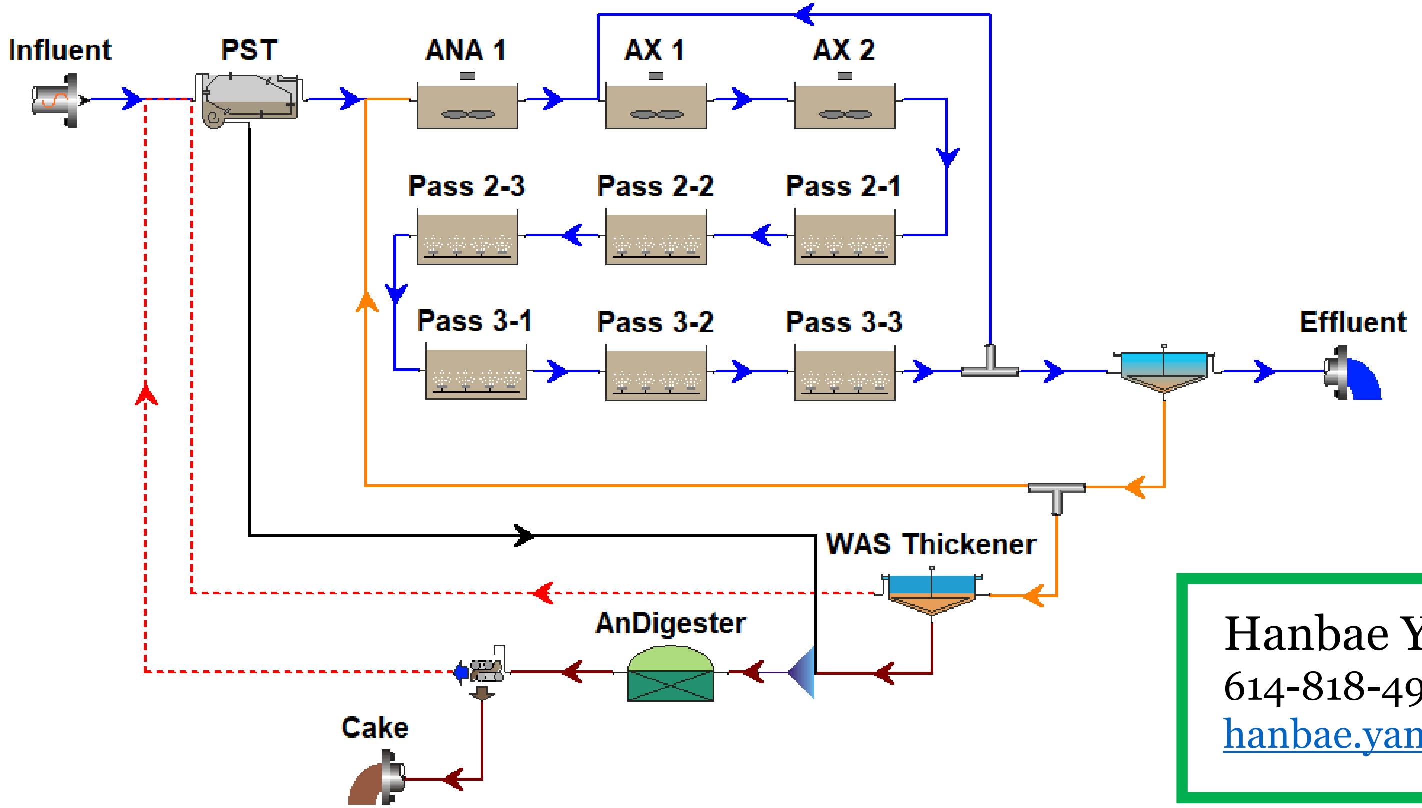
BioWin - Wastewater Treatment Process Modeling



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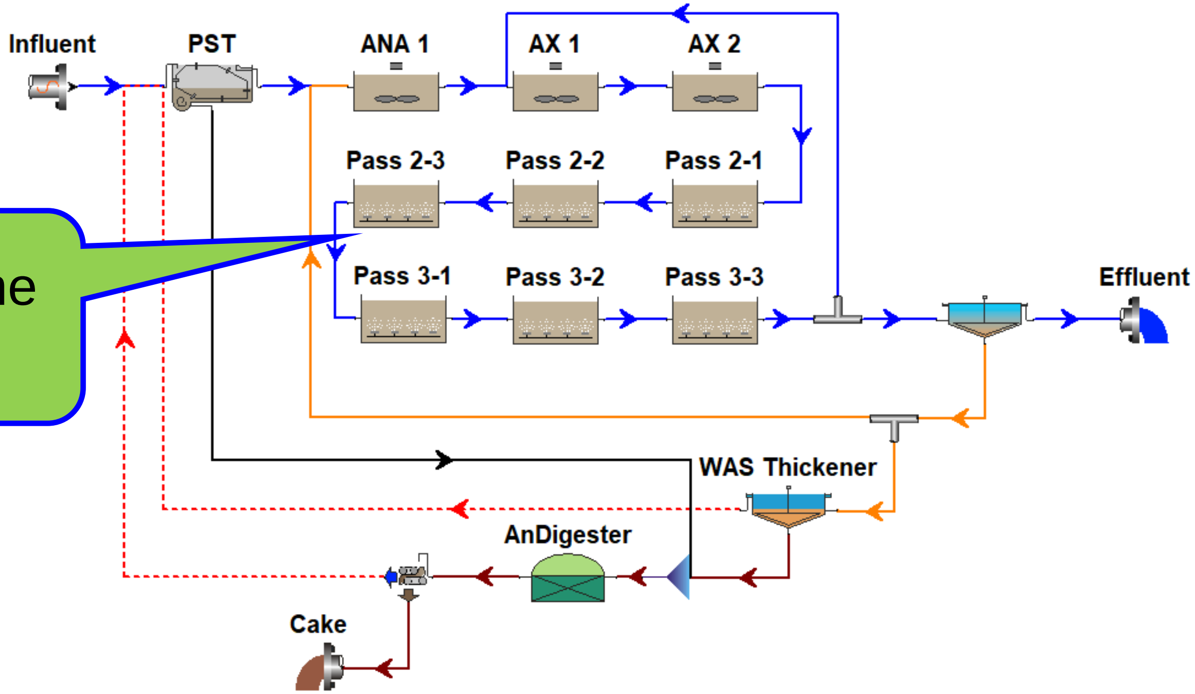
Why Use Modeling & Simulation?

"The Wastewater Treatment Industry is using modeling as a tool to extend traditional design methods"

- New generation of WWTPs are complex
  - Nutrient Removal
  - Return Streams

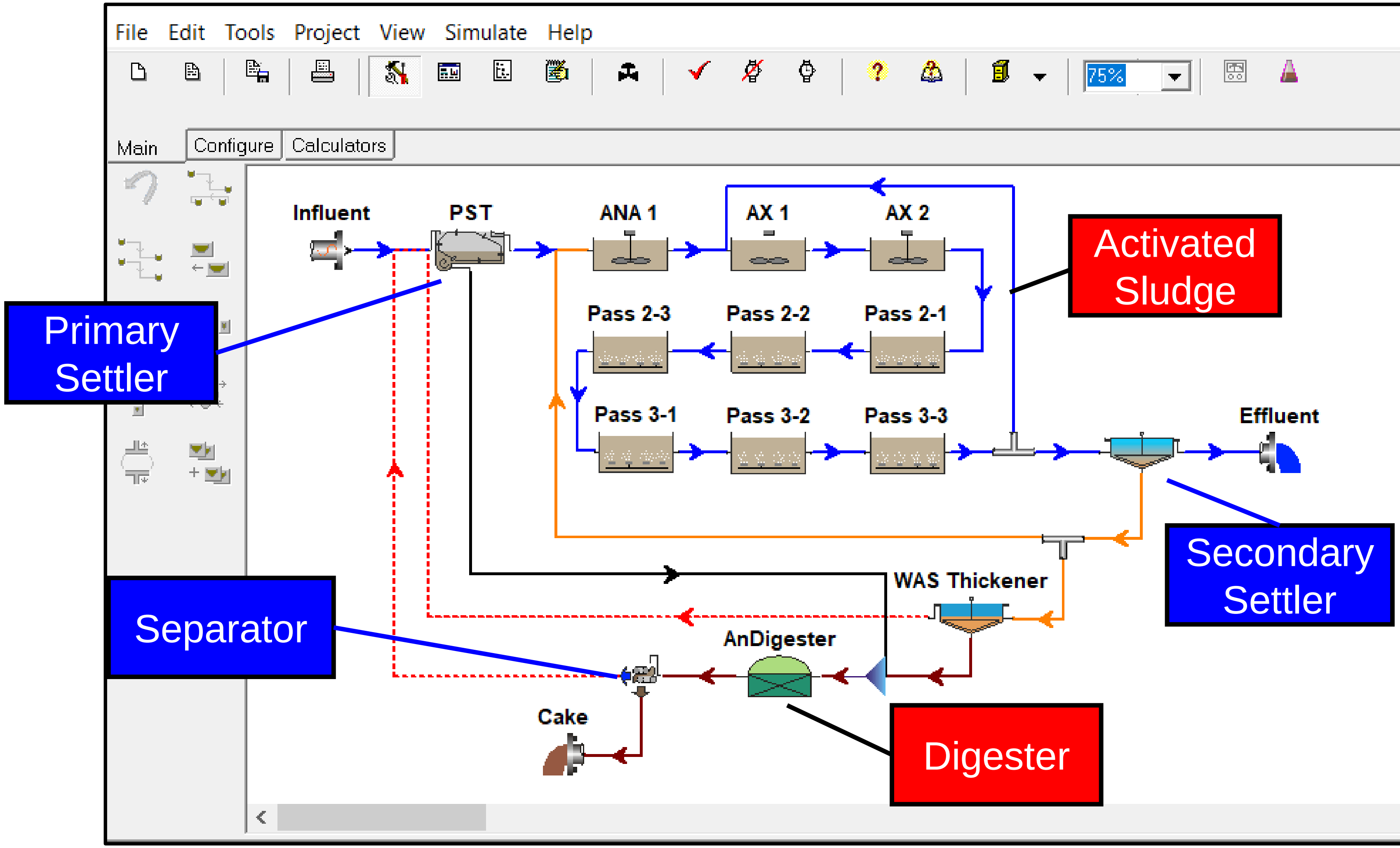
Simulation allows us to understand the interactions in the WHOLE WWTP



Main Purposes for Process Simulation

- ❑ **For process design**
  - To evaluate unit sizes and operating ranges
- ❑ **For process analysis**
  - As an optimization tool
- ❑ **For process operation**
  - To answer “What if…?” questions
- ❑ **For operator training**

Models in BioWin



BioWin Model

Activated Sludge – Anaerobic Digestion Model

- ❑ Carbonaceous material removal
- ❑ Nitrification (NH_4 → NO_2 → NO_3)
- ❑ Denitrification (NO_3 → N_2)
- ❑ Deammonification (Partial nitrification + Anammox)
- ❑ Biological phosphorus removal
- ❑ Sulfur oxidation / reduction
- ❑ Fermentation
- ❑ Anaerobic digestion (i.e. methane production)
- ❑ Chemical precipitation (pH)

BioWin Model

Tracking Components (State Variables)

❑ Biomass Components

→ Ordinary (non-polyP) heterotrophs (OHOs)

→ PolyP heterotrophs (PAOs)

→ Nitrifiers (AOBs and NOBs)

→ Anammox organisms

→ Anoxic methanol utilizers

→ Propionic acetogens

→ Methanogens

→ Endogenous residue

→ Sulfur oxidizing organisms

→ Sulfur reducing organisms

❑ Other Components

→ Organics
- Soluble/particulate
- Biodegradable/unbiodegradable

→ Nitrogen
- Ammonia, nitrite, nitrate
- Soluble/particulate organic N

→ Phosphorus
- Soluble and precipitated phosphate
- Organic P

→ Inorganic suspended solids
- ISS = TSS – VSS

→ Metals (Ca, Mg, Fe, Al) & Cations/Anions

→ Precipitates (e.g. Struvite, metal oxides)

→ Oxygen and other gases

BioWin Model

Model Processes

❑ Biological

→ Aerobic heterotrophic growth

→ Anoxic heterotrophic growth on nitrate & nitrite

→ Anaerobic fermentation

→ Growth of bio-P microorganisms and storage of polyphosphate

→ Various hydrolysis, ammonification and colloidal flocculation reactions

→ Assimilative nitrate and nitrite reduction

→ Growth of ammonia and nitrite oxidizer biomasses

→ Growth of Anammox microorganisms

→ Growth of autotrophic and heterotrophic methanogens

→ Decay of all active biomasses in different environments

→ Inorganic suspended solids fixation during polyP storage and heterotrophic growth

BioWin Model

Model Processes

❑ Physical & Chemical

→ Species distribution for weak acid systems:

- Carbonate
- Ammonia
- Phosphate
- Acetate and propionate
- Nitrous acid

→ pH estimation based on strong acids and bases, week acids, charge balancing, and reactions

→ Precipitation of various calcium, magnesium, aluminum and iron complexes

→ Gas transfer for stripping and dissolution of gases: O_2, CO_2, N_2, N_2O, NH_3, H_2S, H_2, CH_4

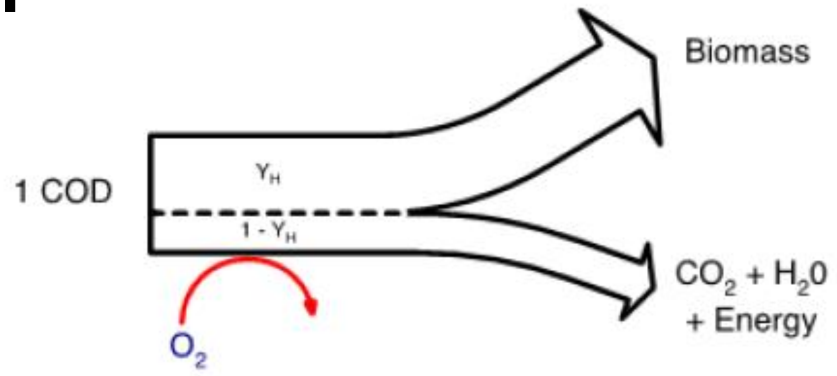
Model Basics

Carbonaceous Material Removal

❑ Aerobic Heterotrophic Growth

$$2.57\ C_{2.43}H_{3.96}O + 2.50\ O_2 + NH3 \rightarrow$$

$$C_5H_7O_2N + 1.24\ CO_2 + 3.09\ H_2O$$



Biomass

$$C_5H_7O_2N + 5O_2 \longrightarrow 5CO_2 + 2H_2O + NH_3$$

5x12 + 7x1 + 2x16 + 1x14 = 113 g VSS

5x32= 160 g O_2

$$1\ g\ COD \xrightarrow{\text{Stabilized by}} (1 - Y_H)\ g\ O_2$$

$$\frac{COD}{VSS} = \frac{160}{113} = 1.42\ gCOD/gVSS$$

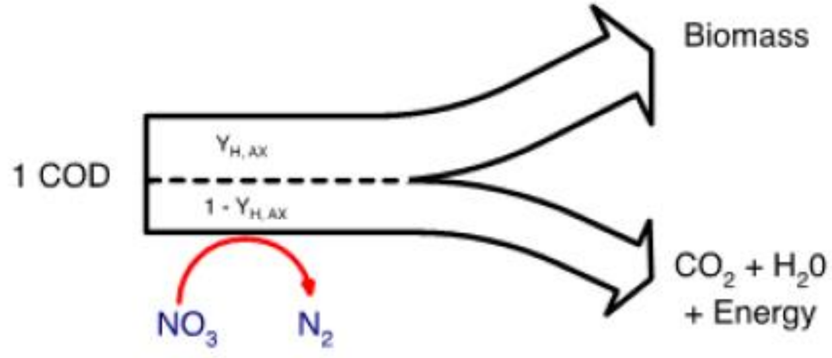
$$\frac{N}{VSS} = \frac{14}{113} = 0.12\ gN/gVSS$$

Model Basics

Carbonaceous Material Removal

- ❑ **Anoxic Heterotrophic Growth - Denitrification**

$$2.57\ C_{2.43}H_{3.96}O + 2.0\ HNO_3 + NH_3 \rightarrow$$
$$1.24\ CO_2 + C_5H_7O_2N + N_2 + 4.09\ H_2O$$



$$1\ g\ COD \xrightarrow{\text{Stabilized by}} (1 - Y_H)\ g\ O_2 \cdot \frac{1\ g\ NO_3 \cdot N}{2.86\ g\ O_2}$$

Model Basics

Nitrification

❑ Nitrification

$$NH_4 \xrightarrow{AOB} NO_2 \xrightarrow{NOB} NO_3$$

$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + 2H^+ + H_2O$$

$$2\ mol\ O_2 \Longrightarrow 1\ mol\ NO_3^- \cdot N$$

$$64\ g\ O_2 \Longrightarrow 14\ g\ NO_3^- \cdot N$$

$$\frac{64}{14} = 4.57\ g\ O_2 \Longrightarrow 1\ g\ NO_3^- \cdot N$$

$$2\ mol\ H^+ \Leftrightarrow 1\ mol\ NO_3^- \cdot N$$

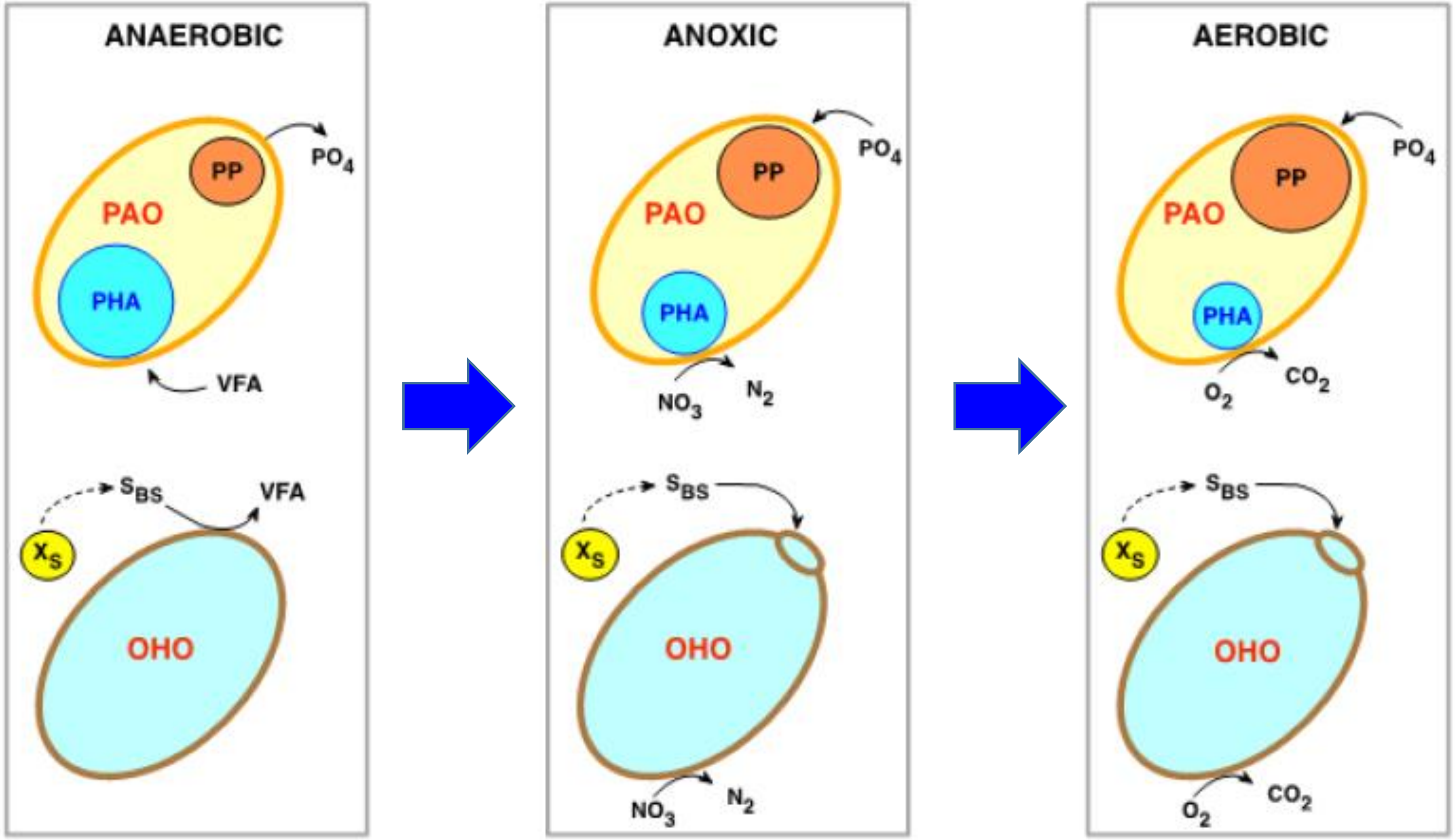
$$2\ mol\ H^+ \cdot \frac{1\ mol\ CaCO_3}{2\ mol\ Alk} \Leftrightarrow 14\ g\ NO_3^- \cdot N$$

$$100\ g\ CaCO_3 \Leftrightarrow 14\ g\ NO_3^- \cdot N$$

$$\frac{100}{14} = 7.14\ g\ CaCO_3 \Leftrightarrow 1\ g\ NO_3^- \cdot N$$

Model Basics

Biological P Removal



Fermentation Denitrification Nitrification

→ Phosphorus Accumulating Organisms (PAO) have the ability to store phosphorus within the cells as long chains of inorganic polyphosphate (PP), commonly known as volutin granules

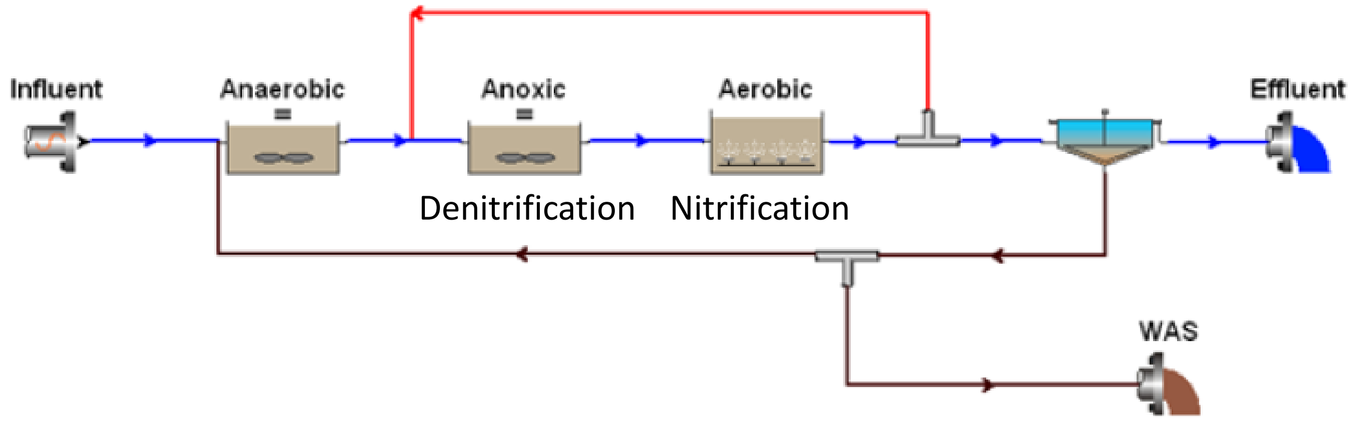
→ Under anaerobic conditions, the energy associated with PP bonds can be used to take up VFAs and PAOs store Polyhydroxyalkanoates (PHA) until they reach alternative terminal electron accepters (i.e. NO_3 & O_2)

→ In the anoxic & aerobic zones, PAOs metabolize the PHA and use the energy to take up all available phosphorus using oxygen or nitrate as electron acceptor

BioWin Model

Biological Nutrient Removal System

❑ Biological N & P Removal (3-Stage Bardenpho Process)



❑ What impacts nutrient removal performance?

- → Influent wastewater characteristics
- → Size of anaerobic and anoxic zones
- → Temperature
- → Solid retention time (SRT)
- → Dynamic behavior