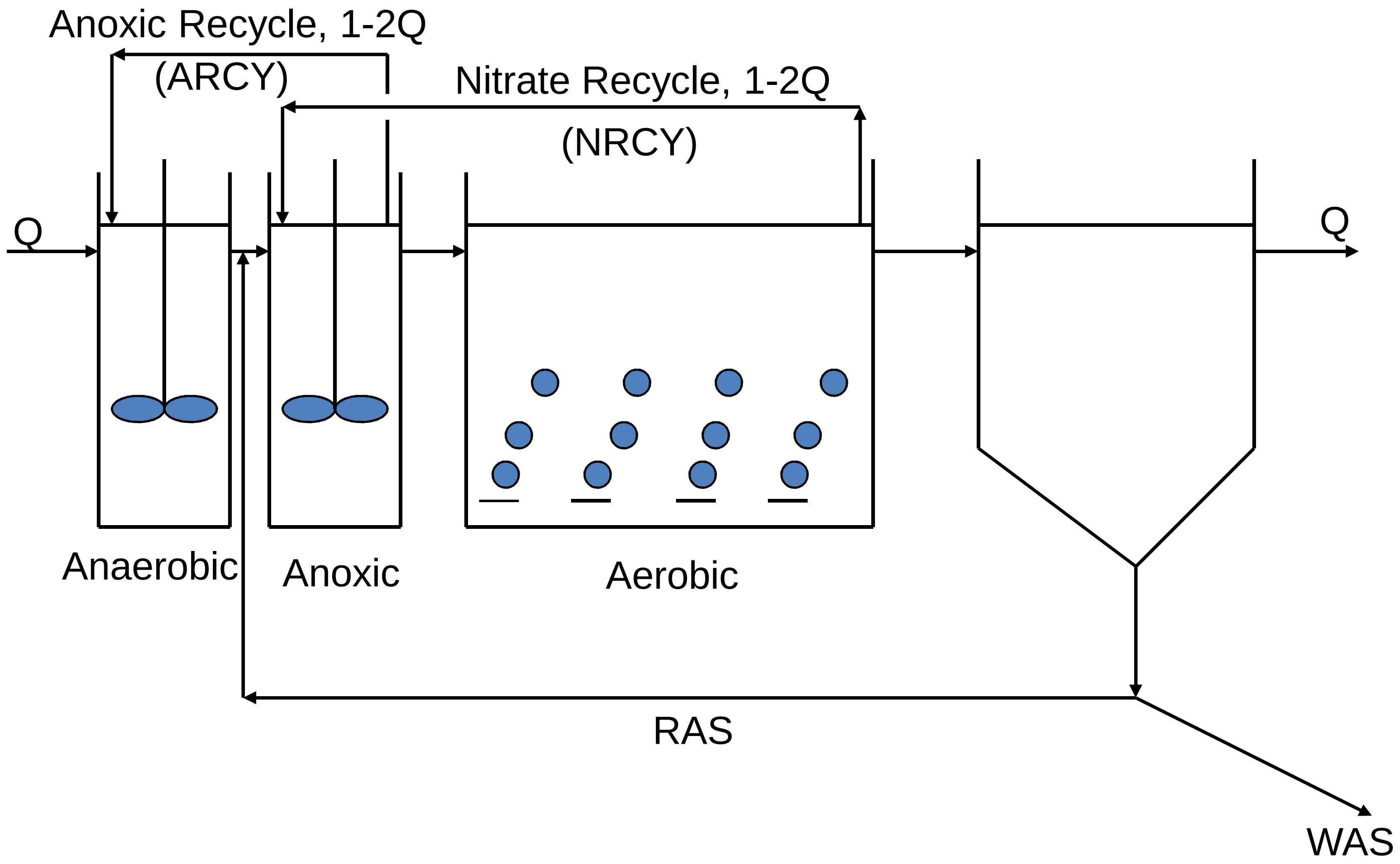


Nitrified Recycle, 1-3Q
(NRCY)
Q
Q
Anaerobic
Anoxic
Aerobic (Oxic)
RAS
WAS

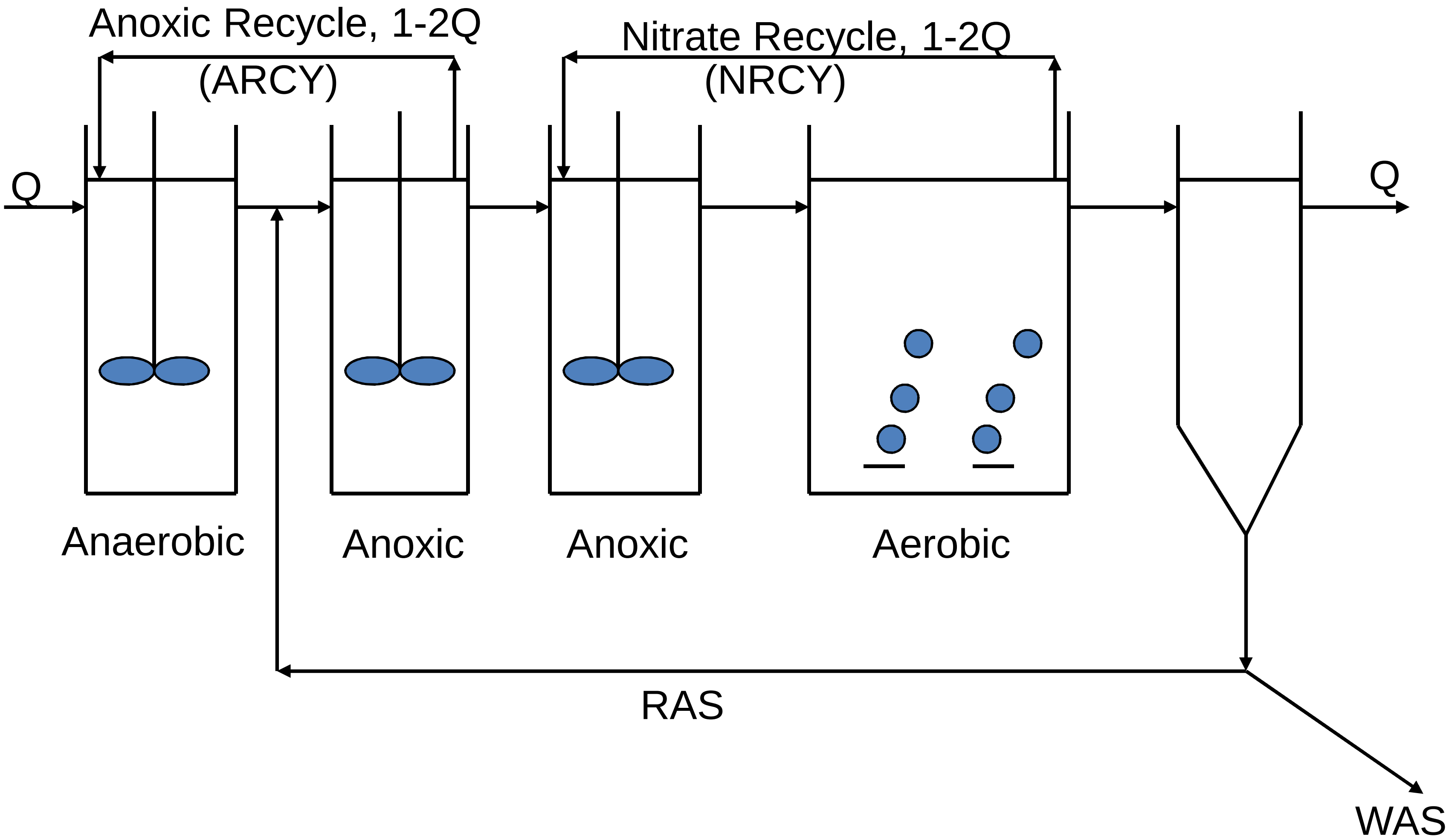
Five-stage Bardenpho Process



University of Cape Town (UCT) Process



Modified UCT Process

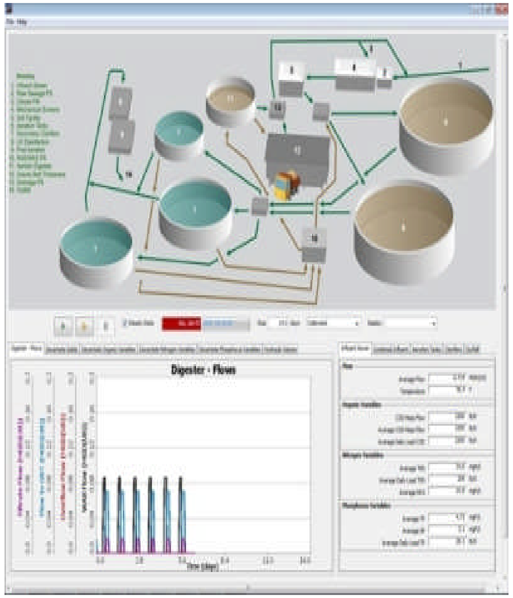


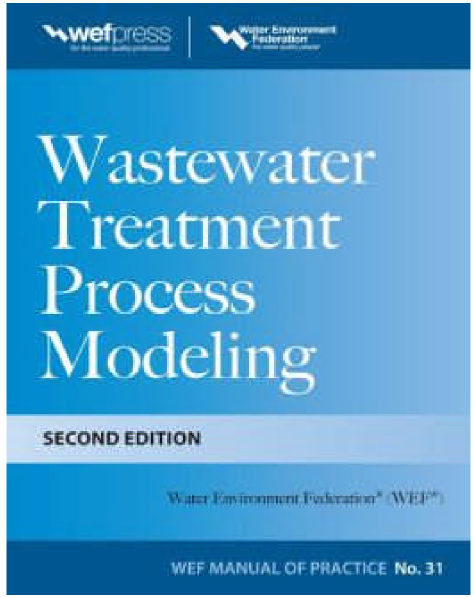
Relative Comparison of Biological and Chemical P-removal

Parameters of Concern	Chemical	Biological
Capital cost	Lower	Higher
O&M cost	Higher	Lower
Ability to meet TP limits	More reliable	Less reliable
Ease of operation	Simpler	More complex
Alkalinity and pH issues	Less favorable	More favorable
Sludge production	More	Less

Process Modeling

- Models help during process selection and design
- Models also help operation and crisis management
- Proper data input and calibration is important





Models are to be used, but not to believed.
-Henri Theil (1924-2000)

All models are wrong, but some are useful.
-George E.P. Box (1919-2013)

A model is a lie that helps you see the truth.
-Howard E. Skipper (1915-2006)

Nutrient Recovery

- Struvite ($MgNH_4PO_4.6H_2O$) can form and clog digester pipes
- Better to intentionally form and recover struvite which can be sold commercially
- Several commercial systems: Multiform Harvest, NuReSys, Ostara (Crystal Green), Paques (Phospaq), Procorp (Crystalactor), SH+E Group (Airprex)

Summary

- Nutrient limits coming soon to your TPDES permits
- Capacity evaluation and wastewater characterization helpful for selection of appropriate processes
- Chemical P removal preferred for smaller plants
- BNR economical in the long run, especially for larger plants; requires more skilled operation
- Chemical P removal: higher O&M costs than BNR
- Modeling for process selection, design and operation
- Consider struvite recovery with BNR

Questions, Comments?