2017 Annual Conference

March 28-31

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pa rural water Association

Welcome!

NUTRIENT REMOVAL PROCESSES IN WASTEWATER TREATMENT

We're Glad You're Here!

Please, put your cell phones on vibrate during sessions and, take calls to the hallway

NUTRIENT REMOVAL PROCESSES IN WASTEWATER TREATMENT

Presenters:

Heath Edelman, PE

Chris Hannum, PE

ENTECH ENGINEERING

1.800.825.1372 | www.entecheng.com

References

- *Biological Nutrient Removal (BNR) Operation in Wastewater Treatment Plants*. WEF Manual of Practice No. 29. Virginia: Water Environment Federation, 2005. Print.

- Gerardi, Michael. *Nitrification and Denitrification in the Activated Sludge Process*. New York: John Wiley and Sons, Inc., 2002. Print.

References

- *Wastewater Engineering: Treatment and Disposal, 4th Edition*. Metcalf and Eddy, McGraw-Hill, 2003. Print.

SECTION 1

- Wastewater Characteristics
- Pollution Concerns
- BNR Zones and Conditions
- Nitrogen Removal
- Phosphorus Removal

Section 1 – Main Goals

- Identify the rational for nutrient limits including their pollution concerns
- Identify the **zones** and **conditions** required for nitrification, denitrification, and enhanced biological phosphorus removal

WW CHARACTERISTICS

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

Contaminants	Low (mg/L)	Medium (mg/L)	High (mg/L)
TSS	**120**	**210**	**400**
BOD	**110**	**190**	**350**
Nitrogen (total as N)	**20**	**40**	**70**
Organic	8	15	25
Free Ammonia	12	25	45
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P)	**4**	**7**	**12**
Organic	1	2	4
Inorganic	3	5	10

Sources of Nitrogen

- Nitrogen is a naturally occurring element that is essential for growth and reproduction in all living organisms.

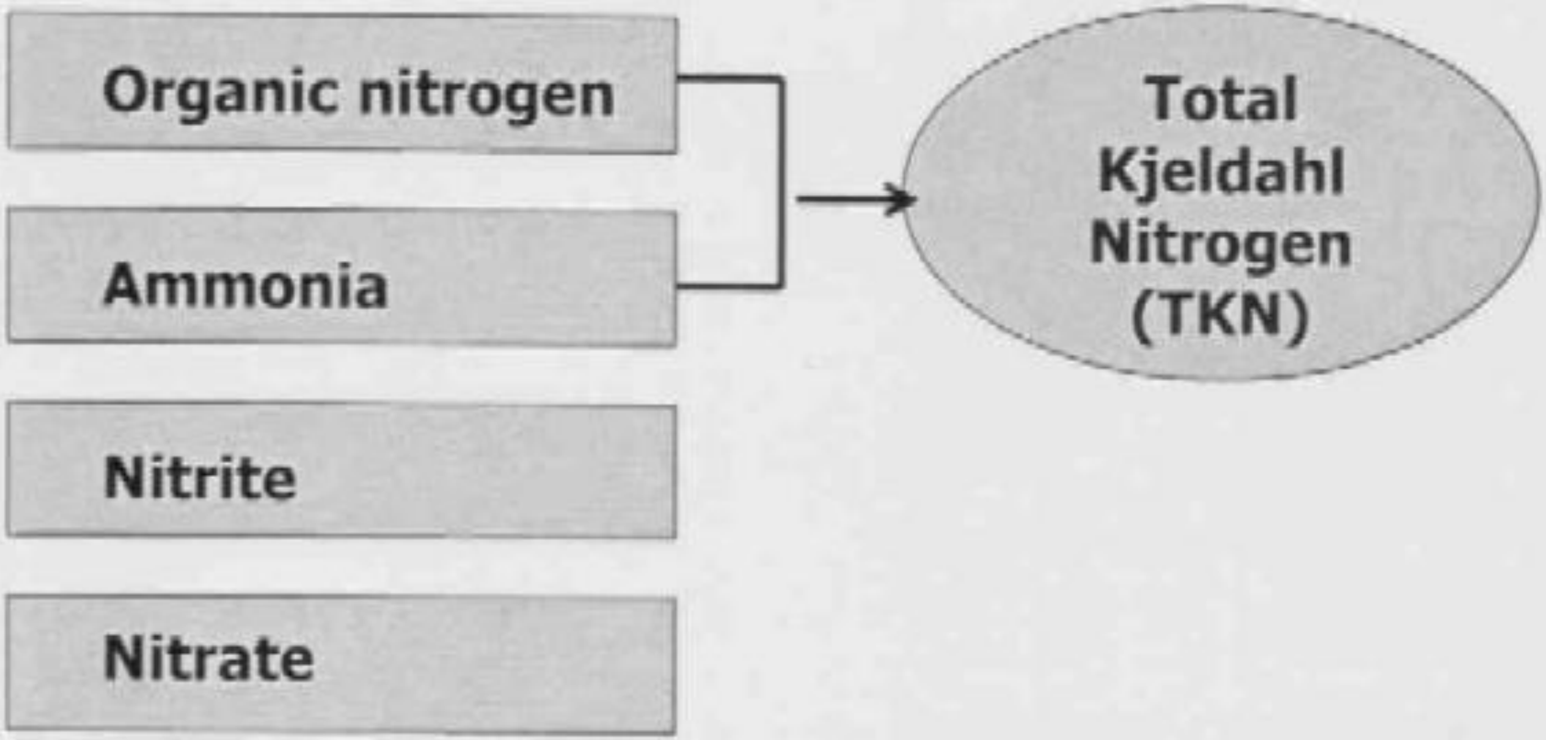
- Nitrogen is the most abundant compound in the atmosphere

Forms of Nitrogen

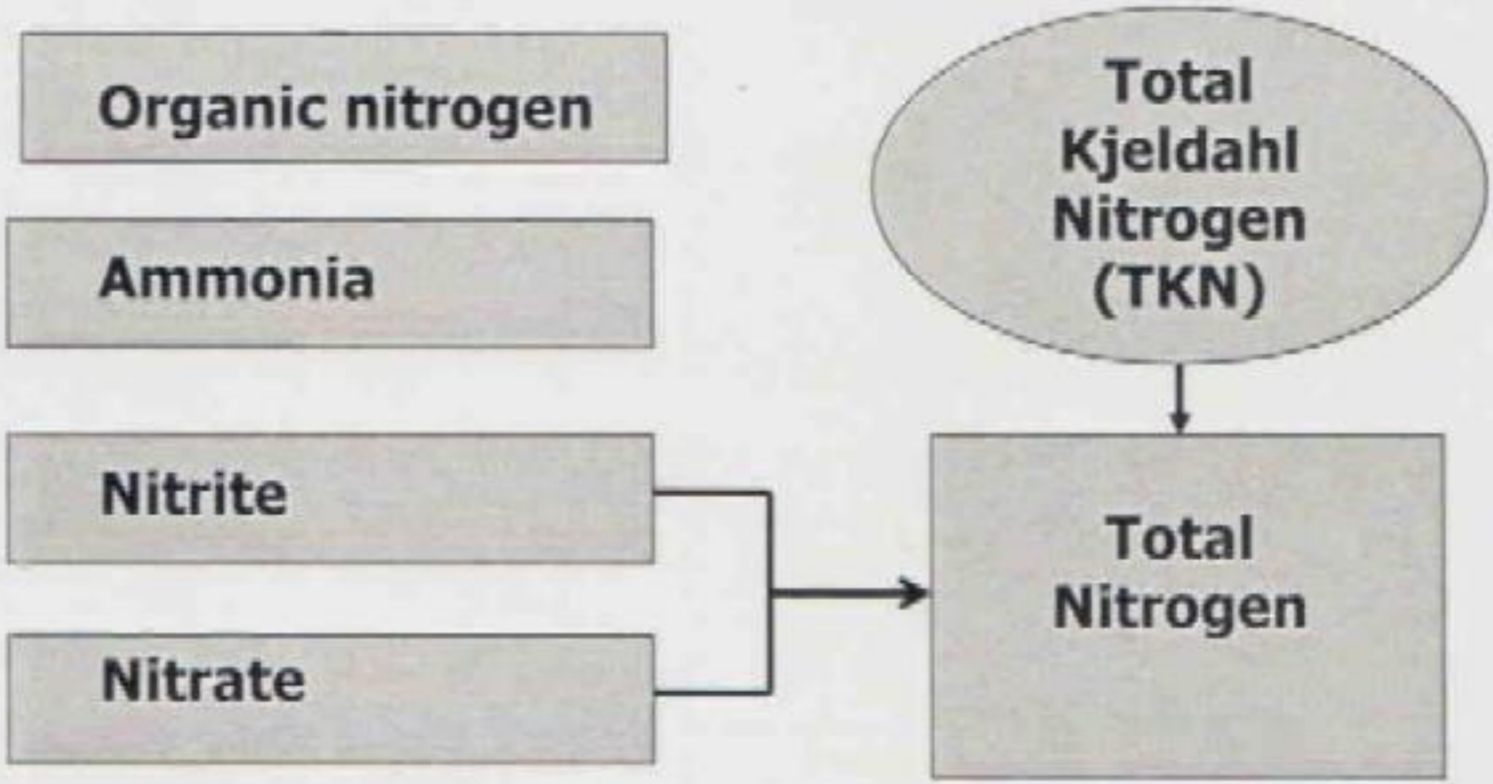
- Ammonia (NH_3)
- Ammonium ion (NH_4^+)
- Organic Nitrogen

- Nitrite (NO_2^-)
- Nitrate (NO_3^-)
- Nitrogen Gas (N_2)

Groups of nitrogenous compounds



Groups of nitrogenous compounds



Sources of Phosphorus

- Phosphorus is a key component in the process of energy metabolism by cells and the cell membrane

- Phosphorus is found in:
  - Fertilizers
  - Detergents / Cleaning Products
  - Human / Animal Waste

Forms of Phosphorus

- **Orthophosphates**
  - Phosphate ion (PO_4^{3-})
    - Simplest form; available for biological
    - Form that is precipitated; chemical removal
    - 70% - 90% of TP
  - Phosphoric Acid (H_3PO_4)
  - Dihydrogen Phosphate ($H_2PO_4^-$)
  - Hydrogenophosphate (HPO_4^{2-})
- **Polyphosphates (condensed phosphates)**
  - Complex forms of inorganic orthophosphates

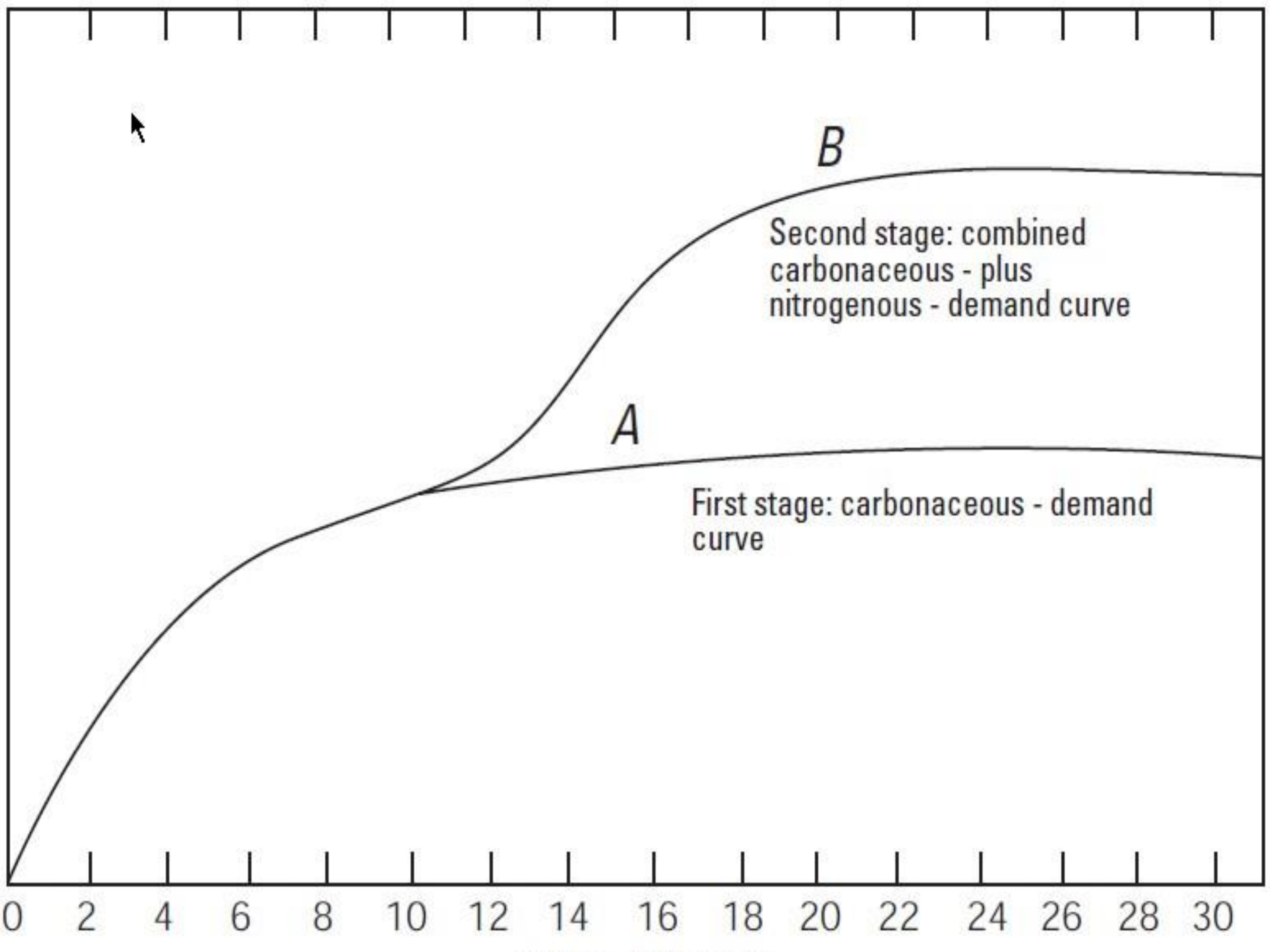
Forms of Phosphorus

- **Organic Phosphates**
  - Soluble
    - Biodegradable
    - Non-Biodegradable (refractory)
  - Particulate

POLLUTION CONCERNS

Nutrient – Pollution Concerns

- DO Depletion
- Ammonia (Fish) Toxicity – NH_3
- Eutrophication; plant and algae growth
- Nitrate in Groundwater
  - Methemoglobinemia
    - Blue Baby Syndrome


B
Second stage: combined carbonaceous - plus nitrogenous - demand curve
A
First stage: carbonaceous - demand curve
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

Effluent Limits

- Approximately 25% of all water body impairments are due to nutrient-related causes (US EPA, 2007)

- Stringent effluent limits for Nitrogen and Phosphorus
  - DEP; NPDES
  - Basin Commissions; Docket

Chesapeake Bay Strategy

- Chesapeake Bay Strategy
  - – Existing WWTP not designed to limit nutrients
  - – Limit Total Nitrogen (TN) and Total Phosphorus (TP) discharges

    - 0.4 MGD X 6.0 mg/L TN X 8.34 X 365 days

      = 7,306 # TN per year

    - 0.4 MGD X 0.8 mg/L TP X 8.34 X 365 days

      = 974 # TP per year

Nutrient Credits

- Act 537 Planning
- Current cost of credits

BNR - Zones and Conditions

Biological Nutrient Removal (BNR)

- BNR (Biological Nutrient Removal)
  - The biological removal of nitrogen and/or phosphorus through the use of microorganisms under different environmental conditions in the treatment process. (Metcalf and Eddy, 2003)

BNR – Basic Design Considerations

- SRT: Solids inventory in reactor (MLSS) / Mass of MLSS wasted per day
  - Stable population of nitrifiers
- HRT: Hydraulic – allow time to react with pollutant
- Process parameters
  - Organic loading rate
  - F:M
  - Aeration system capacity and layout

Biological Nutrient Removal (BNR)

- **Aerobic Zone**
  - BOD removal
  - Nitrification
  - Phosphorous removal

BNR – Basic Design Considerations

Aerobic Zone

- Optimum Oxygen and Mixing
- Aerobic SRT for Nitrification
- MLSS Concentration
- HRT
- Temperature

Biological Nutrient Removal (BNR)

- **Anoxic Zone**
  - **Still has Oxygen Available in the form of NOx**
  - Conversion of nitrate (NO_3-) to nitrogen gas (N_2)
    - Denitrification

Picture: www.suikime.com

Biological Nutrient Removal (BNR)

- **Anaerobic Zone**
  - Production of VFA for growth of Bio-P bacteria
  - Control of obligate aerobic filamentous bacteria

Picture: www.suikime.com

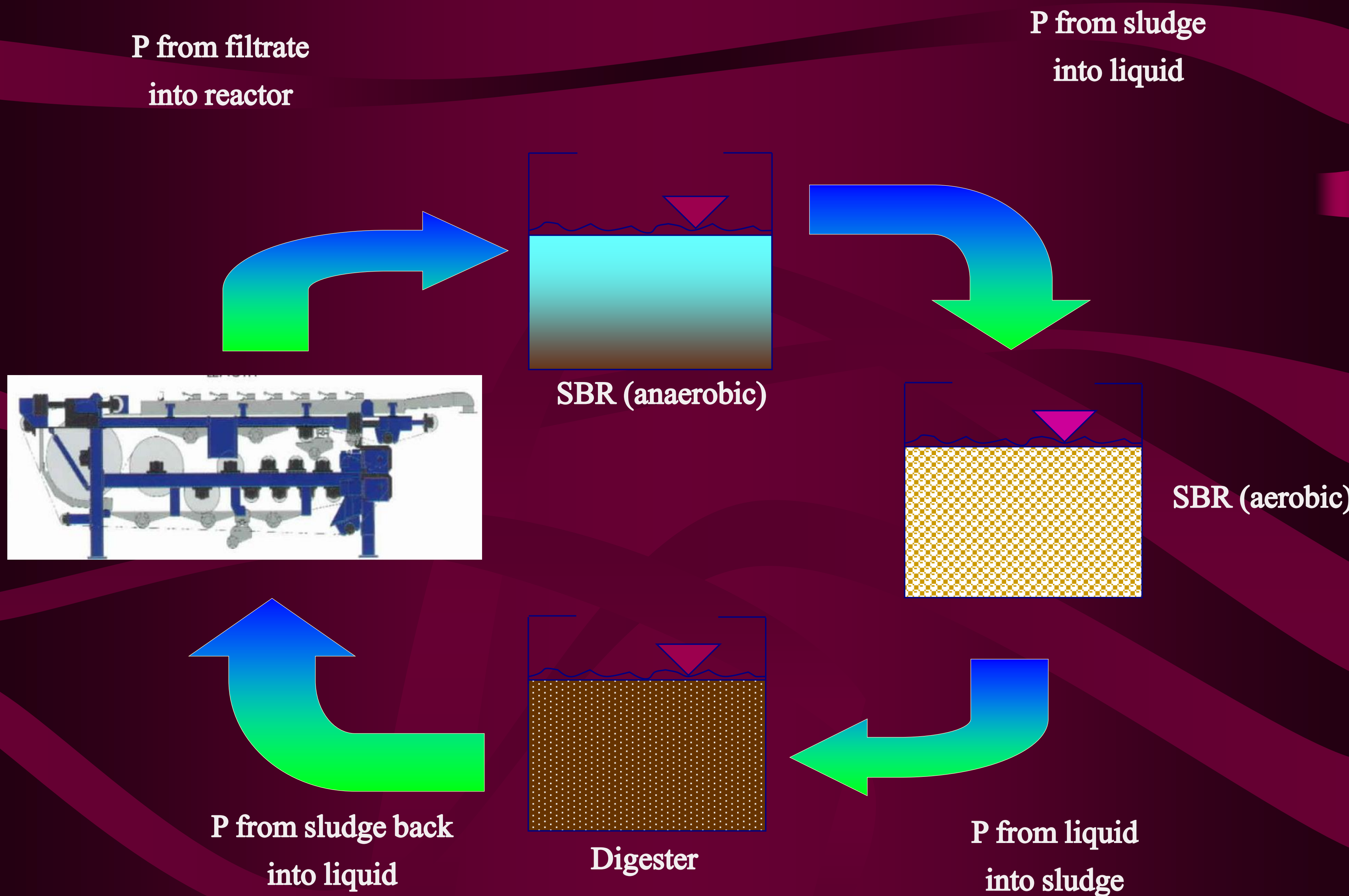
BNR – Basic Design Considerations

- **Anoxic Zone**
  - Little to no D.O; <0.5 mg/L
  - BOD: NO_3-N Ratio *(2.86 : 1)*
  - HRT *(2.5 – 3.0 Hours)*
  - MLSS Recirculation Rate *(1 – 4Q)*

- **Anaerobic Zone**
  - No D.O. and minimum nitrate
  - HRT *(1.0 – 1.5 Hours)*
  - BOD: P Ratio *(30:1)*
  - MLSS Recirculation Rate *(~2Q)*

BNR – Slug Loads / Recycle

- Sludge Thickening
- Digestion
  - Anaerobic
  - Aerobic
- Dewatering
- Filter backwash
- Septage Receiving


P from filtrate into reactor
P from sludge into liquid
SBR (anaerobic)
SBR (aerobic)
P from liquid into sludge
Digester
P from sludge back into liquid

NITROGEN REMOVAL

NITRIFICATION

- Two-step biological conversion
  - The conversion of ammonium (NH_4^+) to nitrite (NO_2^-), and finally to nitrate (NO_3^-)
    - Nitrosomonas; rate limiting step
    - Nitrobacter; max growth rate is higher

- Nitrification bacteria grow much slower than heterotrophic bacteria.
  - Need longer hydraulic retention time
  - Need longer solids retention time

NITRIFICATION

$$NH_4^+ + 1.5\ O_2 \longrightarrow NO_2^- + H_2O + 2\ H^+$$

Oxygen Required = 3.43 lb / lb N Oxidized

Alkalinity Required = 7.14 lb as $CaCO_3$ / lb N Oxidized

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

Oxygen Required = 1.14 lb / lb N Oxidized

For Both Reactions

Oxygen Required = 4.57 lb / lb N Oxidized

Alkalinity Required = 7.14 lb as $CaCO_3$ / lb N Oxidized

NITRIFICATION

- As with BOD removal, nitrification can be accomplished in both suspended growth and attached growth processes:

- Suspended Growth (Activated Sludge)
  - Single Sludge Nitrification
    - Aeration Tank / Clarifier / Sludge Return System
  - Two Sludge Nitrification
    - Two aeration tanks and two clarifiers in series
      - First Aeration tank = BOD Removal
      - Second Aeration Tank = Nitrification

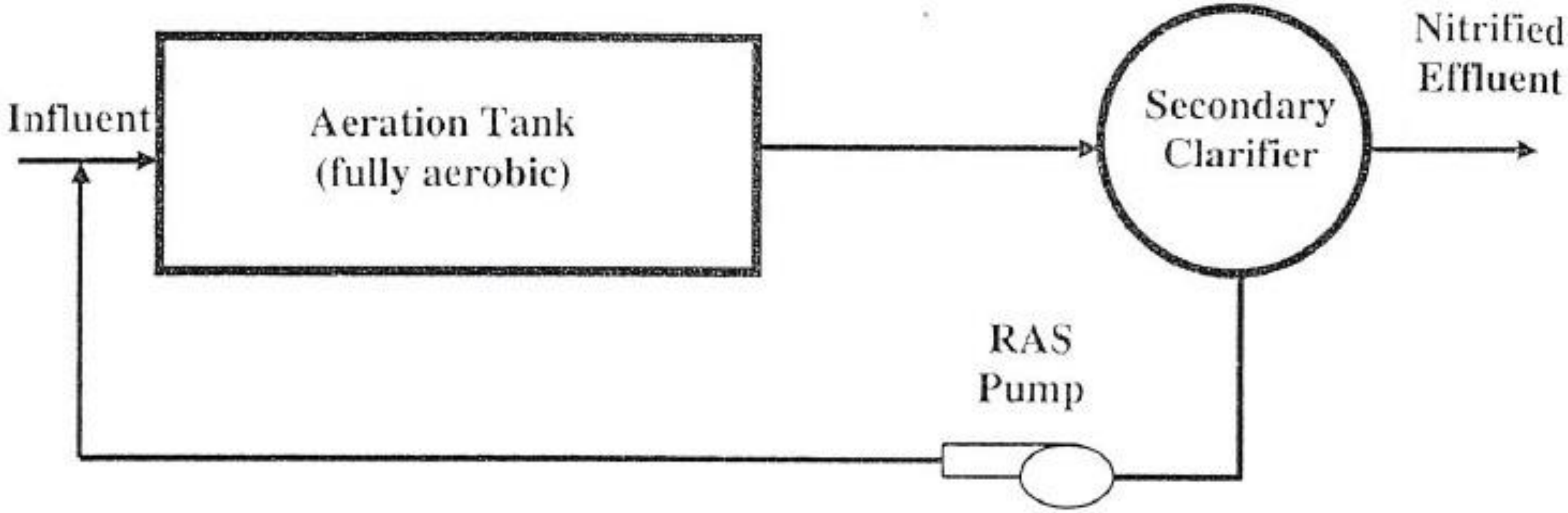
- Attached Growth
  - BOD consumed first / then nitrification

Environmental Factors

- Temperature
- DO Concentration
- pH and Alkalinity
- Toxicity / Inhibition
  - Sensitive
  - Heavy metals
  - Un-ionized ammonia

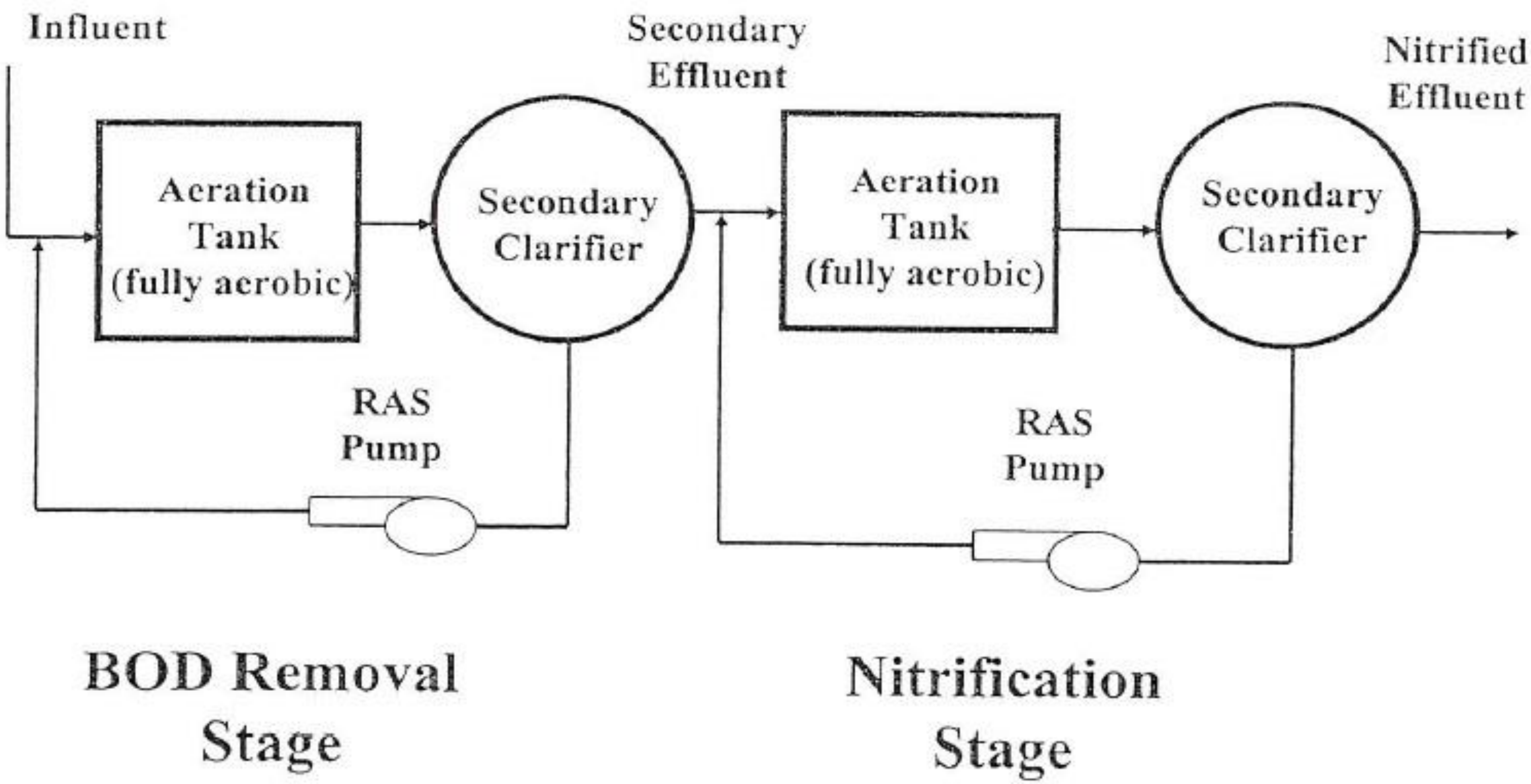
Single Sludge System

Biological Nutrient Removal (BNR) Operation in Wastewater Treatment Plants



BOD Removal & Nitrification

Two Sludge System



DENITRIFICATION

- The conversion of nitrate (NO_3^-) to nitrogen gas (N_2)
  - Can use Oxygen, Nitrate, or Nitrite as their terminal electronic acceptor (oxygen source)

DENITRIFICATION

NO_3 + **Org. Carbon** → $N_2 + CO_2 + OH + H_2O$

$CO_2 + OH$ → HCO_3

NO_3 → NO_2 → NO → N_2O → N_2

2.86 lbs oxygen recovered / lb NO_3-N

3.57 lbs alkalinity recovered / lb NO_3-N

DENITRIFICATION – Carbon Augmentation

- Methanol
- Ethanol
- Acetic Acid
- Molasses
- Food processing organic waste (sugars)
  - Soft drink wastes
- Engineered substances

PHOSPHORUS REMOVAL

Don't I Remove Phosphorus Now?

- Influent phosphorus = 4 mg/L to 12 mg/L

- Without phosphorus removal
  - 5% to 10%: Primary Settling / Secondary Clarification
  - 20% to 25%: Bacteria growth in Activated Sludge process
    - 200 mg/L BOD removes 2 mg/L TP

Final effluent: 3 mg/L to 4 mg/L TP

(Further) Phosphorus Removal

- **Chemical Precipitation**
  - Iron
  - Aluminum
  - Calcium

- **Enhanced Biological Phosphorus Removal (EBPR)**

- **Physical**
  - Filtration
  - Membrane Technologies

Chemical Precipitation

- Phosphate concentration
- Effects of pH
- Dose Requirements

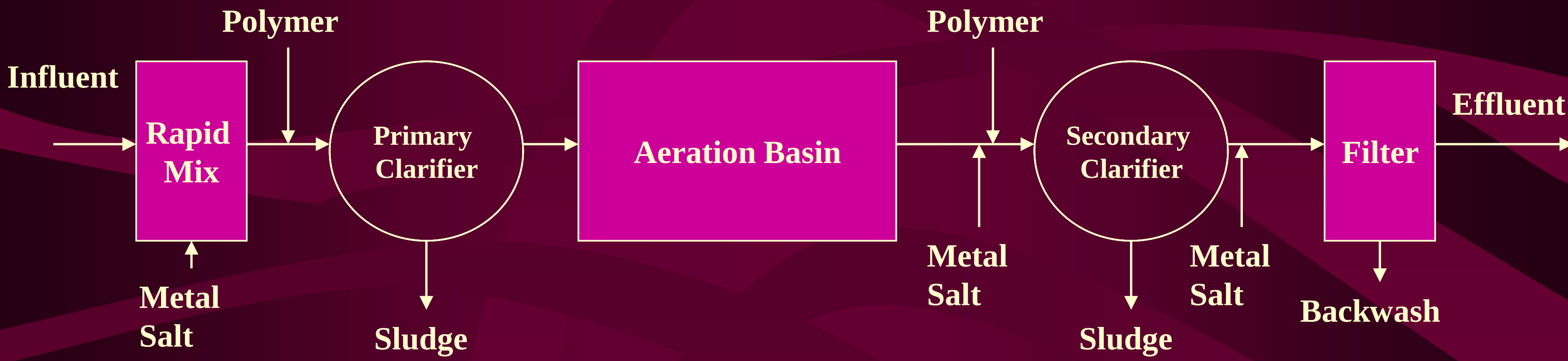
Chemical Precipitation

- **Iron Compounds**
  - Ferric Chloride ($FeCl_2$); Most typical
  - Ferrous Chloride ($FeCl_3$)
  - Ferrous Sulfate ($Fe(SO_4)$)

- **Aluminum Compounds**
  - Aluminum Sulfate (Alum); Most typical
  - Sodium Aluminate
  - Polyaluminum Chloride

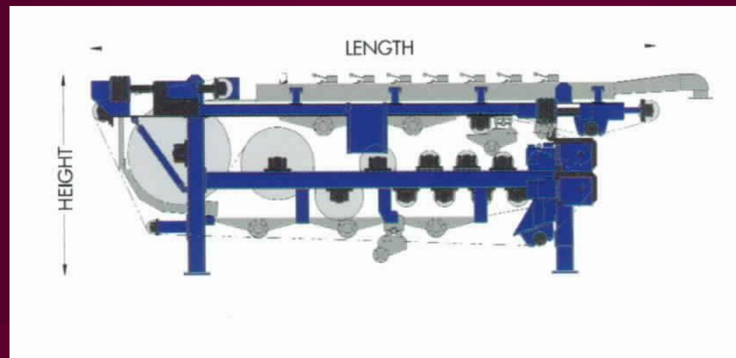
- **Lime Addition**

Chemical Precipitation – Dosing Locations



Sludge Increase - Chemical Precipitation

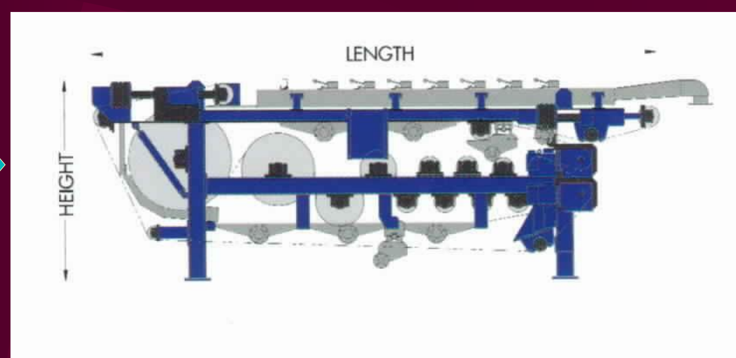
62 dry T/day



Before Phosphorus Removal

353 wet T/day hauled

80 dry T/day



After Phosphorus Removal

414 wet T/day hauled

Biological Phosphorus Removal

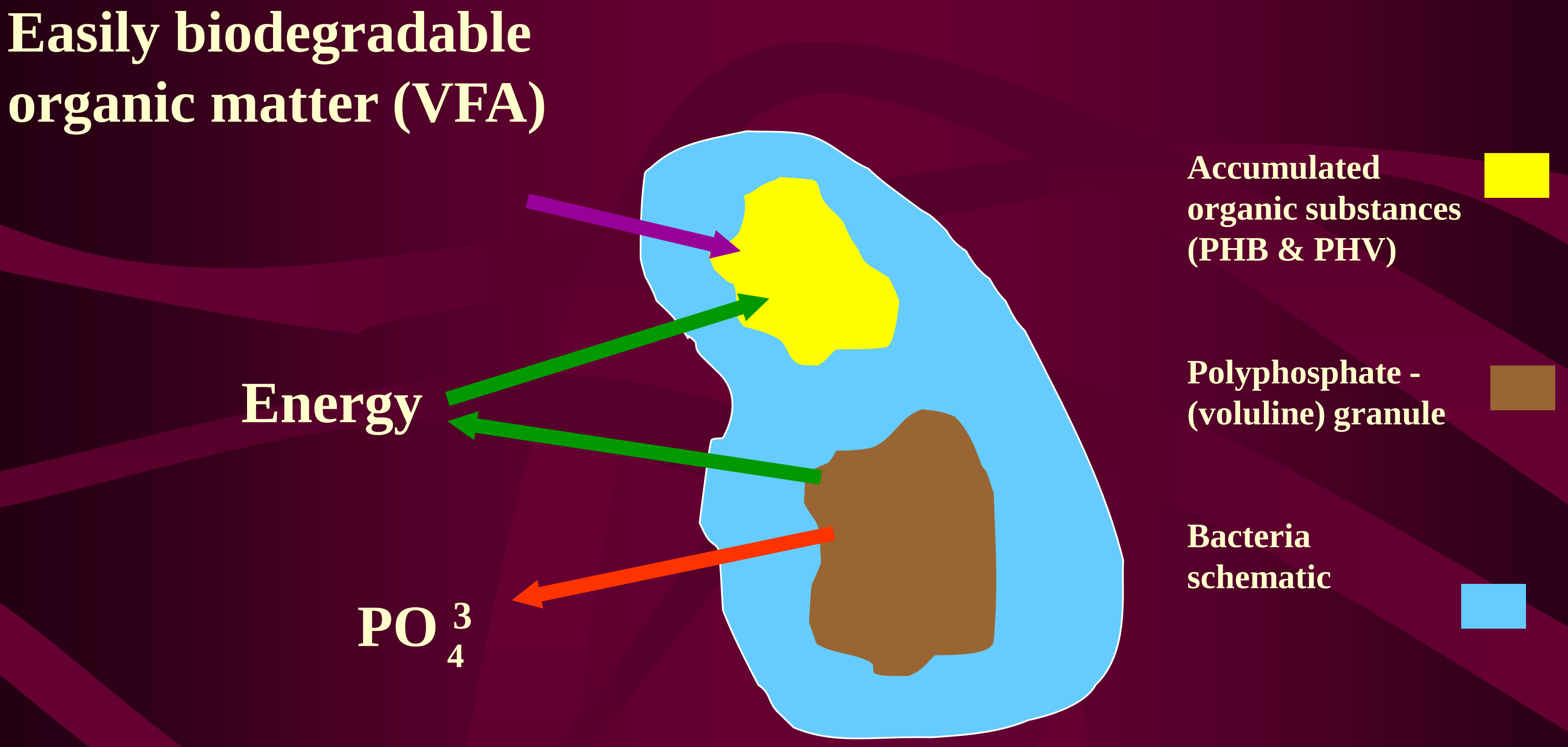
- **Advantages**
  - Less sludge production compared to chemical precipitation
  - More easily dewatered than Alum sludge
  - Less chemical usage

- **Disadvantages**
  - Dependability
  - More Phosphorus release in sludge handling
  - May require chemical backup

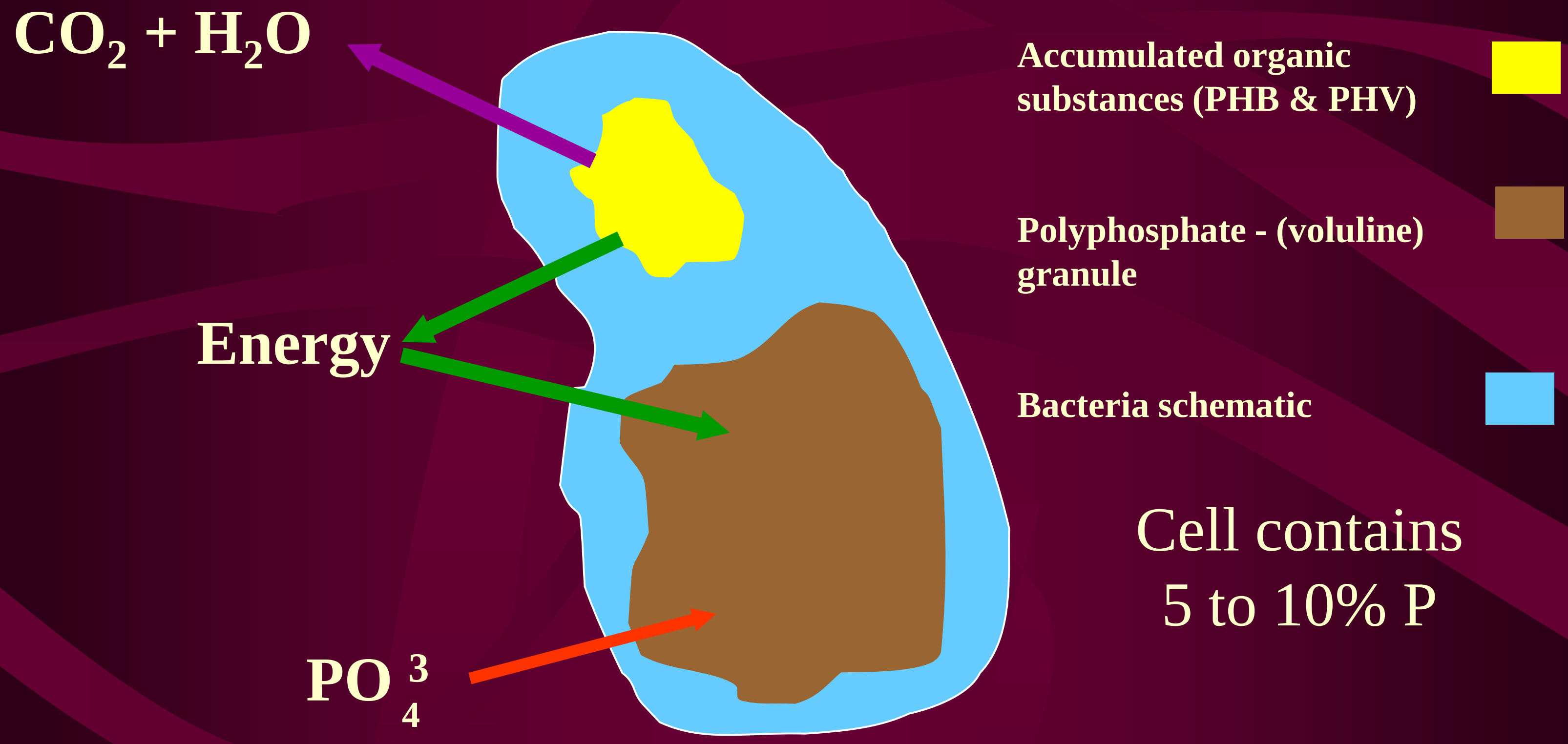
Enhanced Biological Phosphorus Removal (EBPR)

- Volatile fatty acid (VFA) production (anaerobically)
- Phosphorus release by bio-P bacteria (anaerobic conditions)
- Excess phosphorus uptake by bio-P bacteria

Phosphorous Release
Anaerobic Zone



Phosphorus Uptake
Aerobic Zone



Cell contains
5 to 10% P

EBPR Treatment Processes

- Biological Alternatives (anaerobic zone)
  - Modified Bardenpho Process (5-stage)
  - SBR Process
  - Operationally Modified Activated Sludge Process (i.e. oxidation ditch)

Physical

- **Filtration**
  - 2 to 3% of organic solids is TP
  - Effluent TSS of 20 mg/L = 0.4 to 0.6 mg/L TP

- **Membrane**
  - Removes TP is TSS
  - Removes dissolved TP

QUIZ ON SECTION 1 (10 min)

- And then Break (10 min)

SECTION 2

- BNR Processes

Section 2 – Main Goals

- Identify the different treatment processes used to conduct Biological Nutrient Removal (BNR)

- Discuss design and process considerations for retrofitting systems or building new

BNR PROCESSES

BNR Process Configurations

- Although the exact configurations of each system differ, BNR systems designed to remove TN must have:
  - Aerobic Zone for nitrification and ortho P uptake
  - Anoxic Zone for denitrification

- BNR systems designed to remove TP must have:
  - Anaerobic Zone

(Anaerobic = No NOx Anoxic = No D.O.)

Inflow and Infiltration

- How well you control Inflow and Infiltration (I/I) can limit process modifications
- All wastewater systems are only as good as their biology
- Most BNR requires longer MCRT
- Regular wash outs cannot occur if BNR is to occur

Decision Making

- Data, data and more data (more data = less construction costs)

- Synchronized influent and effluent (prior to disinfection) sampling
  - Composite as well as grabs
  - Ammonia, TKN, NO3 and NO2
  - BOD (if you have to)
  - COD preferably
  - Phosphorus
  - Soluble and insoluble forms

BNR Process Configurations – What is right for you?

- Target effluent limits
  - Nutrient credits

- New Plant
  - Of course more flexibility and options

- Retrofit of Existing
  - Usually requires a balance of nutrient credits and some new construction

BNR Process Configurations – What is right for you?

- Retrofit of Existing or Selecting New
  - Aeration basin size and configuration
  - Clarifier capacity
  - Type of aeration system
  - Sludge processing units
  - Instrumentation
  - Operator skills

BNR Process Configurations – What is right for you?

- Aeration basin size and configuration
  - Creating anoxic and anaerobic space
  - Hydraulic grade through the system
  - W/O new tanks you are borrowing from existing capacity (see sampling)
  - Depth for aeration and transfer efficiency has to be a consideration
  - Segregation – fiberglass or concrete baffles
  - Package system – post segregation

BNR Process Configurations – What is right for you?

- Clarifier capacity
  - No specific need for a lower mass flux rate
  - BNR sludges are anticipated to settle better
  - Nitrification/Denitrification control requires the removal of sludge from the clarifier in a rapid fashion
  - Direct suction clarifier or single sweep type can enhance the removal
  - Package systems can present issues (air-lifts)

BNR Process Configurations – What is right for you?

- Type of aeration system
  - Gentle fine bubble diffusers avoids potential shearing
  - D.O. control with VFD blower motor is a must for consistent reliability
  - Basin geometry and segregation considerations
  - D.O. trending is recommended

BNR Process Configurations – What is right for you?

- Sludge processing units
  - Accumulation of nutrients in the sludge
  - Dewatering and supernatant can return high strength waste to the process
  - Higher solubility that allows for accelerated uptake
  - Low digester alkalinity can solubilize phosphorus
  - Test your current filtrate and supernatant

BNR Process Configurations – What is right for you?

- Operator skills
  - Finer touch with your system
  - In house sampling and knowledge takes on a larger role
  - Data logging and understanding takes additional operator time
  - Most new systems require an understanding of PLC and SCADA components

Suspended Growth Systems

- Wuhrmann Process
- Ludzack-Ettinger Process
- Modified Ludzack-Ettinger (MLE) Process
- Bardenpho Process (Four Stage)
- Bardenpho Process (Five Stage)
- Sequencing Batch Reactor (SBR)
- Oxidation Ditch Processes

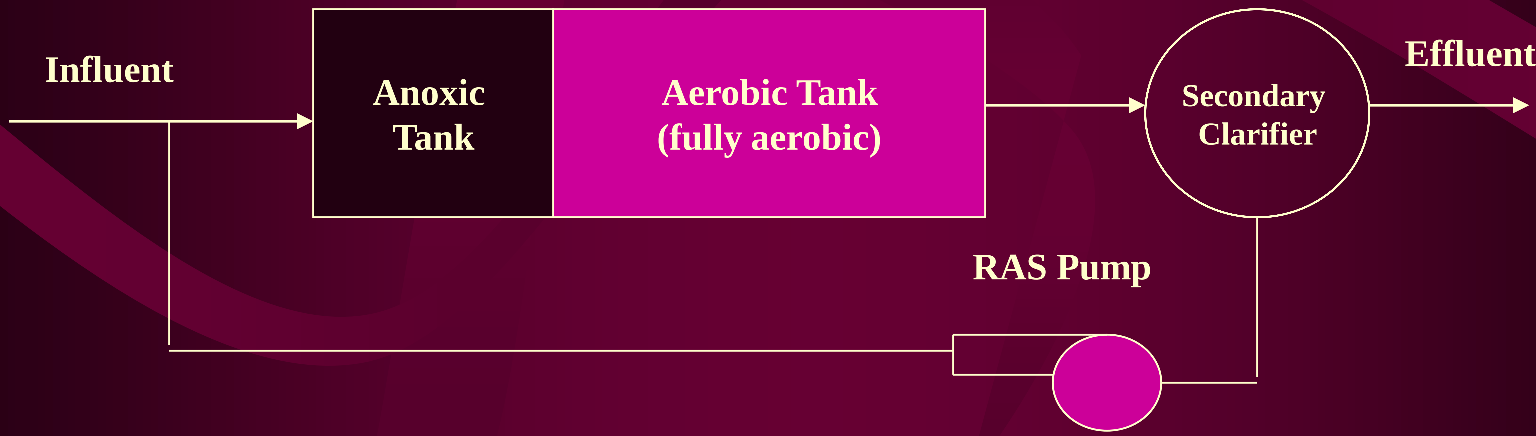
Wuhrmann Process

- The Wuhrmann Process is a single sludge nitrification system with the addition of an unaerated anoxic reactor between the aerobic nitrifying reactor and the secondary clarifiers.

- This treatment system configuration places the denitrification reactor after the nitrification step. It should be noted that the lack of carbonaceous substrate available for denitrification in the anoxic tank significantly limits the denitrification rate.

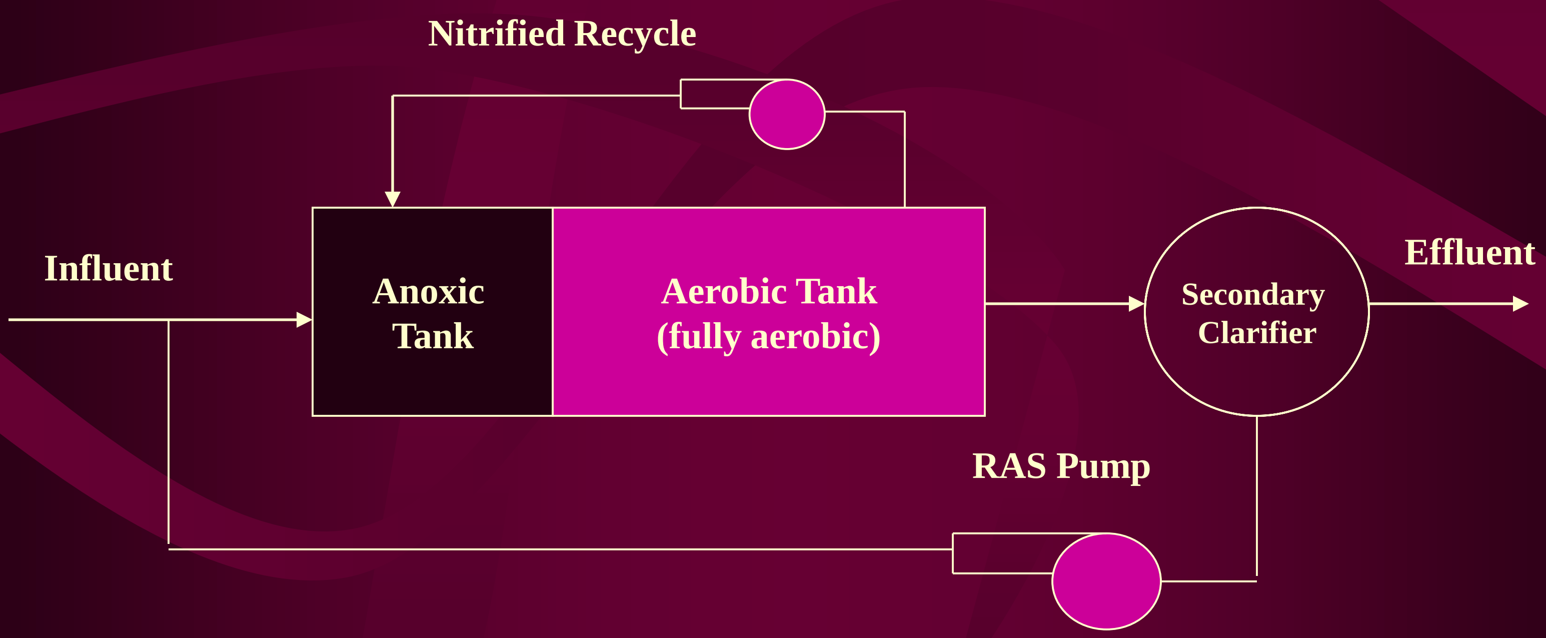
Ludzack-Ettinger Process

- Initially developed to take advantage of the carbonaceous substrate available in the influent wastewater by placing the anoxic reactor upstream of the nitrification reactor.
- In this design, nitrates included in the RAS flow are mixed with influent wastewater and "reduced" to nitrogen gas in a pre-denitrification reactor upstream of the aeration basin.
- This process is limited in total nitrogen removal efficiency due to the quantity of nitrate recycled back to the anoxic zone in the RAS flow.



Modified Ludzack Ettinger (MLE) Process

- This process modifies the Ludzack-Ettinger process by adding a recirculation of mixed liquor recycle (MLR) from the end of the aeration tank to the beginning of the anoxic tank.



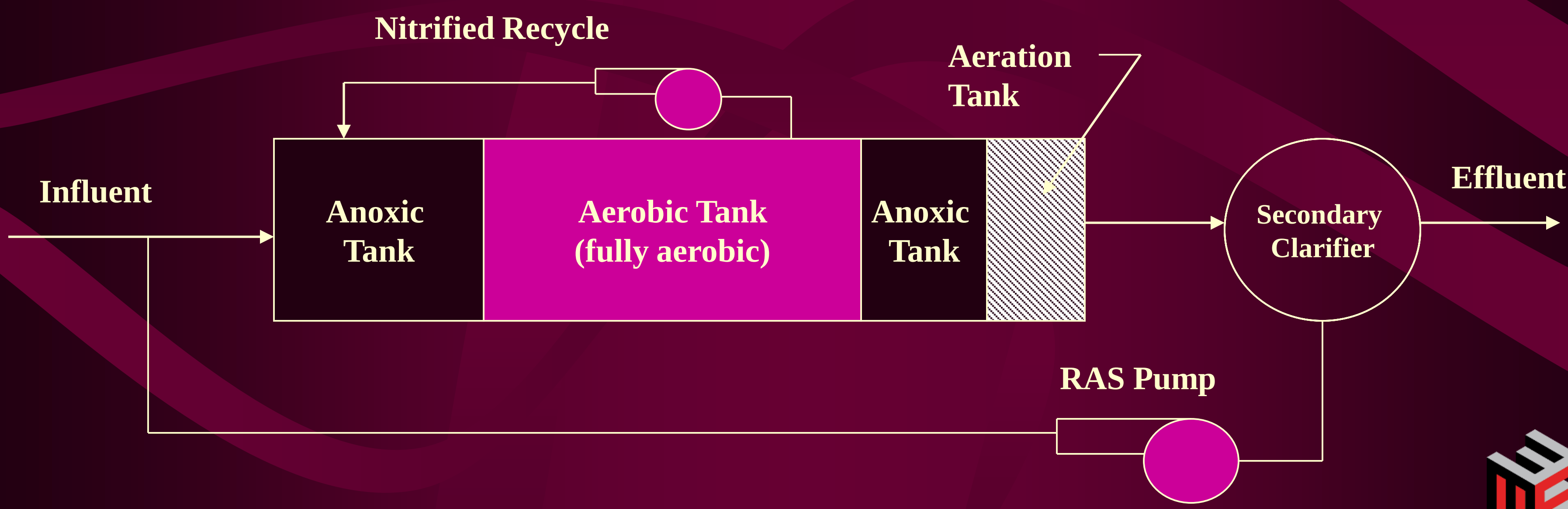
MLE Process – Monitoring Requirements

Reactor	Parameter	Rationale
Anoxic	D.O.	Reduce denitrification rate; will use O2.
	Nitrate-N	High nitrate recycled to aerobic zones may cause filamentous bulking.
Aerobic	Mixed Liquor Recycle	High D.O. may inhibit upstream denitrification. Low D.O. may inhibit nitrification.
	Alk., pH	Nitrification consumes alkalinity.

Bardenpho (4 Stage) Process

- Incorporates the principles used for the MLE and Wuhrmann processes to create two anoxic zones to achieve a higher level of total nitrogen removal.

- The first two stages function similarly to the MLE process, although the anoxic zone is sometimes sized to accommodate at least 400% MLR rate.

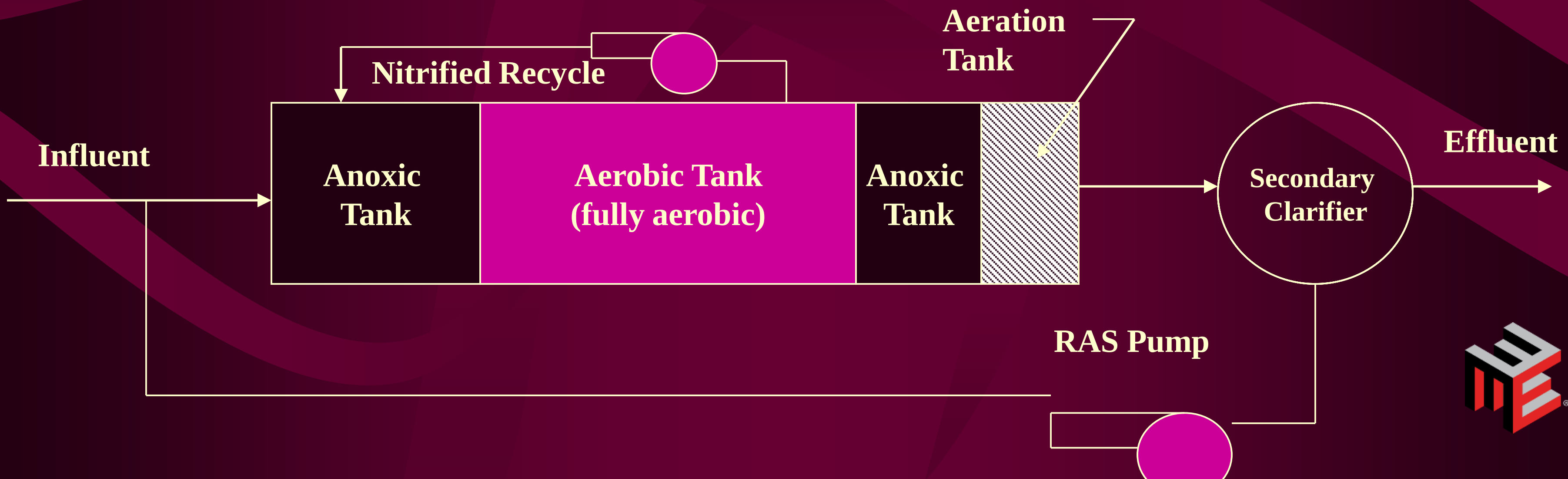


Bardenpho (4 Stage) Process

- The primary anoxic zone removes the majority of the nitrate generated in the process.

- The secondary anoxic zone, located outside the MLE loop, provides denitrification for that portion of the flow that is not recycled to the primary anoxic zone.

- The fourth reactor zone in the process is an aerobic or reaeration reactor and serves to strip any nitrogen gas formed in the second anoxic zone.

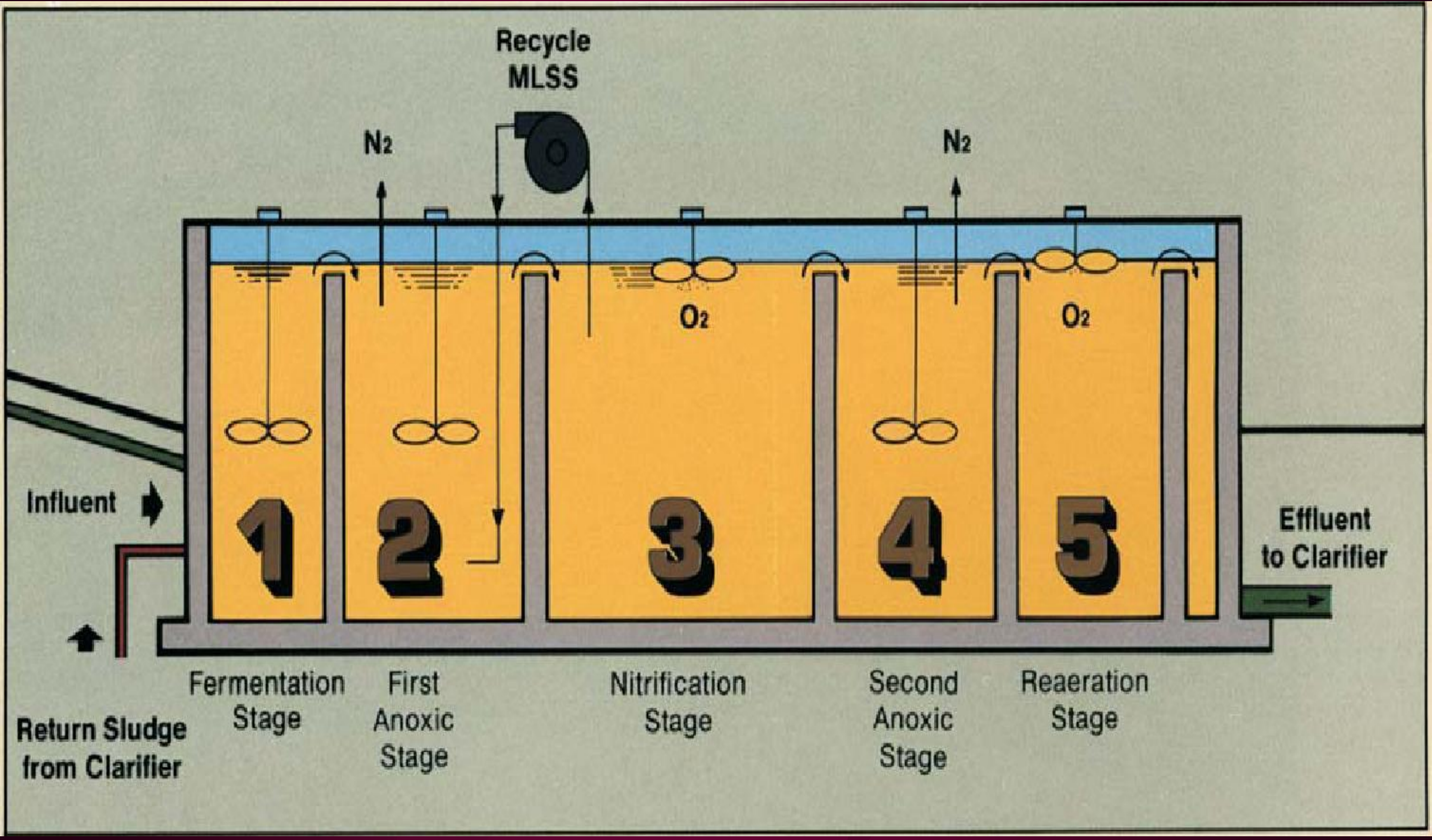


Bardenpho (4 Stage) Process

- Reactor Configurations
  - Plug Flow
  - Oxidation Ditch

- In the U.S. we commonly use the Oxidation Ditch as the MLE portion of the process with separate complete mix reactors for the secondary anoxic and secondary aerobic zones.

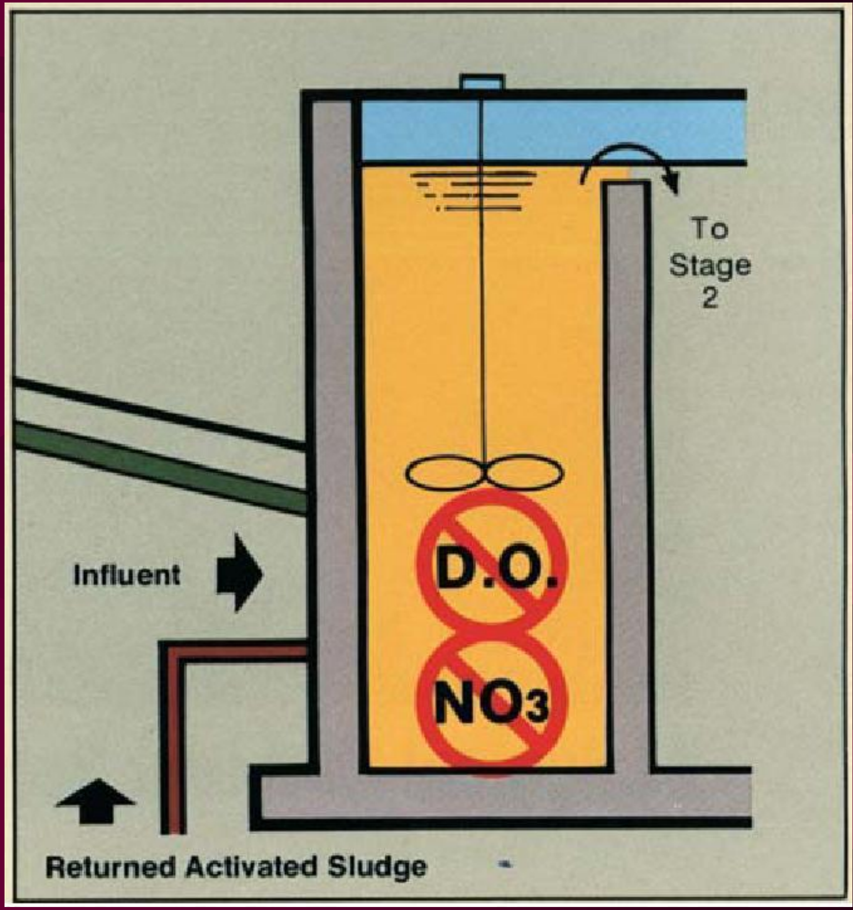
Bardenpho (5 Stage) Process



Bardenpho (5 Stage) Process

Fermentation Stage:

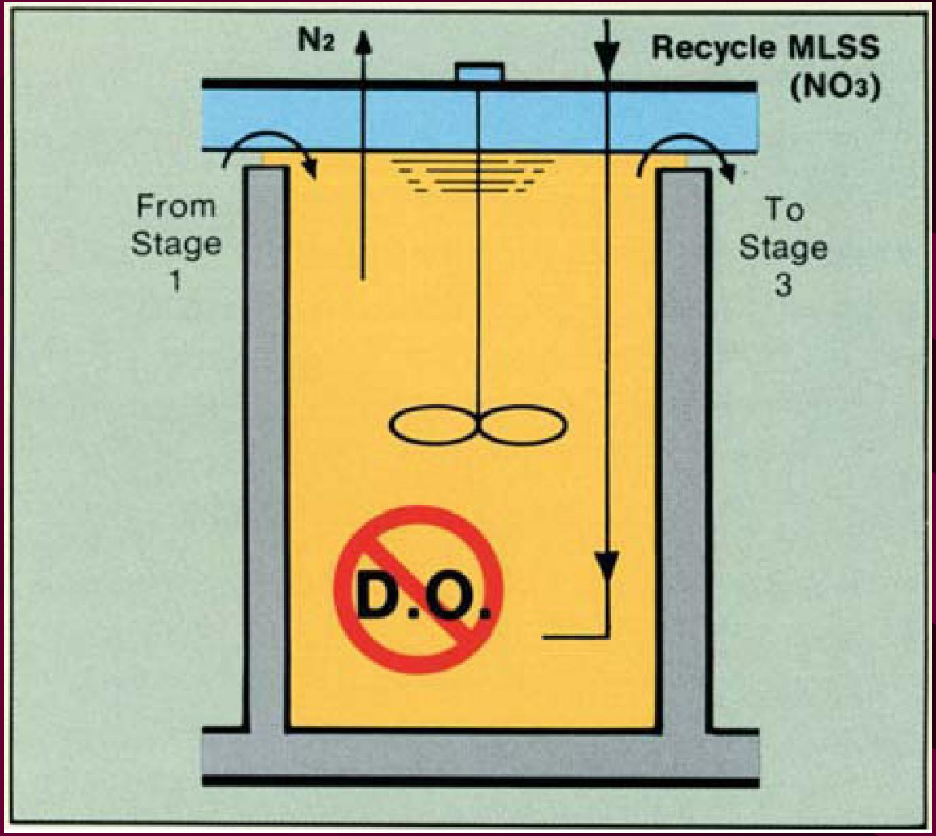
Activated sludge is returned from the clarifier to the fermentation state. This sludge is contacted with the plant influent to produce the a stress condition that allows large quantities of phosphorus to be removed from the wastewater biologically in subsequent aerobic stages. Organism stress occurs in the absence of D.O. and NO_3.



Bardenpho (5 Stage) Process

First Anoxic Stage:

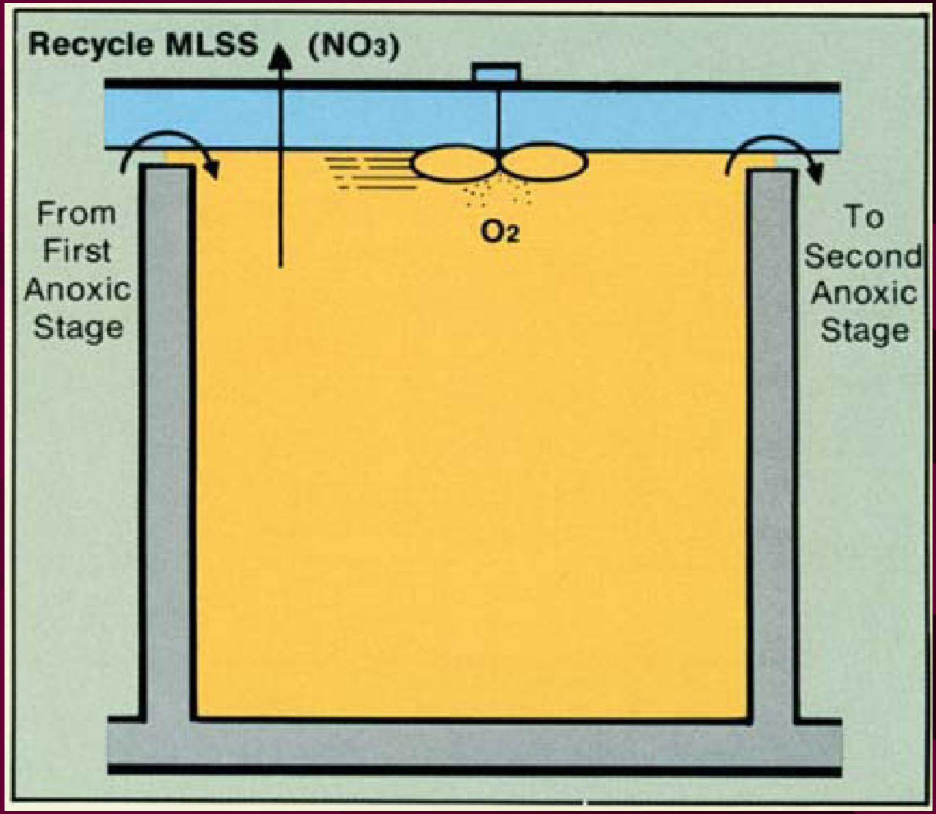
Mixed liquor containing nitrates from the third stage. Here it is mixed with conditioned sludge from the fermentation stage in the absence of oxygen. Bacteria utilized BOD in the influent, reducing the nitrates to gaseous nitrogen.



Bardenpho (5 Stage) Process

Nitrification Stage:

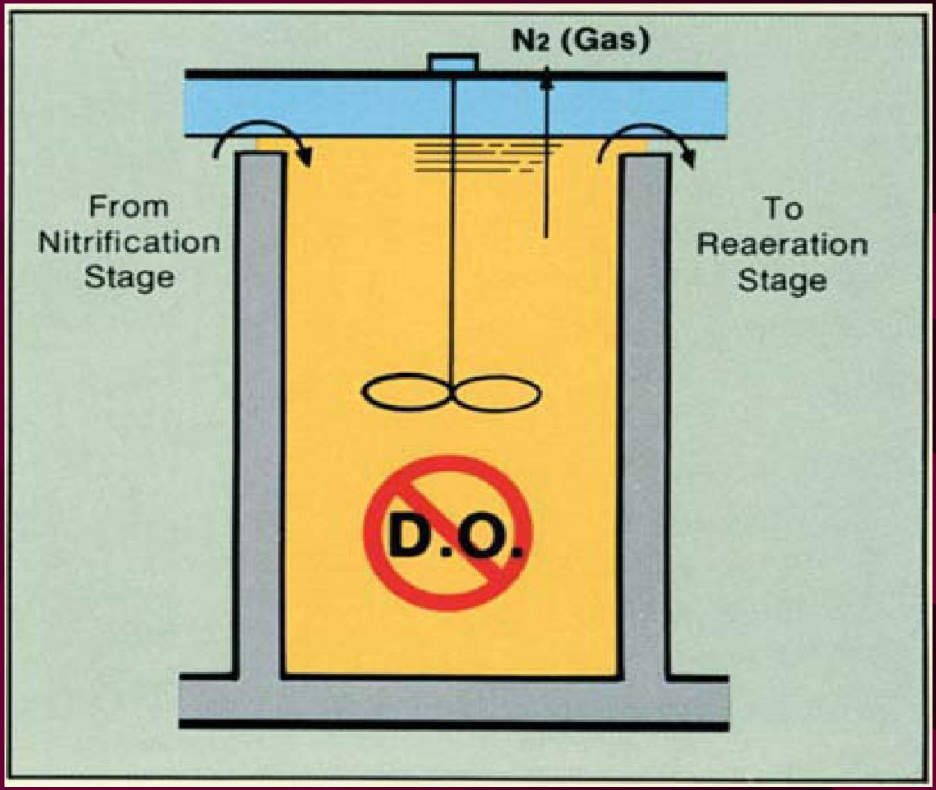
Oxygen is introduced in the nitrification stage to oxidize BOD and ammonia. Mixed liquor, containing nitrates, is recycled back to the first anoxic stage.



Bardenpho (5 Stage) Process

Second Anoxic Stage:

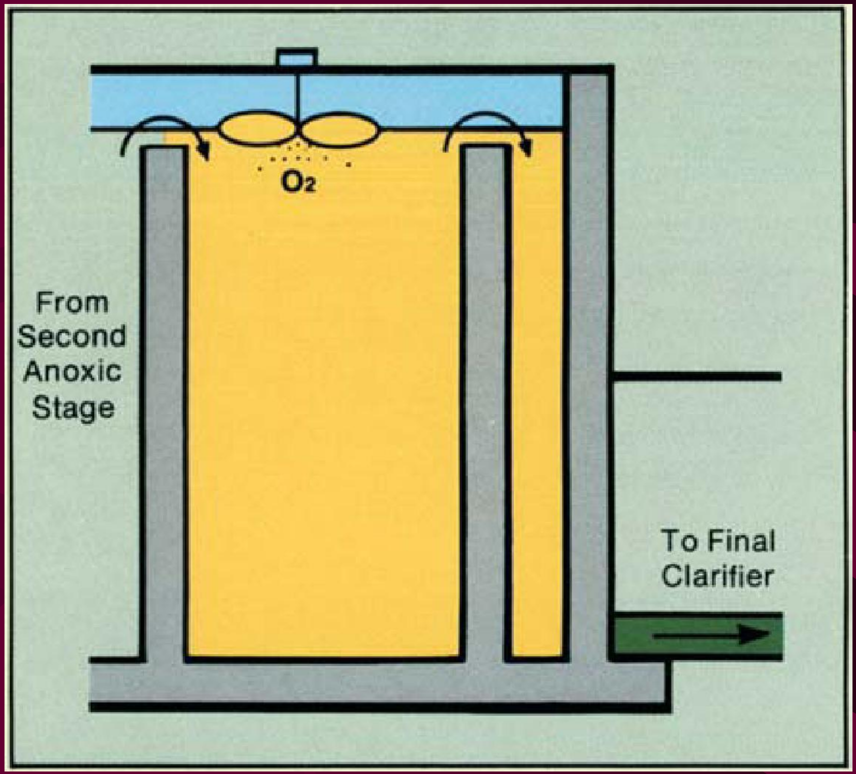
Nitrate, no recycle to the first anoxic stage, is introduced to the second anoxic stage where it is reduced (in the absence of oxygen) to nitrogen gas.



Bardenpho (5 Stage) Process

Reaeration Stage:

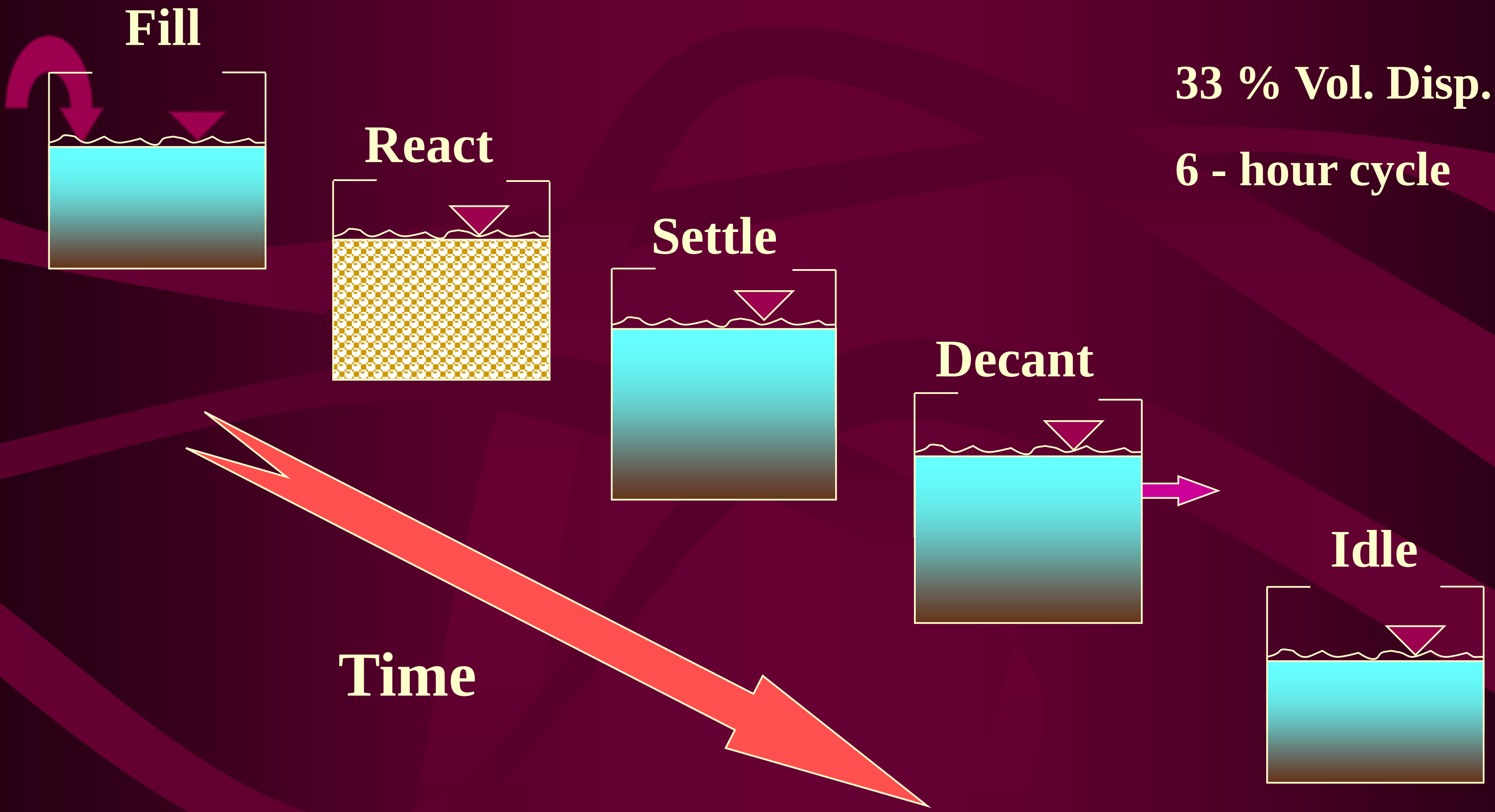
Utilized to ensure the biomass remains aerobic, thereby, ensuring that the sludge does not go septic and release phosphorus in the final clarifier.



Sequencing Batch Reactor (SBR)

- Variable volume suspended growth treatment technologies that uses time sequences to perform the various treatment operations that continuous treatment processes conduct in different tanks.

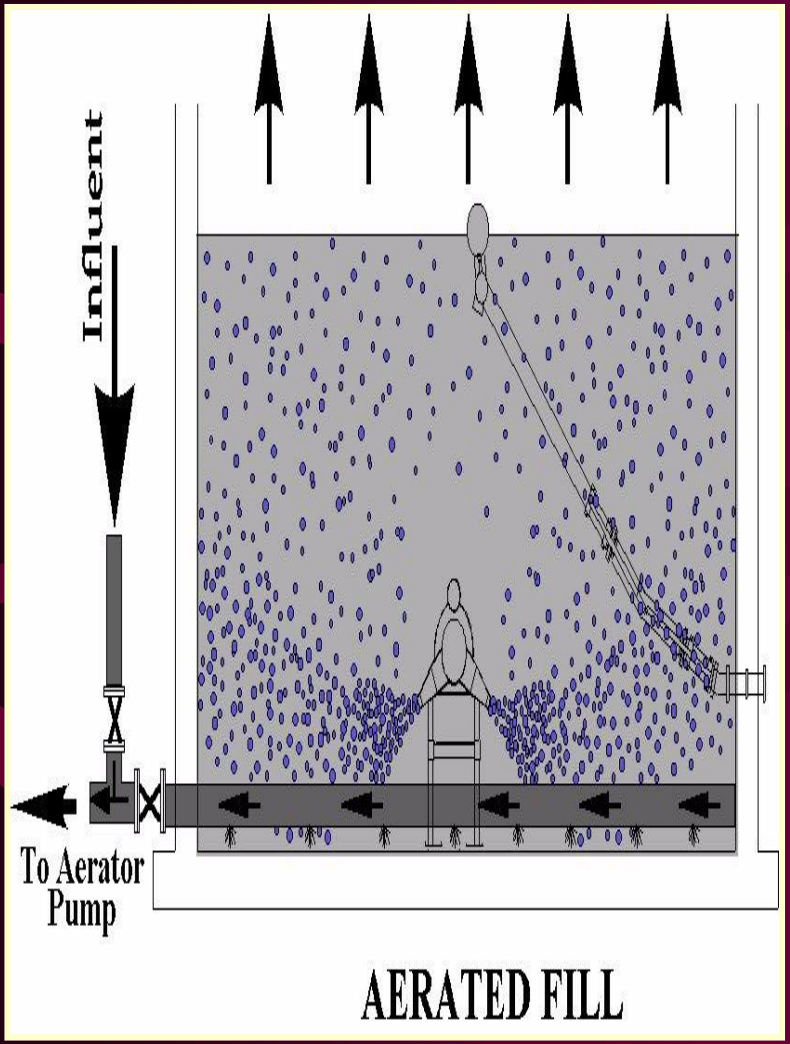
SBR



33 % Vol. Disp.

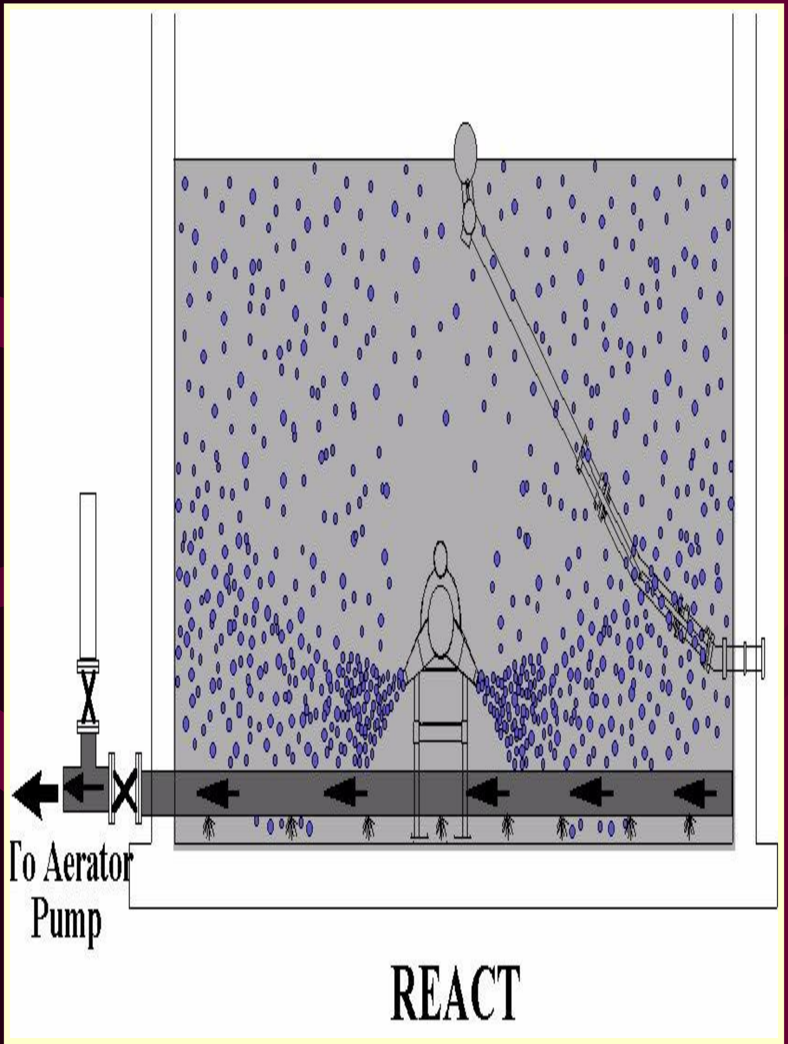
6 - hour cycle

SBR – Aerated Fill



- **To remove BOD and to achieve simultaneous nitrification/denitrification**
  - **Aerated & mixed**
  - **Design time = 0% to 50% of fill time**
- **Design time is a function of BOD & TKN loads, BOD:P ratio, temperature & effluent requirement**

SBR – React

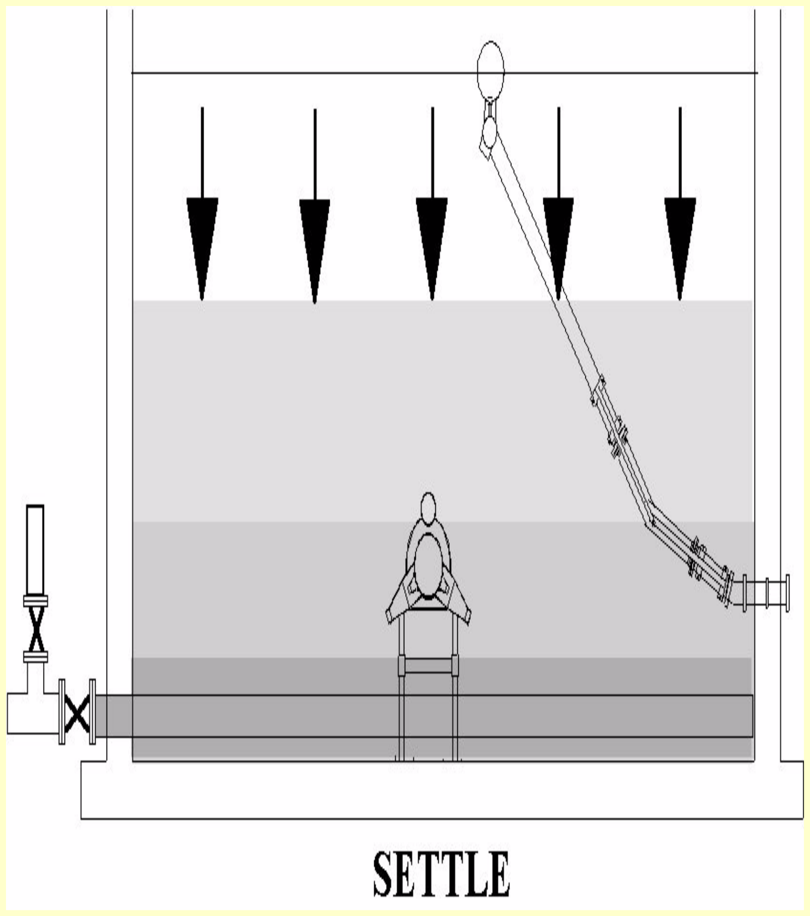


To remove BOD, achieve nitrification, enhance phosphorous uptake, and to Denitrify with anoxic react for low effluent nitrate requirement

- **Aerobic react (aeration & mixing)**
- **Anoxic react (mixing only)**
- **Design time = 25% to 40% of cycle time**

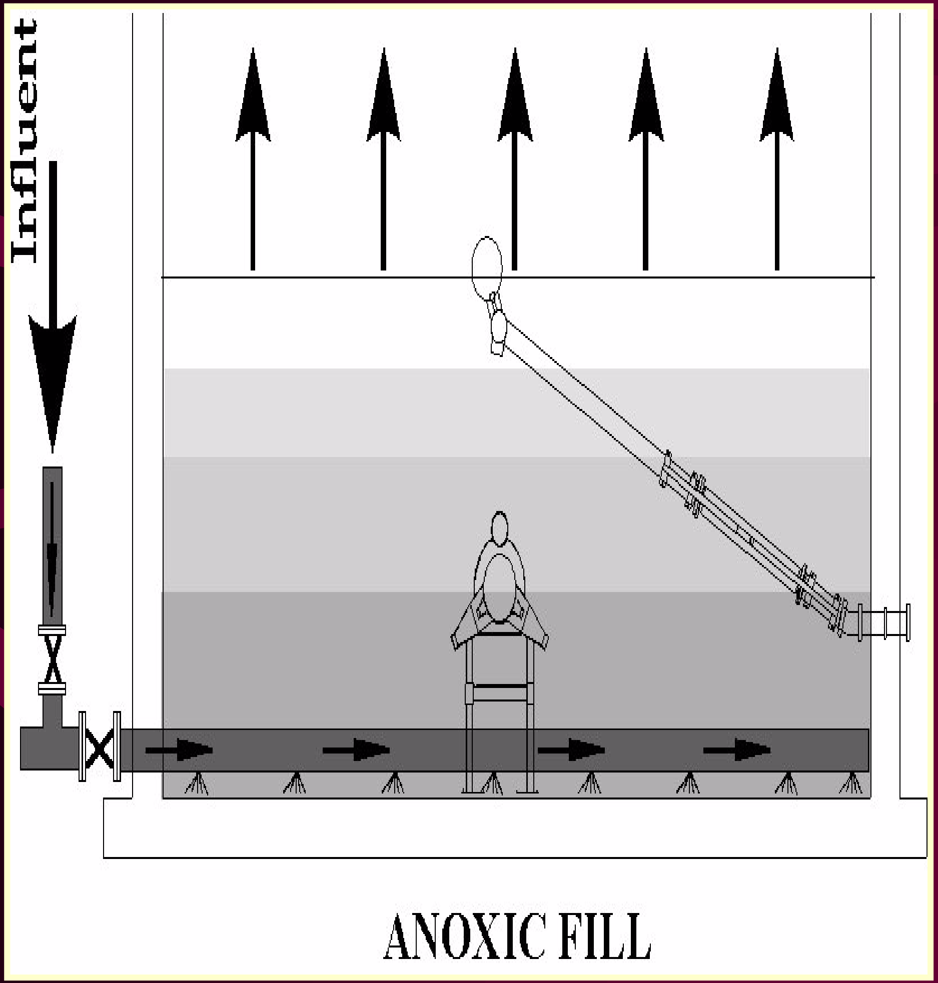
Design time is a function of BOD & TKN loads, temperature & effluent requirement

SBR – Settle, Decant, and Idle



- To settle solids, withdraw clarified effluent, waste excess sludge, and remove nitrate in the sludge blanket
  - Design settle time = 0.75 hrs. (fixed)
  - Design decant time = 0.5 hrs.
  - Design idle time = 0.25 hrs.

SBR – Settle, Decant, and Idle



- To remove nitrate, promote VFA production & growth of Bio-P bacteria, and to control aerobic filamentous organisms.
  - Static Fill
  - Mixed Fill
  - Design Time = 50% to 100% of Fill Time
- Design time is a function of BOD & TKN loads, BOD: P ratio, temperature & effluent requirements

SBR – Cycle Time Distribution

(6 hr cycle) – Effluent Total Nitrogen < 10 mg/L

Anoxic Fill Static+ Mixed	Aerobic Fill	React Aerobic	Settle	Decant	Idle
90 min	90 min	90 min	45 min	30 min	15 min

Total Cycle Time = 360 minutes

SBR – Cycle Time Distribution

(6 hr cycle) – Effluent Total Nitrogen < 5 mg/L

Fill					React					
Anoxic Fill Static+Mixed	AF	AXF	AF	AXF	Air On	Air Off Mix	Air On	Settle	Decant	Idle
60 min	40 min	20 min	40 min	20 min	40 min	20 min	30 min	45 min	30 min	15 min

Total Cycle Time = 360 minutes

AF = Aerated Fill
AXF = Anoxic Fill Mixed

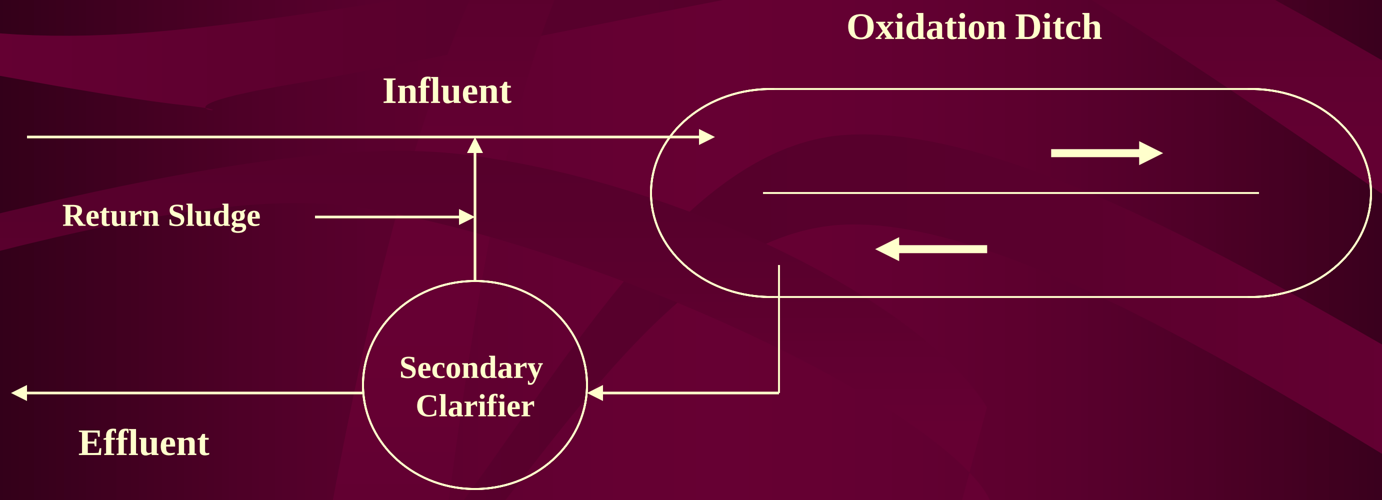
SBR – Considerations

- Significant Headloss through the system (fill and decant take away from reaction time)
- Difficulty removing floatable from the SBR tanks
- High flow decant sometime warrants equalization before downstream processes or discharge.

SBR – Considerations

- More reactor volume required for nitrification compared to a flow through system.
- Typically lower MLSS inventory
- Give the operator more flexibility during I/I events

Oxidation Ditch



Oxidation Ditch

- Extended aeration process
- Complete mix closed loop reactors
- Various Basin Configurations
  - Single Ditch / Dual Ditch
  - Phased Isolation Ditch
  - Vertical Loop Reactor (VLR)
  - Can be used in a sequencing batch mode
  - Allows the operator to protect solids inventory by segregating a ring from the flow and returning it to operation after the event

Oxidation Ditch - Aeration

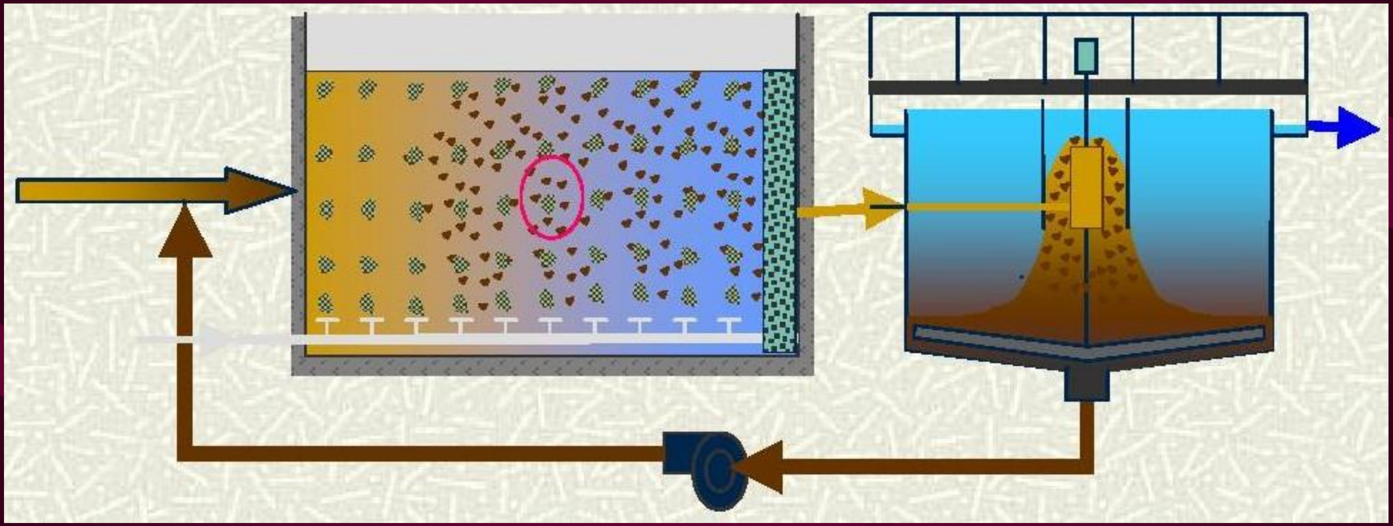
- Can be provided with horizontal brush aerators, vertical shaft mechanical aerators that impart a horizontal liquid velocity, or diffused aeration with submersible mixers.

Hybrid Systems

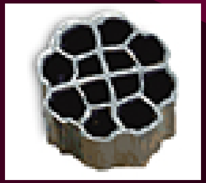
- Integrated Fixed Film Activated Sludge
- Rotating Biological Contactor
- Submerged Biological Contactor
- Membrane Bioreactor

Hybrid – Integrated Fixed Film Activated Sludge (IFAS)

•The IFAS processes include any wastewater treatment system that incorporates some type of fixed film media with a suspended growth activated sludge process.



Hybrid –IFAS



- IFAS Media
  - Varies greatly
    - Ropes
    - Looped strands
    - Sponge cuboids
    - Plastic wheels, or
    - Packing material

(Pictures Courtesy of Entex)

Hybrid –IFAS

- Expand treatment capacity or upgrade the level of treatment by supplementing the biomass in a suspended growth activated sludge process by growing additional biomass on fixed-film media continued within the mixed liquor.

Hybrid –IFAS

- Advantages
  - Additional biomass for treatment without increasing solids loading on final clarifiers
  - High rate treatment possible
  - Improved settling characteristics
  - Simultaneous nitrification and denitrification
  - Improved resistance to toxic shock and washout.
  - Makes tank reuse more feasible

Hybrid – Rotating Biological Contactor (RBC) and Submerged Biological Contactor (SBC)

- Type of IFAS
- Consist of a series of circular disks mounted on a rotating horizontal shaft. This rotating shaft alternately exposing the disks to wastewater and air.
- Nitrification does not commence until CBOD is reduced sufficiently to allow nitrifiers to compete with heterotrophic bacterial on the media.

RBC Considerations

- Lower energy requirement
- Lower operational oversight
- Sizing and expandability can be and issue
- Past history with shaft failure has been mostly overcome through load monitoring
- Not a common treatment method

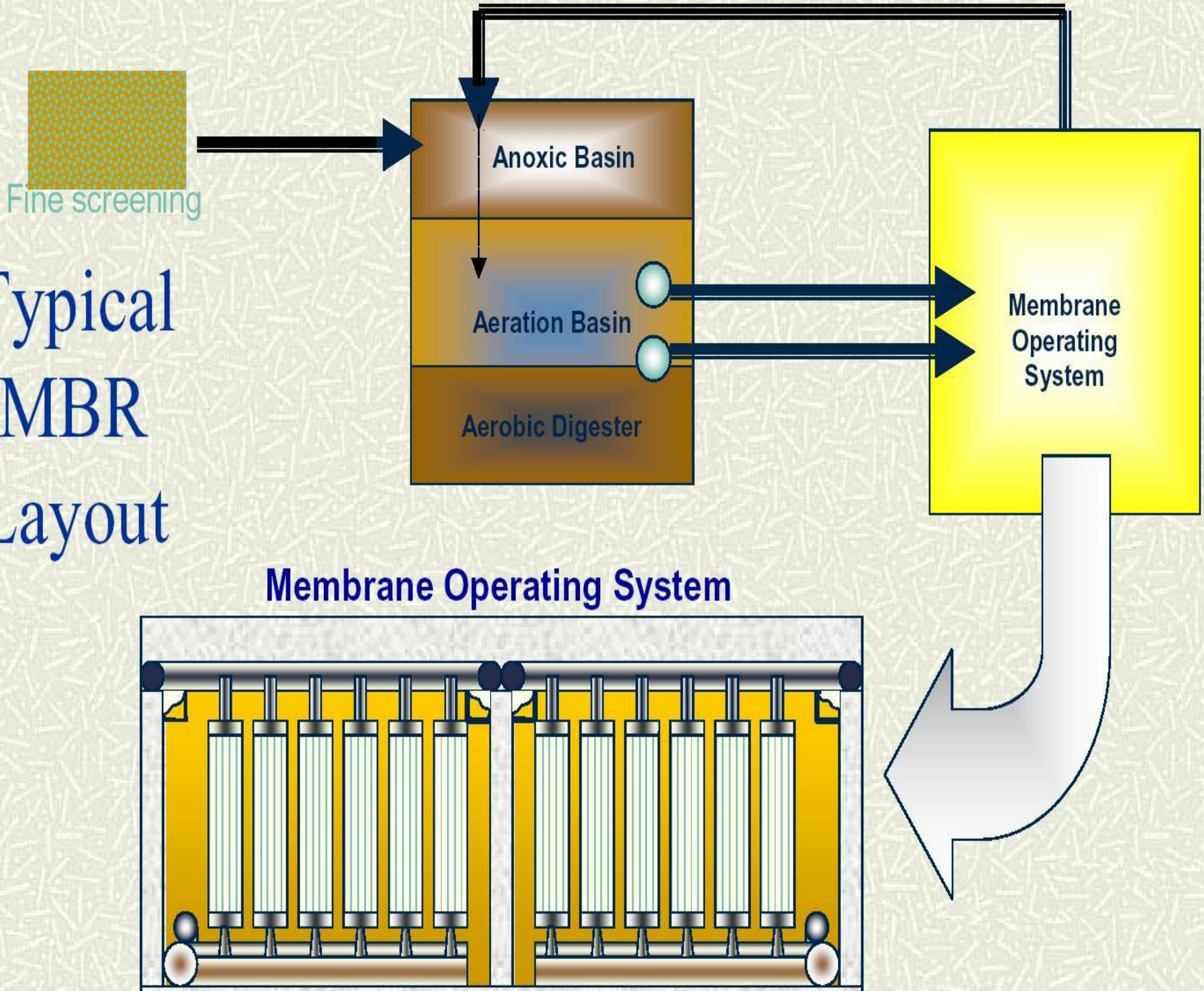
SBC Considerations

- Instead of rotating the media the flow is rotated via aeration around the media
- Potential for a turbid/pin floc in the effluent
- RAS contact to the effluent prior to final discharge
- Can allow for the reuse of existing basins and minimize any upgrade effort

Hybrid – Membrane Bioreactor (MBR)

- Utilize membrane-type filtration units, instead of clarifiers, that are placed either directly in the activated sludge basin or are located outside the basin.

Typical MBR Layout



MBR Considerations

- Increased energy and pumping costs
- Higher quality effluent
- Redundant units needed for cleaning and service
- Allows for basin reuse
- Cost

Phosphorus Removal

- Phosphorus forms – Ortho and Poly
- Anaerobic environment – Fermentation and Acetate Production
- 0.5 to 1.0 hour HRT
- Conversion of Polyphosphate to Orthophosphate
- Orthophosphate taken up in an aerobic environment

QUIZ ON SECTION 2 (10 min)

- And then Break (10 min)

SECTION 3

- Instrumentation Basics
- Troubleshooting
- Case Studies

Section 3 – Main Goals

- Review basic instrument components
- Solve common troubleshooting scenarios
- Review of case studies

INSTRUMENTATION

Operation and Maintenance

- To achieve low TN and TP effluent concentrations, proper operation and control is essential

- Factors include:
  - Temperature
  - DO Levels
  - pH
  - Filamentous Growth
  - etc

BNR Instrumentation

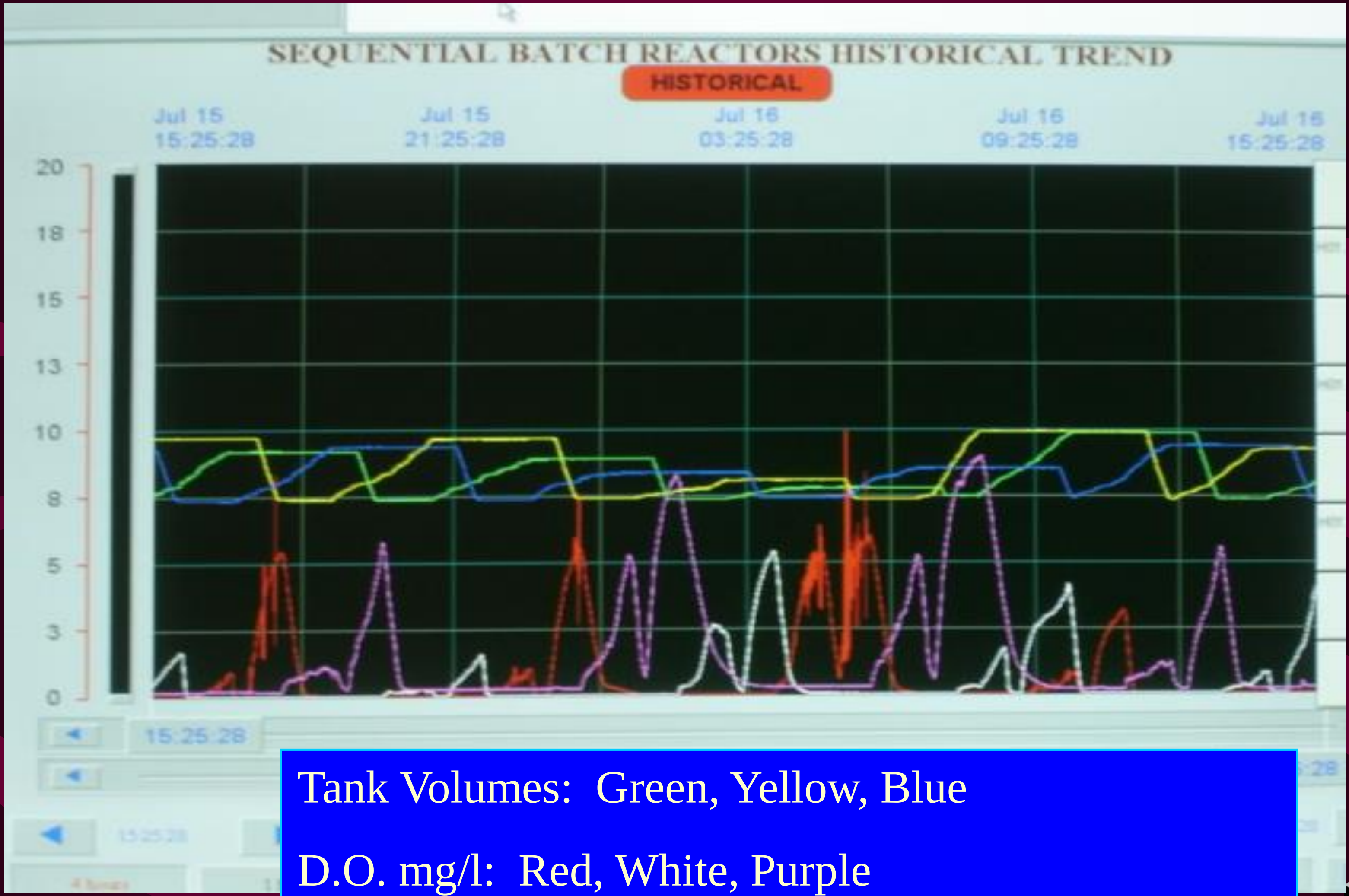
- Purpose – Supplement the operators knowledge of the system
- Measure metrics that can be applied to decision making
- Automate decision making

OPERATOR INPUT ON SETPOINTS IS CRITICAL

BNR Instrumentation

- **Total Suspended Solids Meter**
- **Dissolved Oxygen Measurement**
- **pH Measurement**
- **Oxidation-Reduction Potential**
- **Ammonia and Ammonium**
- **Nitrate / Nitrite**
- **Phosphorus / Orthophosphate**

SCADA Screen
Dissolved Oxygen Trend



Tank Volumes: Green, Yellow, Blue

D.O. mg/l: Red, White, Purple

BNR Instrumentation

- D.O. monitoring has made the biggest impact
- pH and ORP are consistent and stable monitoring devices
- Other instruments are relatively new and continue to advance
- BNR system should incorporate SCADA into the overall control strategy

TROUBLE SHOOTING

Scenario 1 – Nitrification

- Your extended aeration WWTP typically is excellent at both BOD and TKN removal but you recently notice that the BOD and TKN values have been slowly but steadily increasing.

- Is there more information that we need?
- What are some of the probable causes?

Scenario 2 – Nitrification and Denitrification

- Your SBR WWTP is nitrifying (even better than normal) but your NO2+NO3-N is very high and the solids during clarification are rising.

- Is there more information that we need?
- What are some of the probable causes?

Scenario 3 – Phosphorus Removal

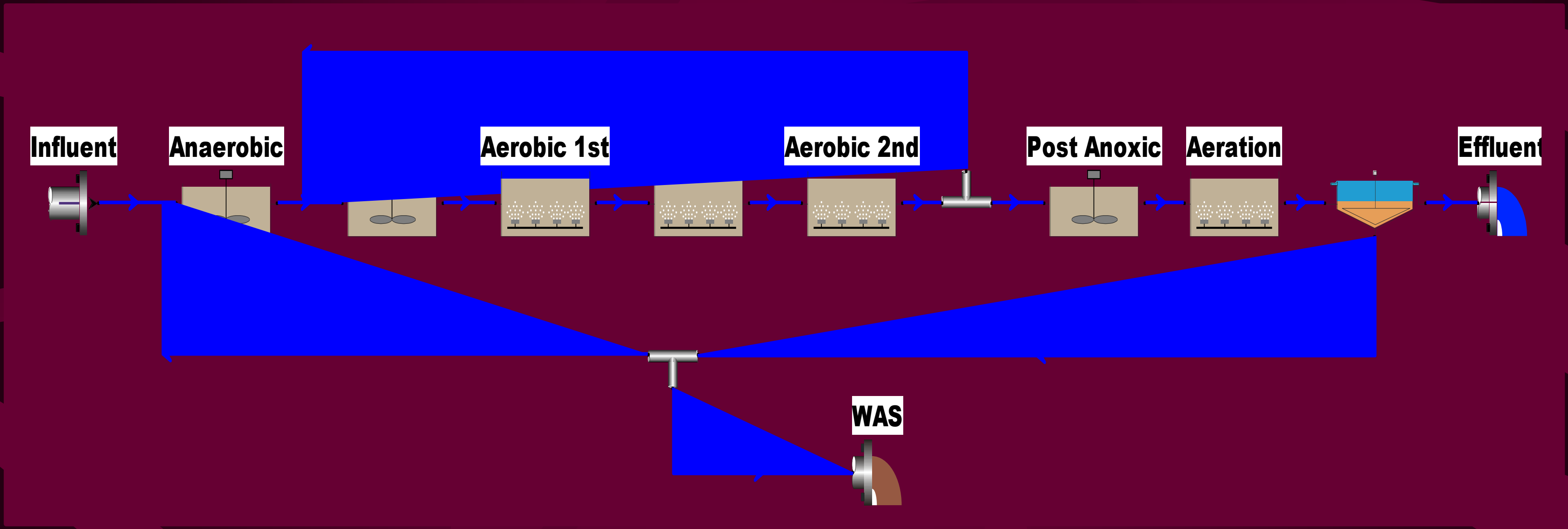
- Your WWTP is typically producing TP effluent numbers below 0.8 mg/L but on April 9, 2013 – the TP was 8 mg/L in the effluent.

- Is there more information that we need?
- What are some of the probable causes?

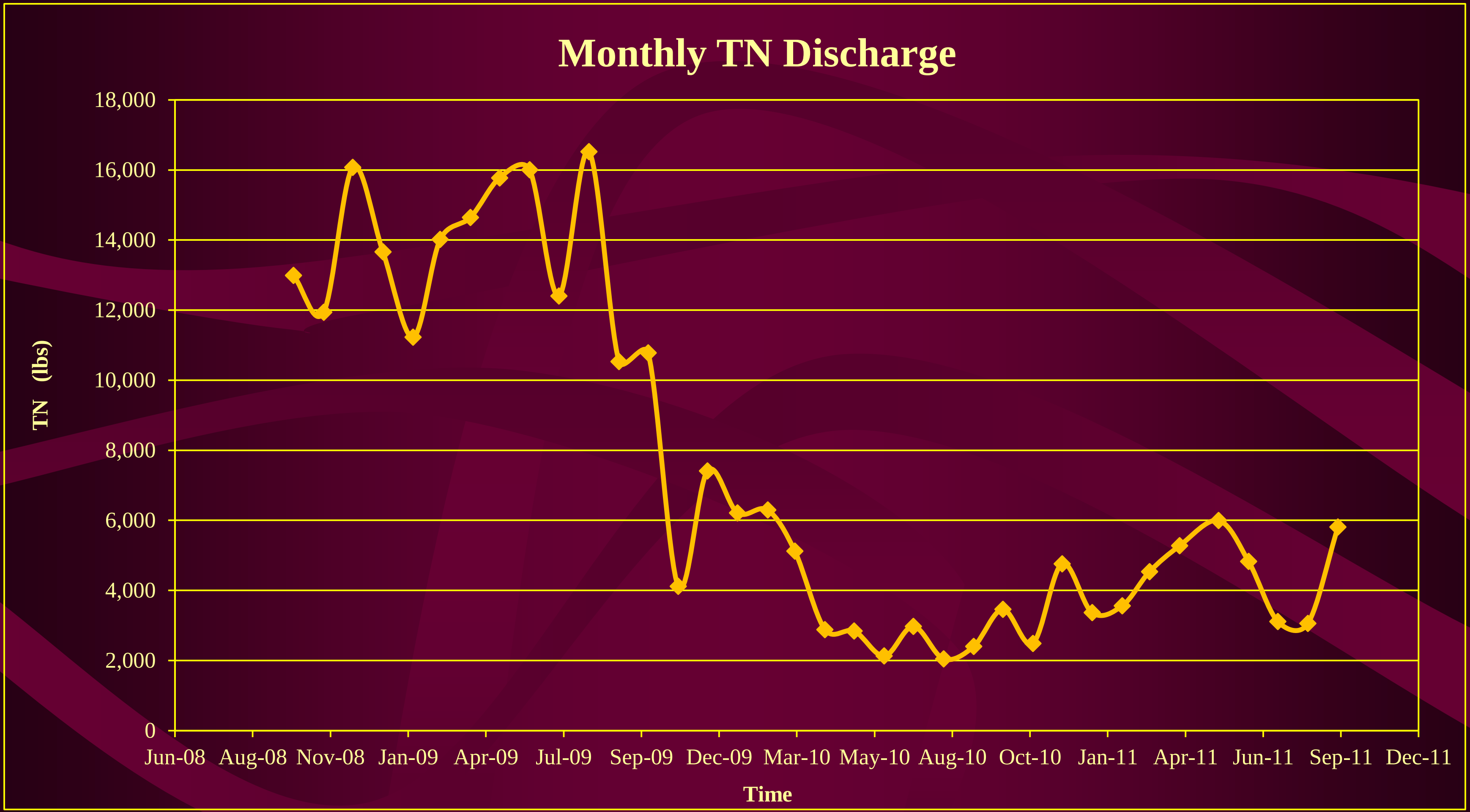
CASE STUDY

Existing Lititz Wastewater Treatment Plant

Lititz Wastewater Treatment Plant
BNR Process Design Modeling
(BioWin)



Lititz Wastewater Treatment Plant Upgrade
BNR Process Operation Data



Lititz Wastewater Treatment Plant Upgrade
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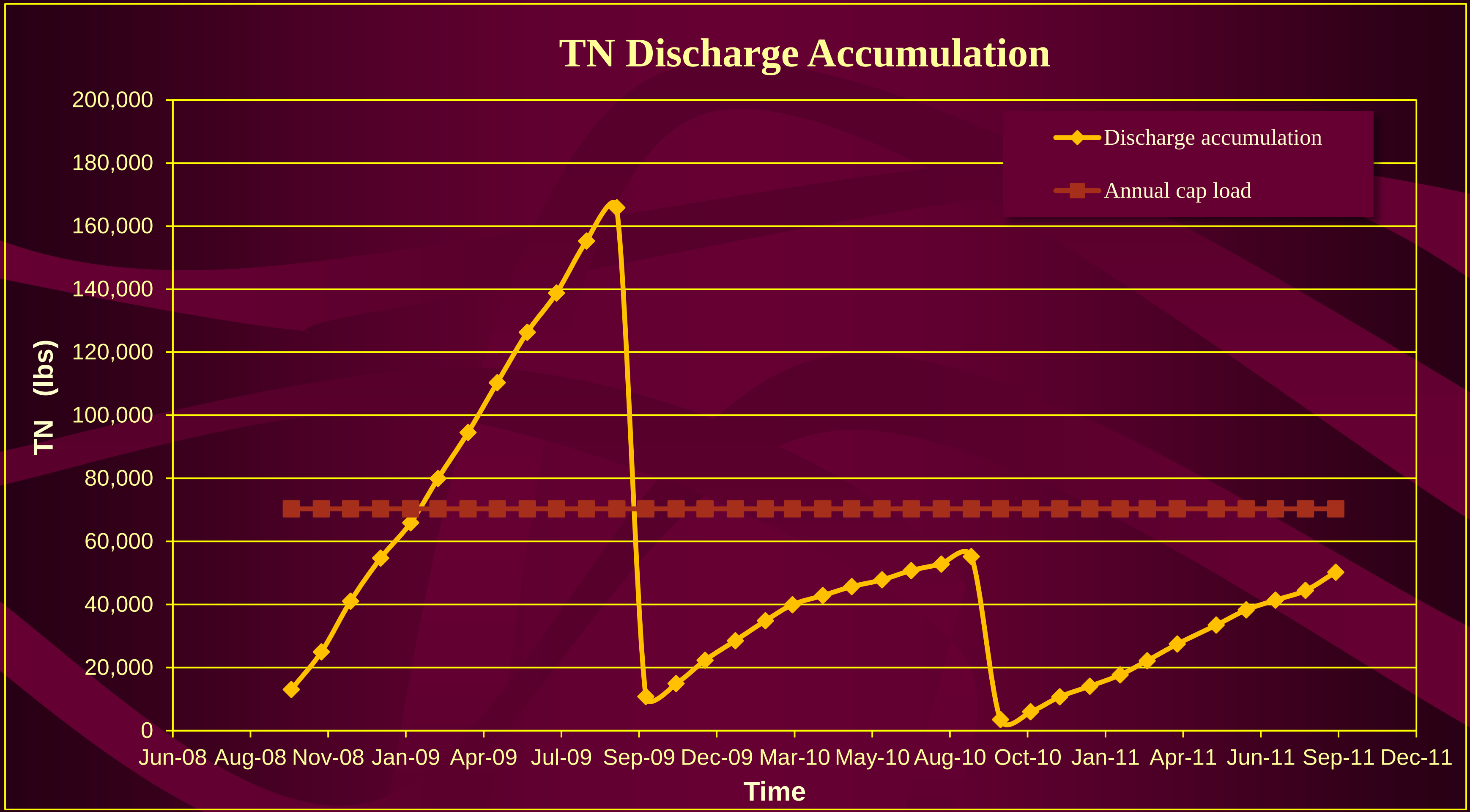

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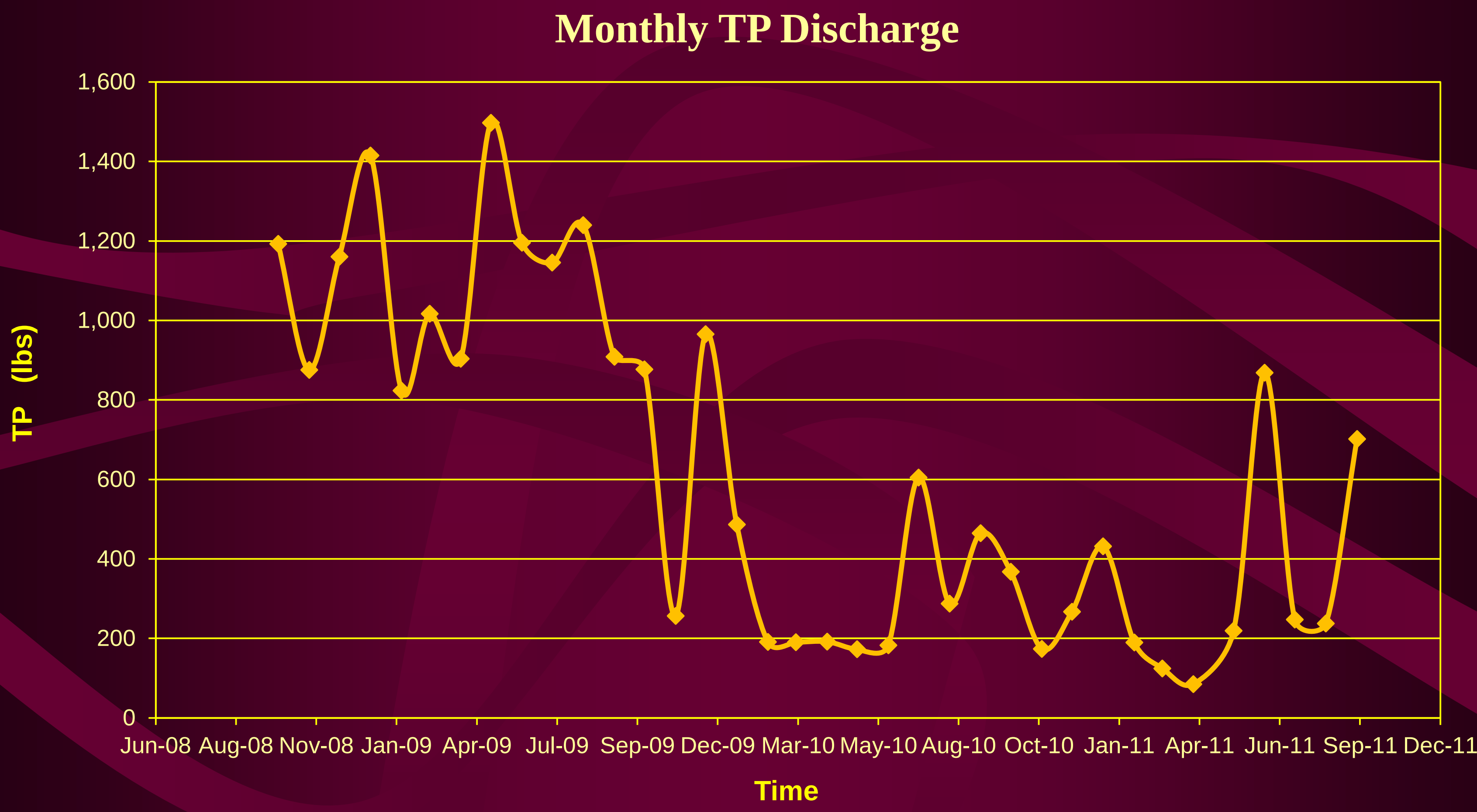

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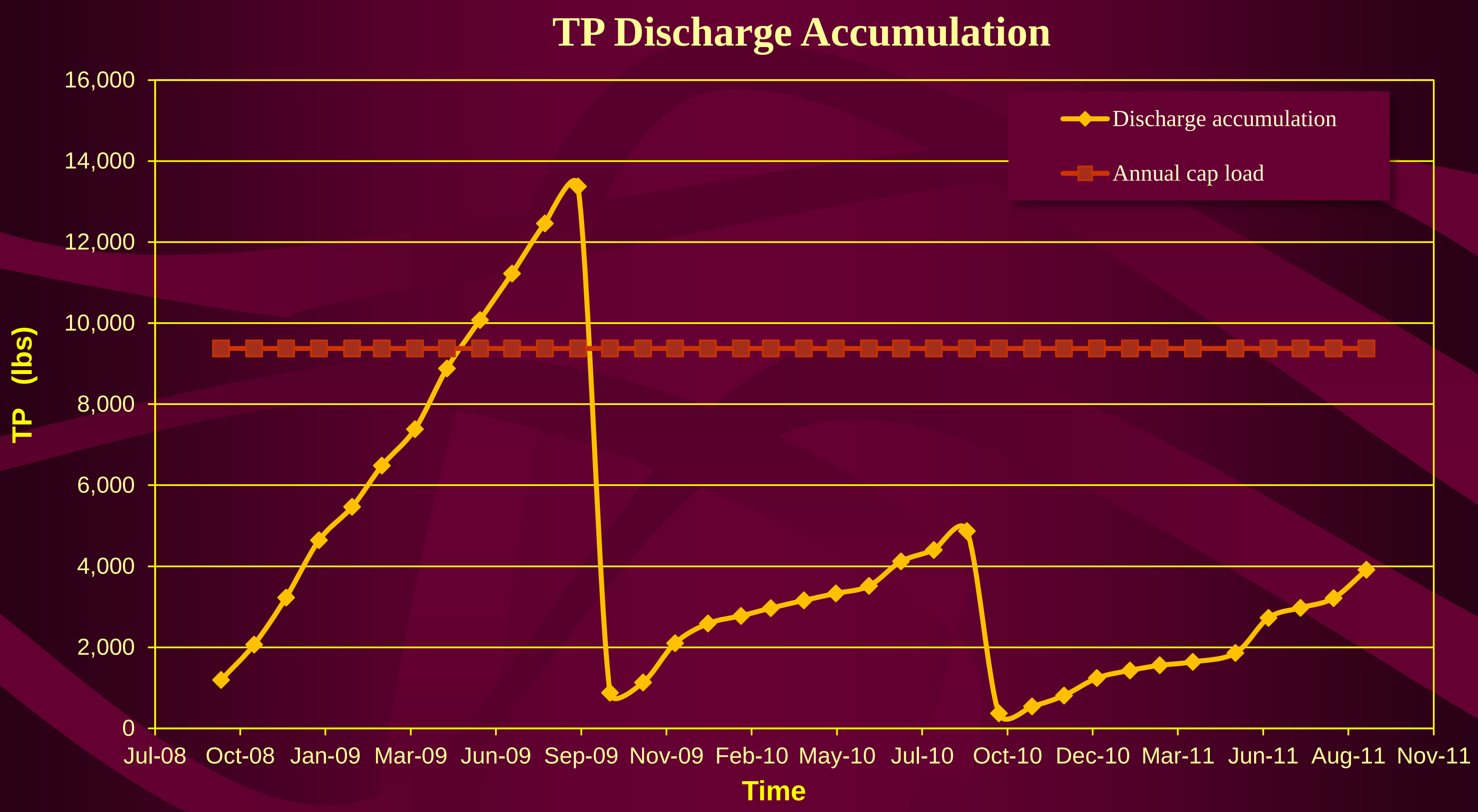

Questions?

Thank You!

NUTRIENT REMOVAL PROCESSES IN WASTEWATER TREATMENT

QUIZ ON SECTION 3

- Thank you