WASTEWATER TREATMENT PLANT REFRESHER


CHAMBER POT
FIRST WWTP

Medieval Woodcut

Chamber Pot to Gutter Waste Disposal System

Rats, Pigs

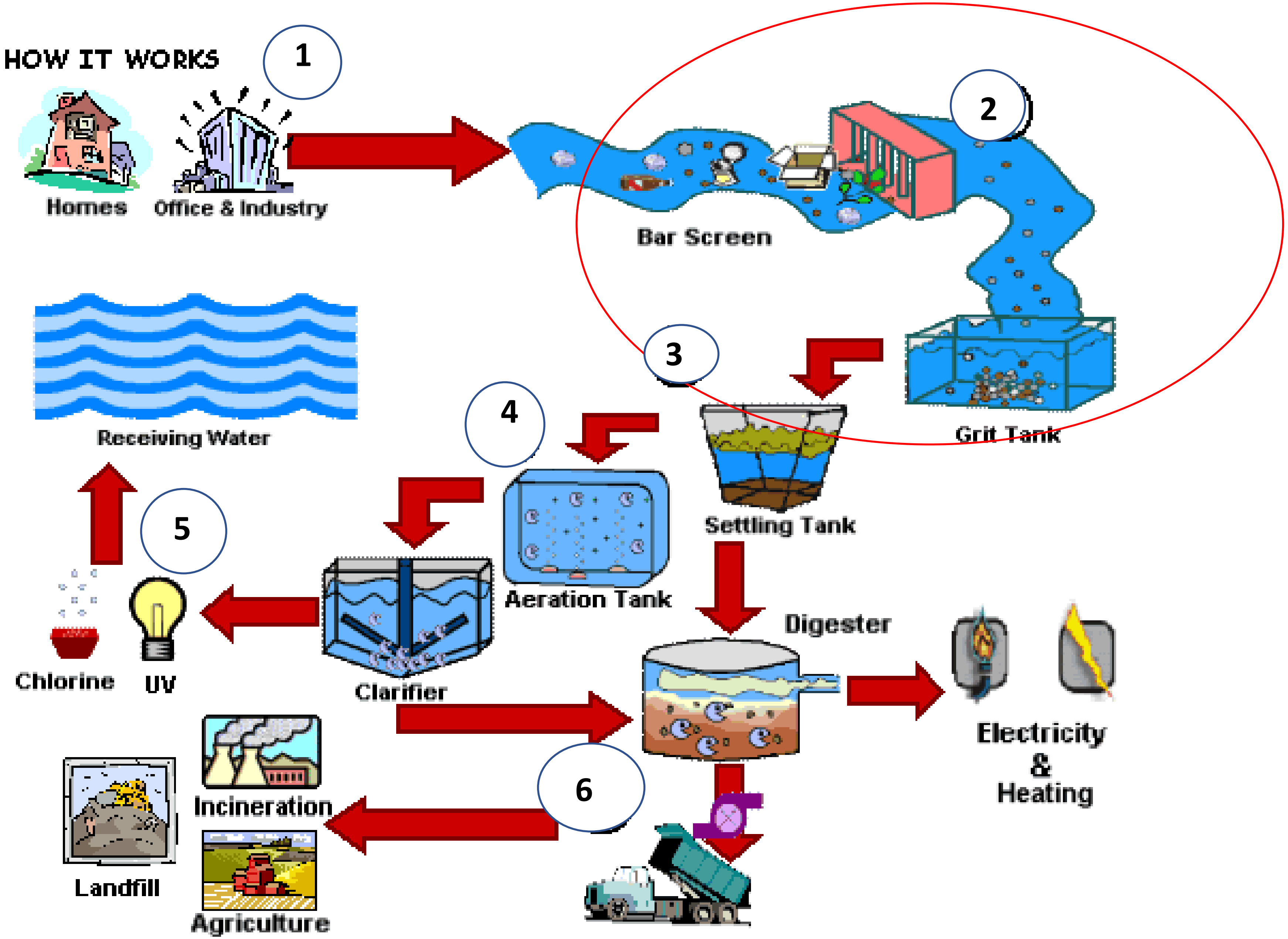
Black Death

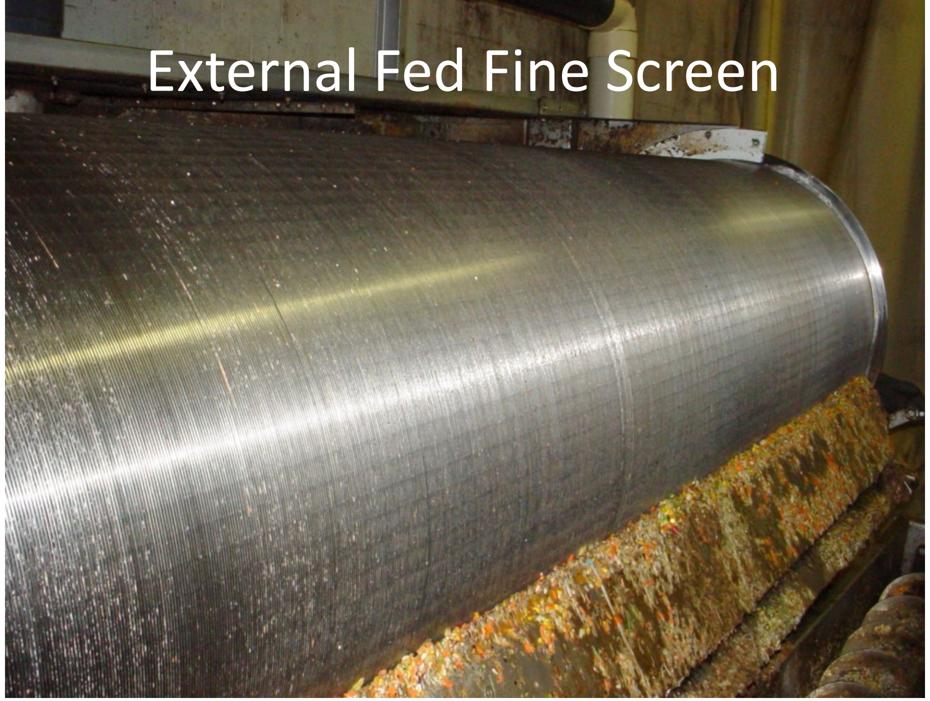
Wastewater: Historical Perspective

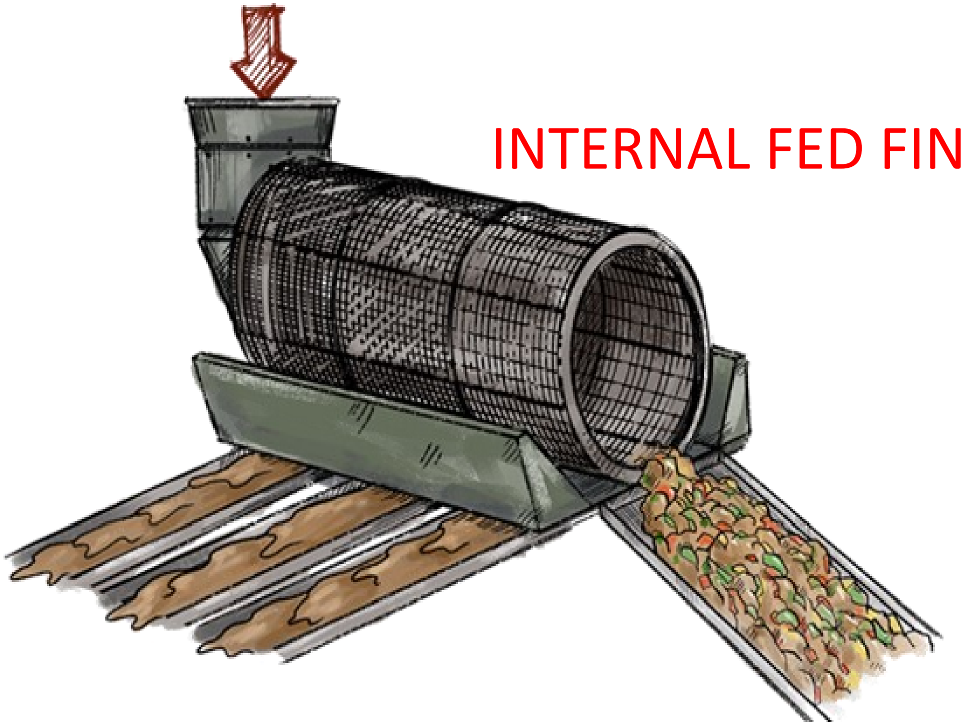
- A major problem since the earliest cities
- Most went down roads to the nearest stream
- 1370: First underground sewers
- 1867: First wastewater treatment (London)
- 1908: The first large municipal wastewater treatment plant to use Trickling Filters began operation in Columbus, Ohio.
- 1914: First Activated Sludge Plant (England)
- 1916: First Activated Sludge in U.S.(San Marcos, Tx.)

Sprayers at the Filteration Plant,
Columbus, Ohio.

Wastewater "Treatment"

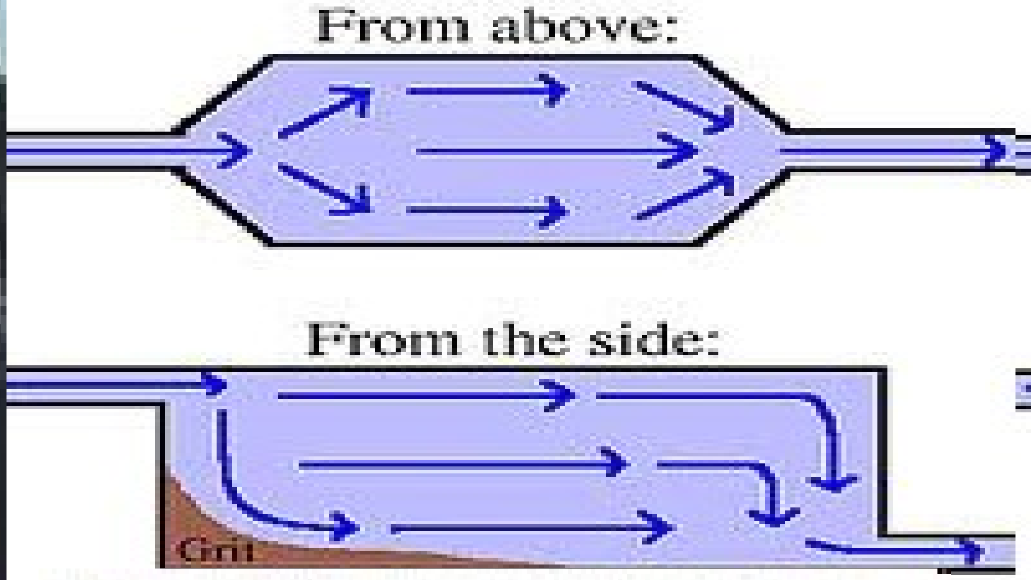






INTERNAL FED FINE SCREEN

Grit Chamber



REMEMBER ?

FLOW

Q

FT3/Sec.

÷ ÷

FT2 X FT/Sec

VELOCITY

V

VELOCITY

1.55 Ft^3/sec. = 1 MGD

THIS MAKES IT EASY !

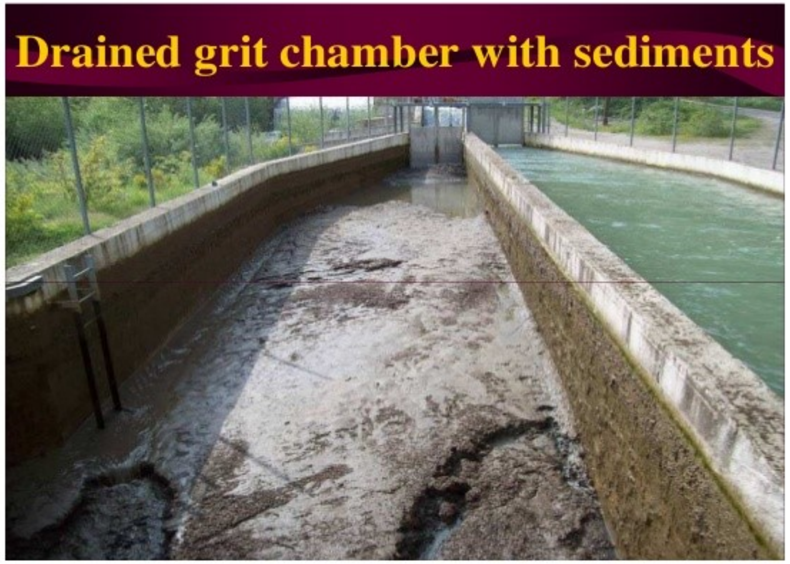
Let's Build a grit chamber for 5.0 MGD; 15" Ht.

5.0 MGD x 1.55 = 7.75

$\frac{7.75\ Ft^3/sec.}{X} = 1.0\ Ft/sec.$

$X = 7.75\ FT^2$

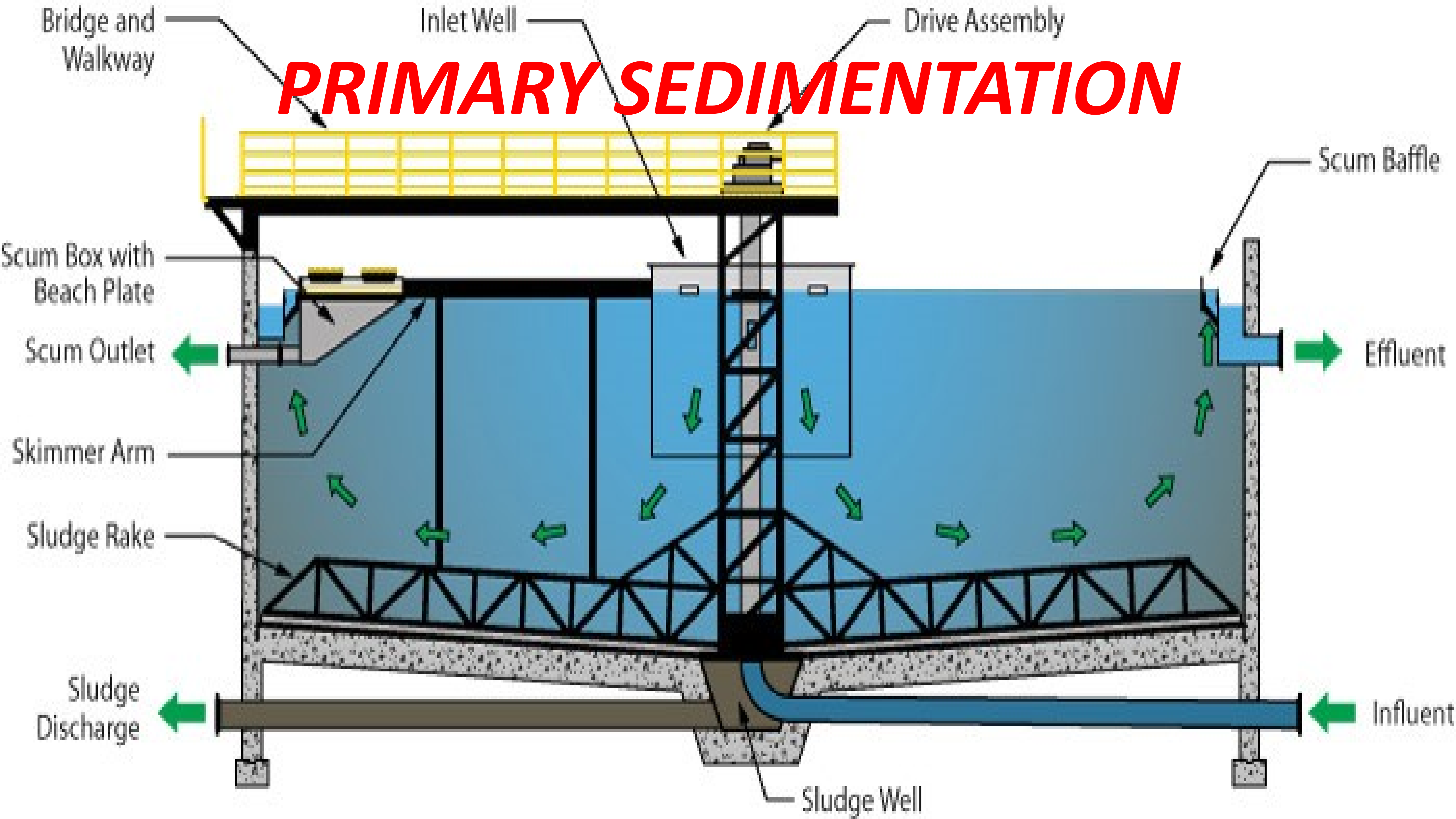
(wastewater height is 15")

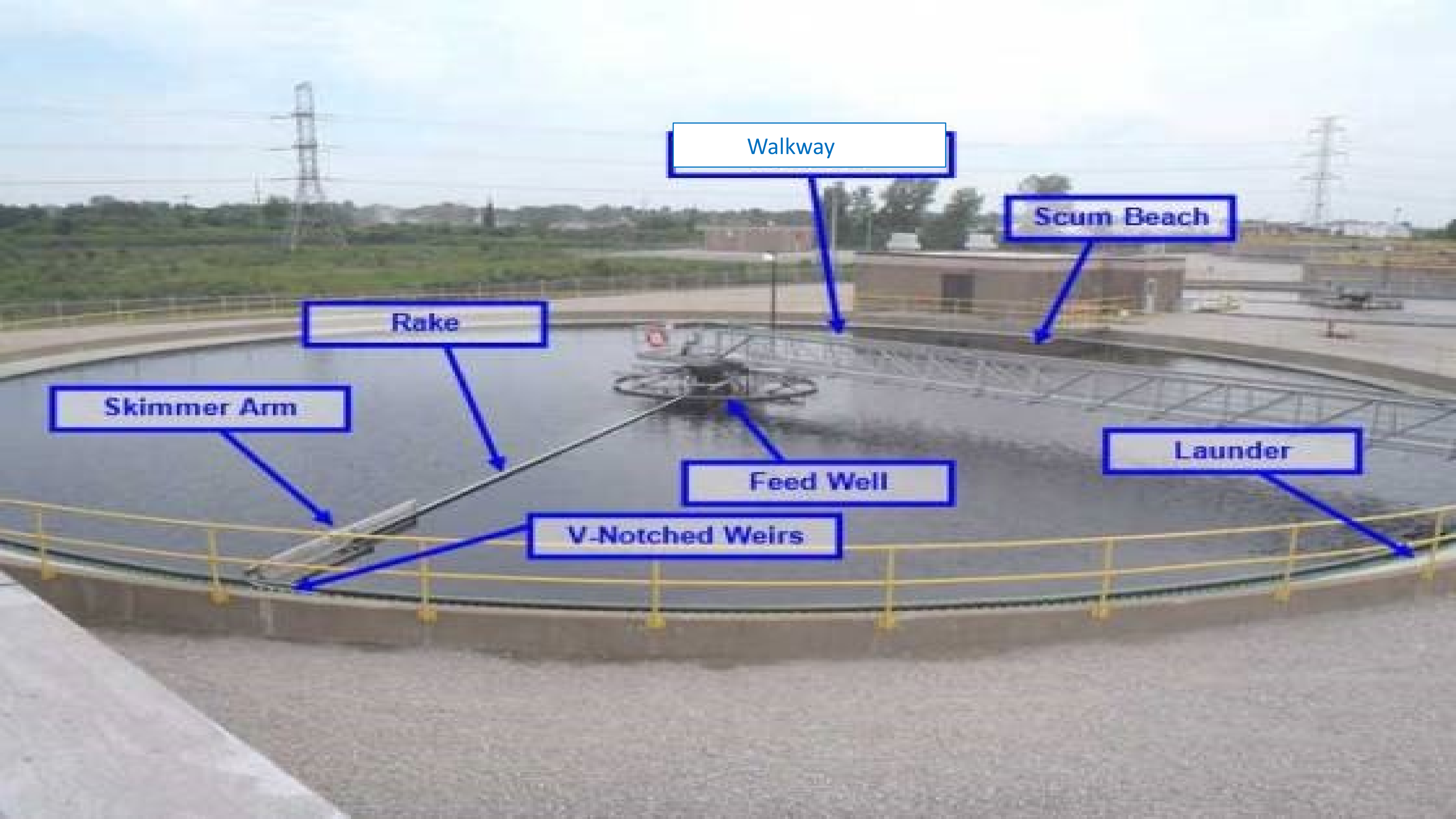


$7.75\ Ft^2 / 1.25\ Ft. = 6.2\ Ft.$ or 6 feet

(.2 x 12" = 2.4")

PRIMARY SEDIMENTATION




Walkway
Scum Beach
Rake
Skimmer Arm
Launder
Feed Well
V-Notched Weirs

PRIMARY SEDIMENTATION

The most important function of the primary clarifier is to remove as much settle-able and suspended material as possible. Removal of organic settle-able solids is important because they cause a high demand for oxygen (BOD) in subsequent biological treatment units in the treatment plant or receiving waters.

Rate of settling in pure, still water (temp=10°C, sp. gravity of particles=2.65, shape of particles=spherical) (Welch, 1935)

Material	Diameter (mm)	Hydraulic subsiding value (mm/sec)	Time required to settle 1 ft.
Gravel	10.0	1000.0	0.3 sec
Coarse sand	1.0	100.0	3.0 sec
Fine sand	0.1	8.0	38.0 sec
Silt	0.01	0.154	33.0 min
Bacteria	0.001	0.00154	55.0 hr
Clay	0.0001	0.0000154	230.0 days
colloidal particles	0.00001	0.000000154	63 years

Many factors influence settling characteristics in a particular clarifier. A few of the more common ones are

temperature,

short circuits,

detention time,

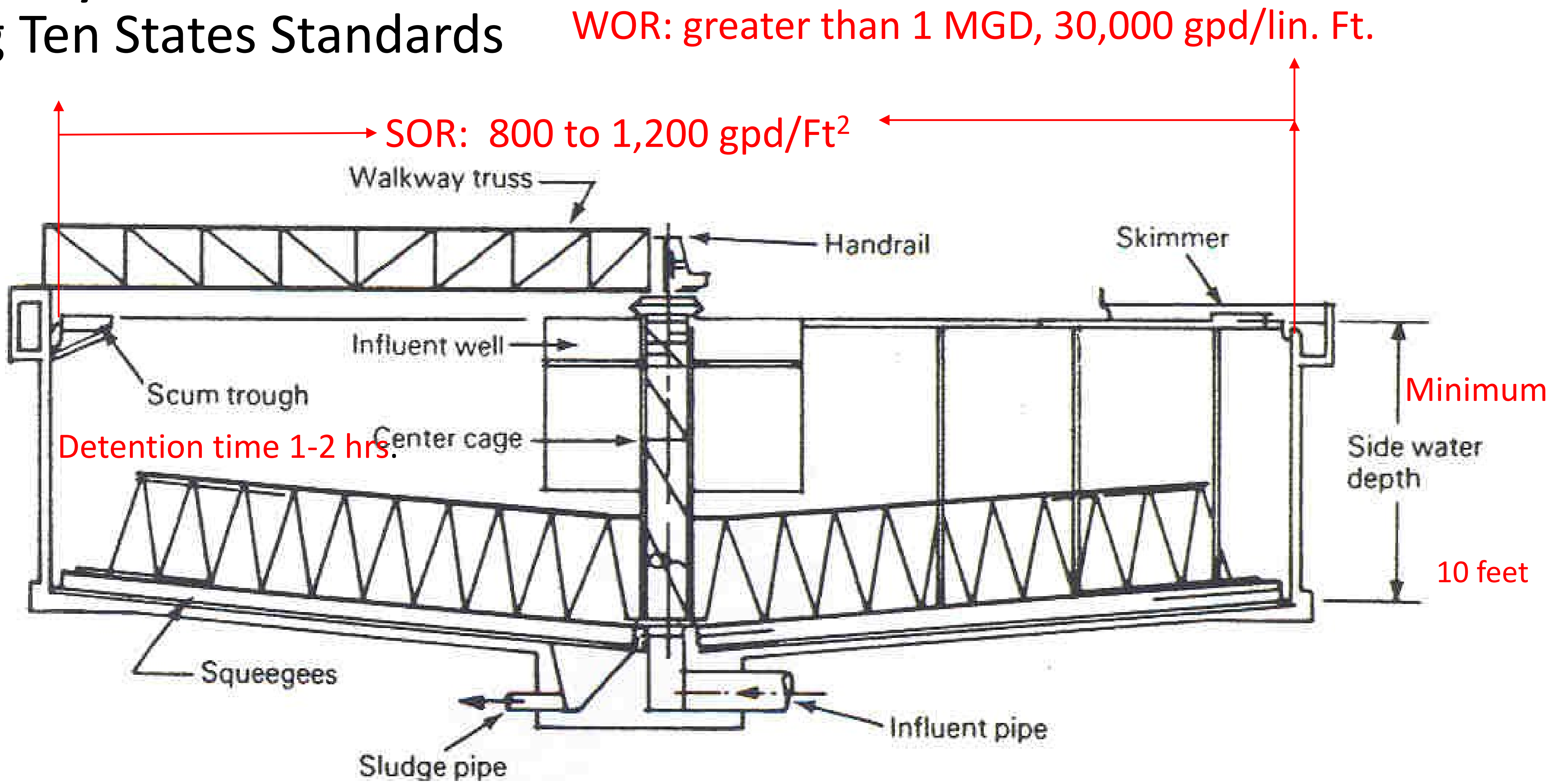
weir overflow rate,

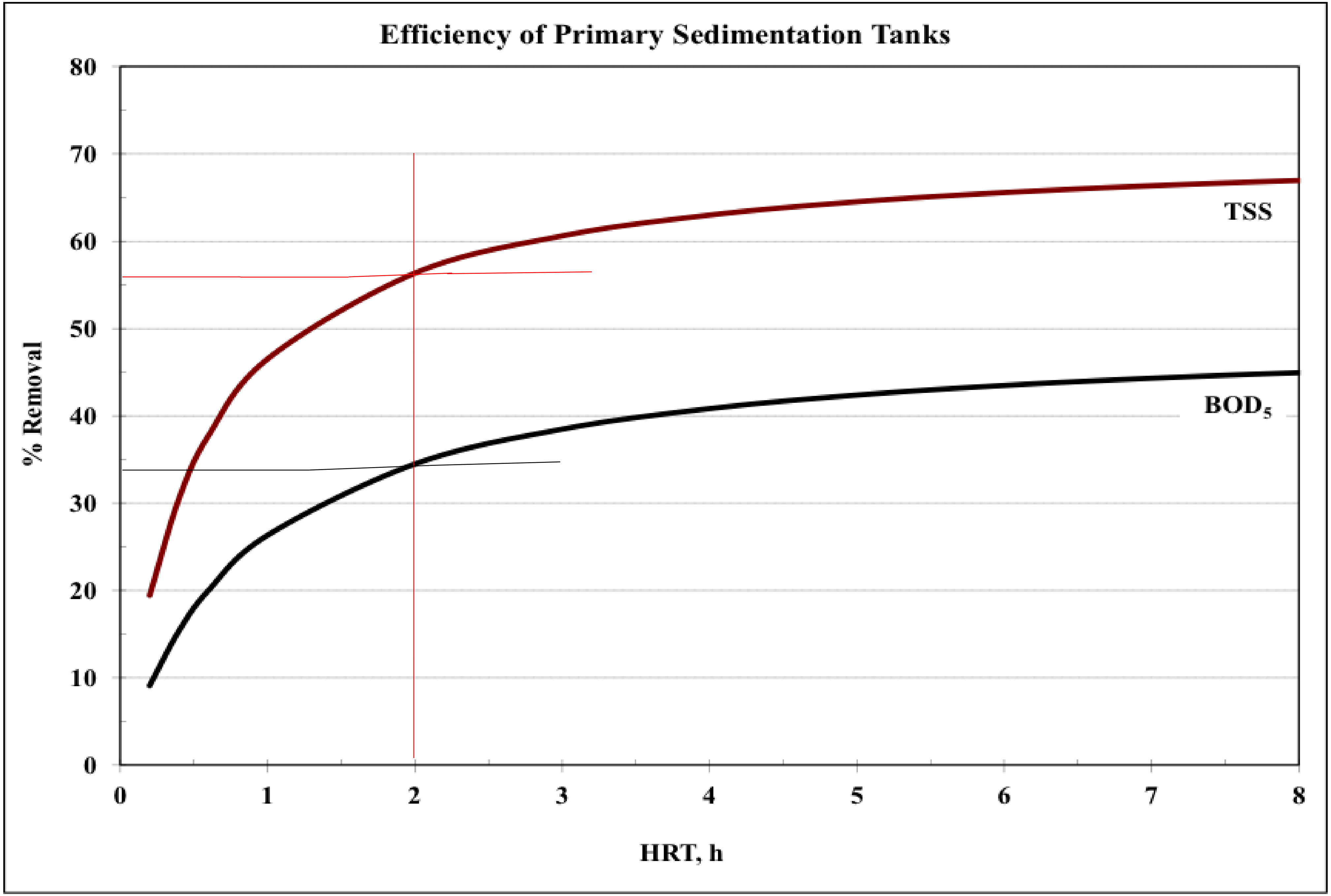
surface loading rate,

solids loading.

Primary Sedimentation

Using Ten States Standards





Efficiency of Primary Sedimentation Tanks
% Removal
HRT, h
TSS
BOD5
0
10
20
30
40
50
60
70
80
0
1
2
3
4
5
6
7
8

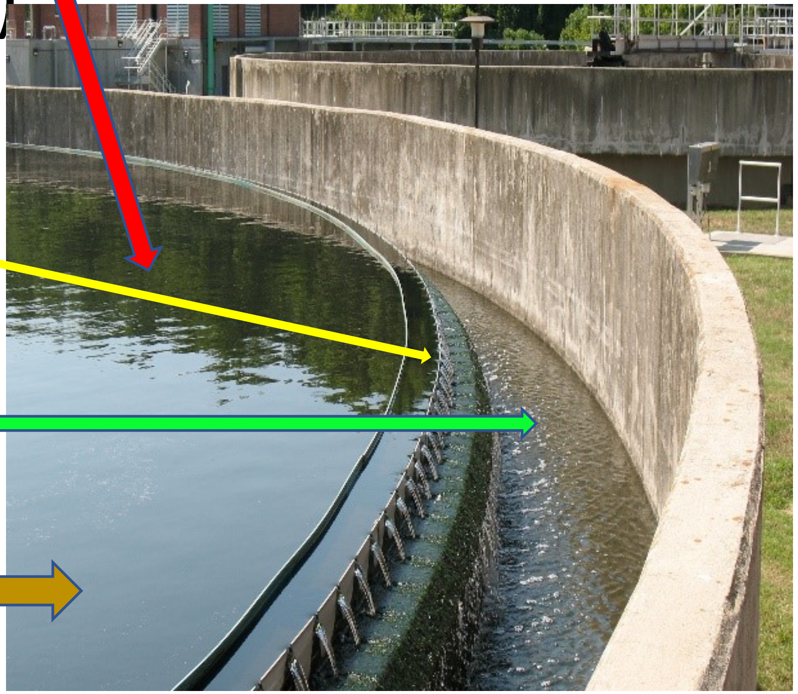
PROCESS CONTROL EQUATIONS FOR SEDIMENTATION

DETENTION TIME: $\frac{\text{VOLUME}}{\text{FLOW}}$

SURFACE OVERFLOW RATE: $\frac{\text{GALLONS PER DAY}}{\text{SURFACE AREA (Ft2)}}$

WEIR OVERFLOW RATE: $\frac{\text{GALLONS PER DAY}}{\text{LINEAR FEET}}$

% Efficiency: $\frac{\text{In} - \text{Out}}{\text{In}} = \%$



TROUBLESHOOTING SHORT CIRCUITING

Which of the following is how the effluent weir of a clarifier should look?

PRIMARY CLARIFIER

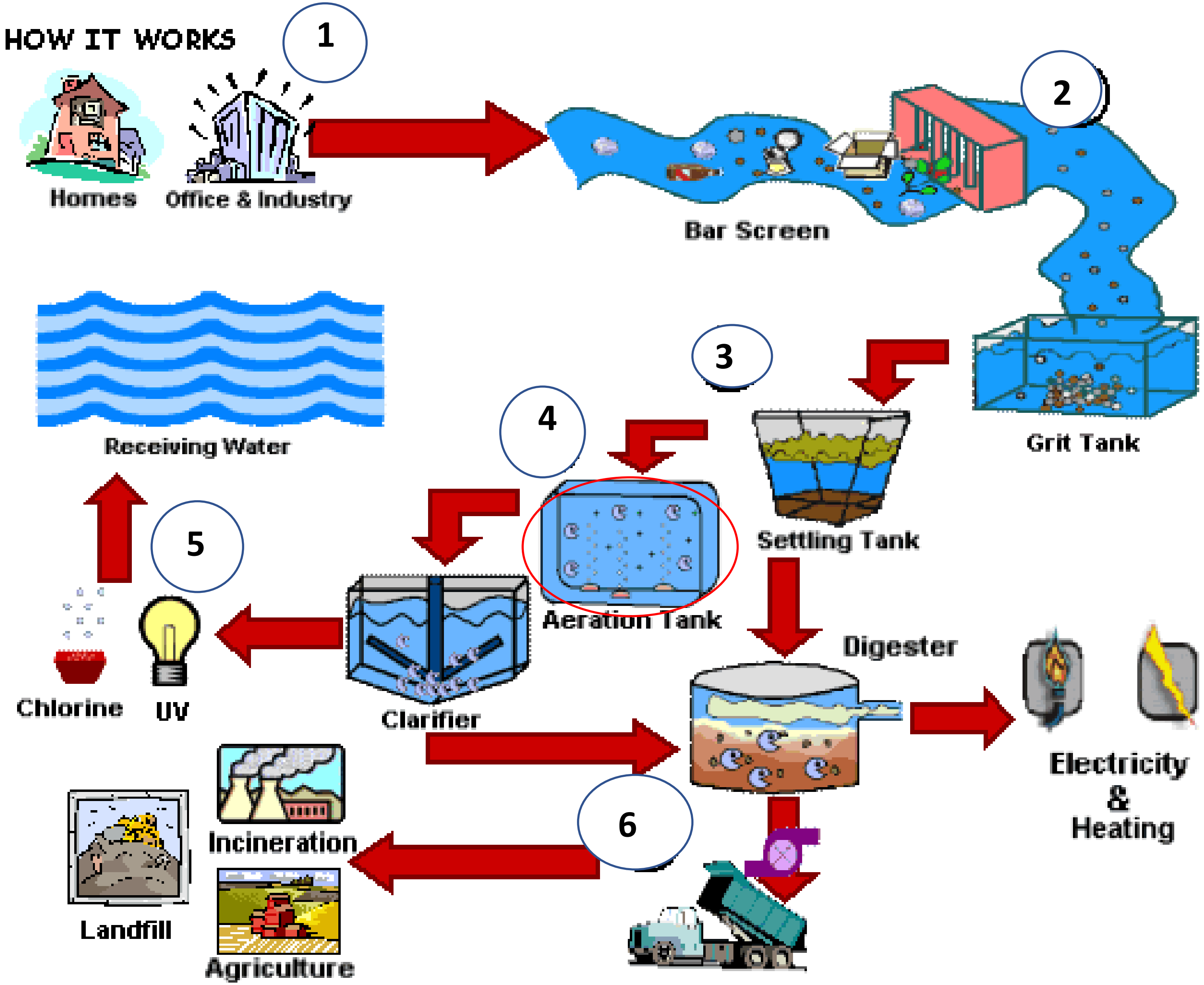
The expected range for percent removal in a primary clarifier is:

- 90%-95% settleable solids
- 40%-60% suspended solids
- 25%-50% total BOD_5.

Are You Seeing these results ???

- Detention time of 1 - 2 hrs;
- Surface overflow rate of (800 – 1200 gpd/ft2) for average flow
- (2000 – 3000 gpd/ft2) for peak flow;
- Weir overflow rate,(10 000 – 40 000 gpd/ft)

Wastewater "Treatment"



Microbial Flora

- The natural microflora is allowed to become enriched- so as to allow decomposition of organic content.
- Organisms include:
- Heterotrophic bacteria: Actinomycetes and Fungi, Protozoa

- Autotrophic Bacteria: although incapable of organic matter decomposition.Oxidize the ammonia and sulfur to nitrate and sulfate.
- Anaerobic Bacteria
- Methanogens-utilize metabolites produced by anaerobic bacteria producing carbon dioxide and methane.

Wastewater activated sludge is made up of approximately:

- **4% Protozoa**
- **1% Metazoa**
- **95% Bacteria**

There are five major groups of microorganisms generally found in the aeration basin of the activated sludge process:

1. **Bacteria**-Aerobic bacteria remove organic nutrients
2. **Protozoa**-Remove & digests dispersed bacteria and suspended particles
3. **Metazoa**-Dominate longer age systems including lagoons
4. **Filamentous bacteria**-bulking sludge (poor settling & turbid effluent)
5. **Algae and Fungi** is present with pH changes & older sludge

Protozoa play a critical role in the treatment process by removing and digesting free swimming dispersed bacteria and other suspended particles. This improves the clarity of the wastewater effluent. Like bacteria, some protozoa need oxygen, some require very little oxygen, and a few can survive without oxygen.
The types of protozoa present give us some indication of treatment system performance which are classified as follows:

1. **Amoebae**-Little effect on treatment & die off as amount of food decreases
2. **Flagellates**-Feed primarily on soluble organic nutrients
3. **Ciliates**-Clarify water by removing suspended bacteria
4. **Ciliates**; Free-swimming-Removes free-dispersed bacteria
5. **Ciliates**; Crawling (grazing)-Dominate activated sludge/good treatment
6. **Ciliates**; Stalked (sessile)-Dominates at process end

Metazoa are multi-cellular organisms which are larger than most protozoa and have very little to do with the removal of organic material from the wastewater. Although they do eat bacteria, they also feed on algae and protozoa. A dominance of metazoa is usually found in longer age systems; namely, lagoon treatment systems. Although their contribution in the activated sludge treatment system is small, their presence does indicate treatment system conditions.

Three most common metazoa found in the activated sludge treatment system.

1. **Rotifers**-Clarify effluent & are first affected by toxic loads
2. **Nematodes**-Feed on bacteria, fungi, small protozoa & other nematodes
3. **Tardigrades** (water bear)-Survive environmental extremes & toxic sensitivity

Oxygen Usage Hierarchy & Alkalinity

The Three Major Zones in WW

Free Dissolved Oxygen	*Aerobic* or Oxic Treatment
Little or No Free Oxygen, But NO_3 Present	*Anoxic* Treatment
Sulfate, SO_4 Is the next choice of the Bugs	*Anaerobic* conditions are beginning, odors forming, H_2S

ALKALINITY

7.14mg/L ↓

↑ 3.57 mg/L

17.86 mg/L ↑

TOTAL ALKALINITY

MULTIPLY DROPS BY 10 – RECORD AS mg/L

Parameter	Range
Food	Proper amount of food to microorganisms
Hydraulic Flow Rate	Within plant design capacity. Excessive flows can result in suspended solids washout
Oxygen	Many of the bacteria in wastewater require between 1 mg/L to 3 mg/L or more of dissolved oxygen
Temperature 50℉ - 77℉	Most microorganisms in wastewater grow best between 10 and 25 degrees C. At >35 to 40 degrees C, thermophilic bacteria will take over
Nutrients	Conventionally a BOD: Nitrogen: Phosphorus ratio of 100:5:1 is recommended in addition to proper micronutrients such as iron and other trace minerals
pH	Between 6.5-8.5 is recommended
Alkalinity	There needs to be enough buffering capacity to maintain the pH. Typically 60 mg/L or more alkalinity at the end of treatment is desired

pH: (6.5 – 8.5) The enzymes which regulate many of the biochemical reactions in bacteria are pH dependent. The optimum pH should be between 7.0 and 7.5 for the proper activated sludge microorganism to dominate.

D.O.: (2 mg/L – 4 mg/L) To know that a system is fully mixed and aerobic, dissolved oxygen of 2.0 mg/L is a good target.

$$C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + 6H_2O + \text{ENERGY}$$

(glucose) (Oxygen) (Carbon Dioxide)

Nutrient Ratio needed to stimulate growth

Carbon : Nitrogen : Phosphorous

100 : 5 : 1

How to Calculate

Using the 100:5:1 Calculation

Raw Data: CBOD 170 mg/L ; NH_3 25 mg/L ; PO_4 10 mg/L

CBOD: 170 / 100 = 1.7

NH_3 (14/17 x 25 = 23 mg/L as Nitrogen) 23 / 1.7 = 13.5

PO_4 (31/95 x 10 = 3.3 mg/L as Phosphorous) 3.3 / 1.7 = 1.9

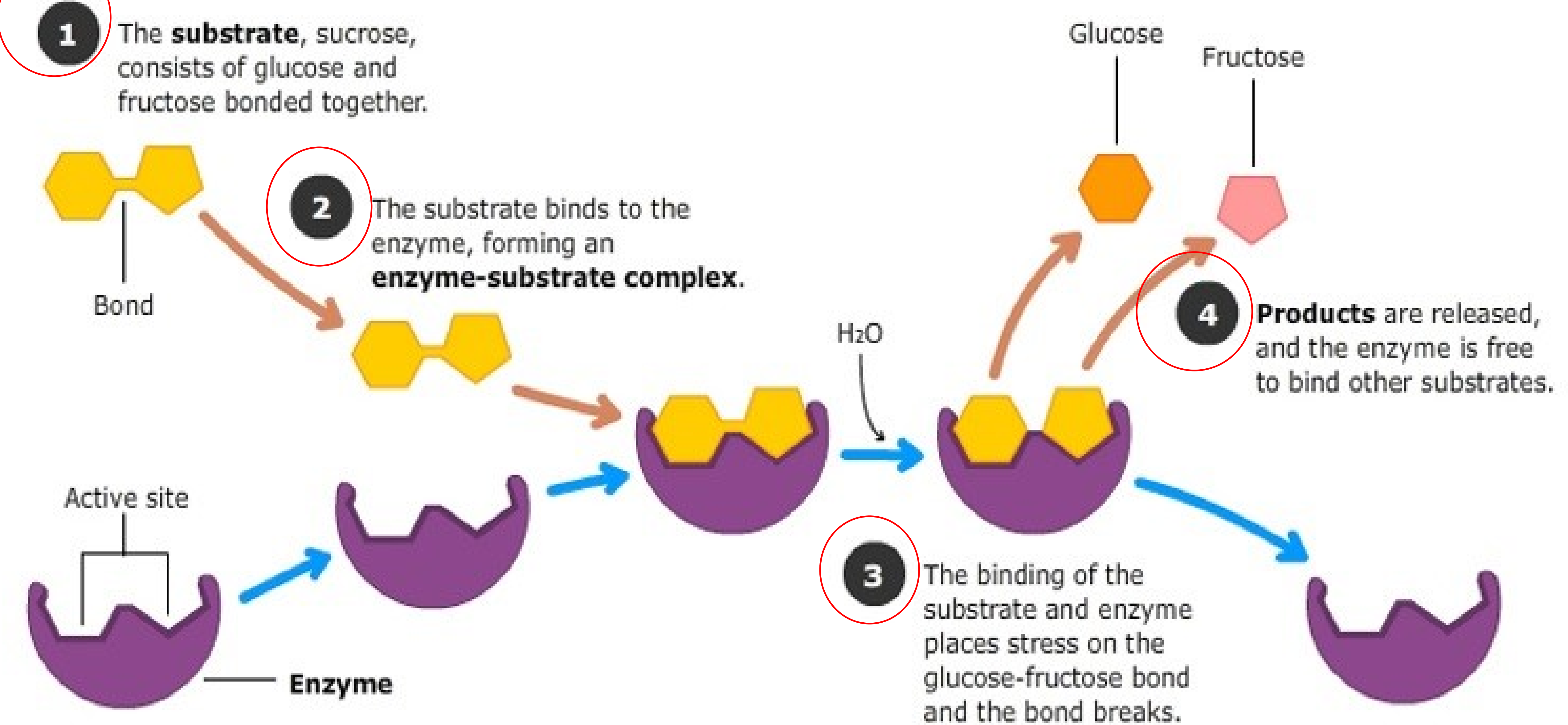
Did We meet the requirements ?

DAP (Di Ammonium Phosphate) can be added in aeration tank if Nitrogen and Phosphorus value is less in the CNP ratio.

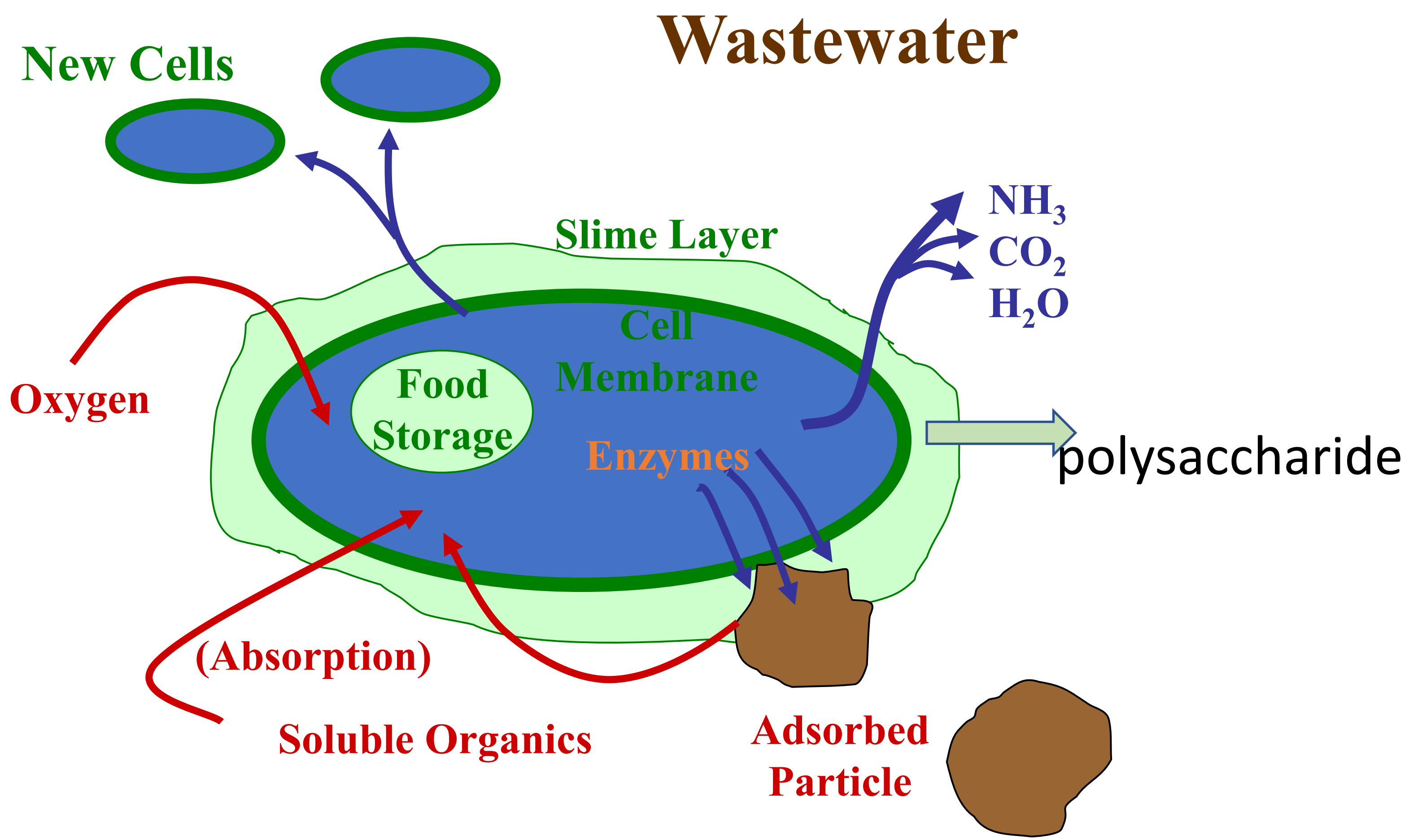
The Effects of pH

The enzymes which regulate many of the biochemical reaction in bacteria are very pH dependent. The optimum pH should be between 7.0 and 7.5 for the proper activated sludge microorganisms to dominate.

How the Enzyme Process Works !



This is why pH is so important

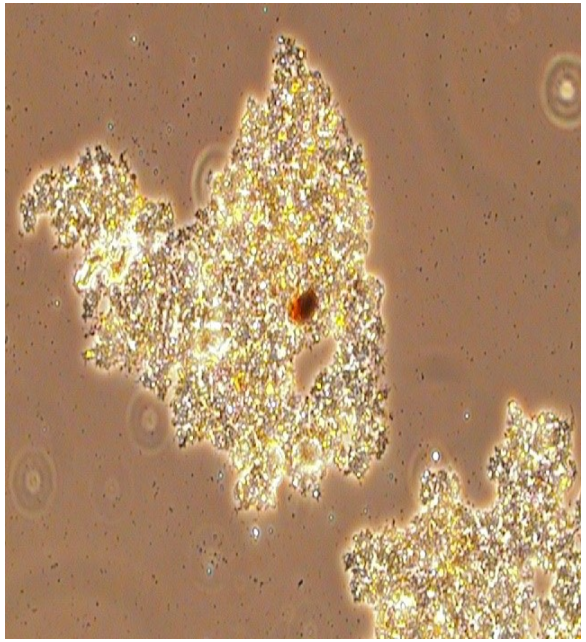


Wastewater
New Cells
Slime Layer
Cell
Membrane
Food
Storage
Enzymes
Oxygen
NH_3
CO_2
H_2O
polysaccharide
(Absorption)
Soluble Organics
Adsorbed
Particle

- Floc forming bacteria contain a polysaccharide (“slime”) layer, known as a glycocalyx.
- The “slime” is made up of protein and carbohydrates and helps to cement the bacteria together
- This occurs at low F/M around 2 and lower
- To form irregularly shaped flocs with a strong “backbone”, a small abundance of filamentous bacteria are desirable.
- It is possible for both strong and weak flocs to exist without filaments

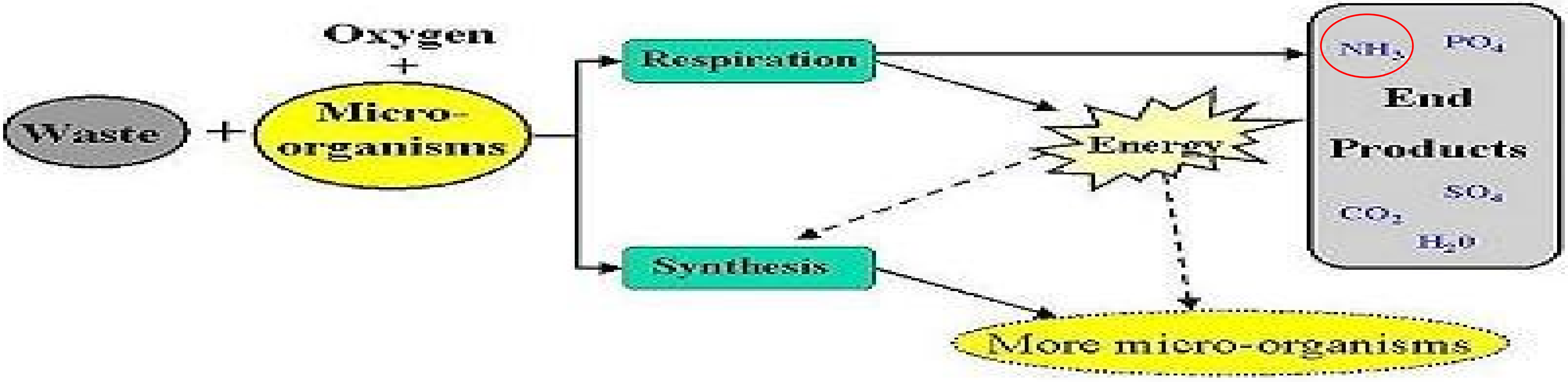
Need Food to create Polysaccharide so they can stick together

Biomass 400X



7200X

These are Heterotrophs another name Organotrophs



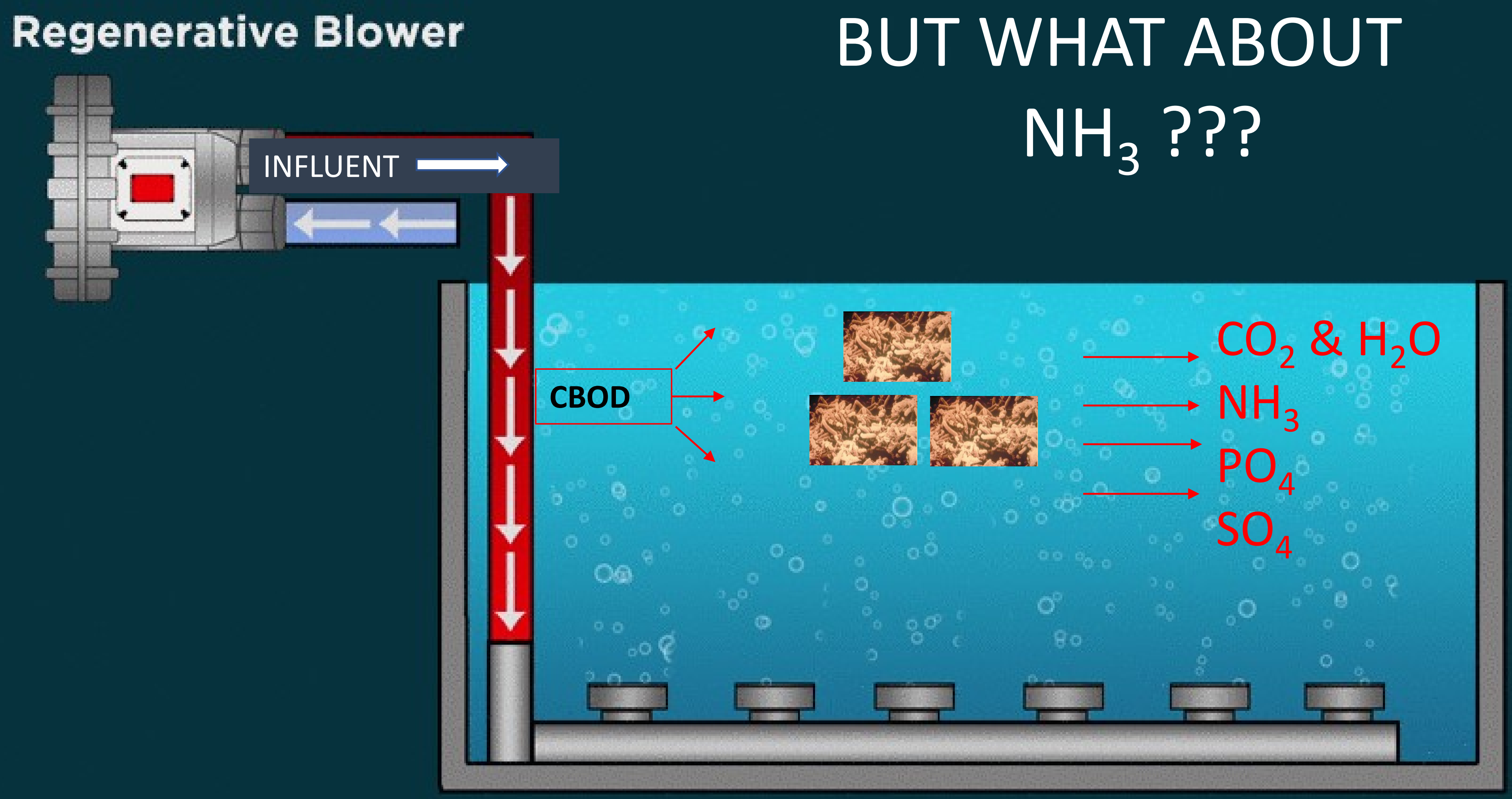
Carbon Source

$$C_6\,H_{12}\,O_6 + O_2 \longrightarrow 6CO_2 + 6H_2O + \textbf{ENERGY}$$

(glucose) (Oxygen) (Carbon Dioxide)

RESPIRATION PROCESS

It's beginning to look like this!
BUT WHAT ABOUT
NH_3 ???




Tests
AMMONIA
NH_3/NH_4^+
TEST KIT


FRESHWATER AMMONIA
(NH3/NH4+) COLOR CARD
0 ppm
(mg/L)
0.25
0.50
1.0
2.0
4.0
8.0

Nitrogen Constituents in wastewater:

The principal forms of nitrogen found in wastewater are:

Organic Nitrogen (Organic – N)

Ammonia Nitrogen (NH_3 – N)

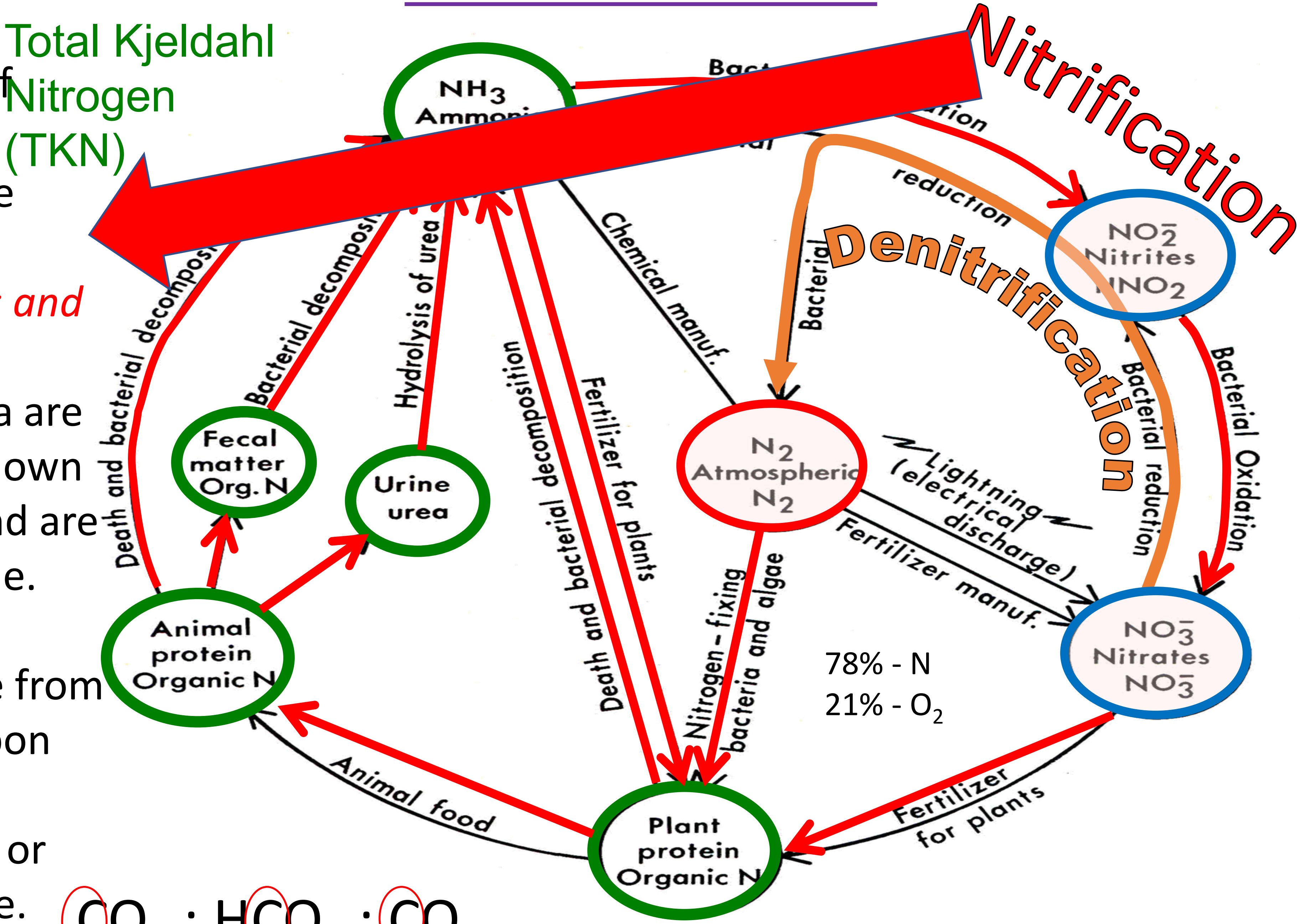
Ammonium Nitrogen (NH_4 – N)

Nitrite Nitrogen (NO_2 – N)

Nitrate Nitrogen (NO_3 -N)

NITROGEN CYCLE

Two species of bacteria are involved in the process – *Nitrosomonas and Nitrobacter.* These bacteria are collectively known as nitrifiers and are autotrophic, i.e. they get their carbon source from inorganic carbon (carbonates, bicarbonates) or carbon dioxide.



CO_3 ; HCO_3 ; CO_2

Nitrification

Nitrification of Ammonia Occurs in Two Steps

NH_3-N → NO_2-N
Ammonia N → Nitrite N

*Autotrophic Bacteria Utilize Inorganic Compounds
(and CO_2 as a Carbon Source)

Nitrosomonas

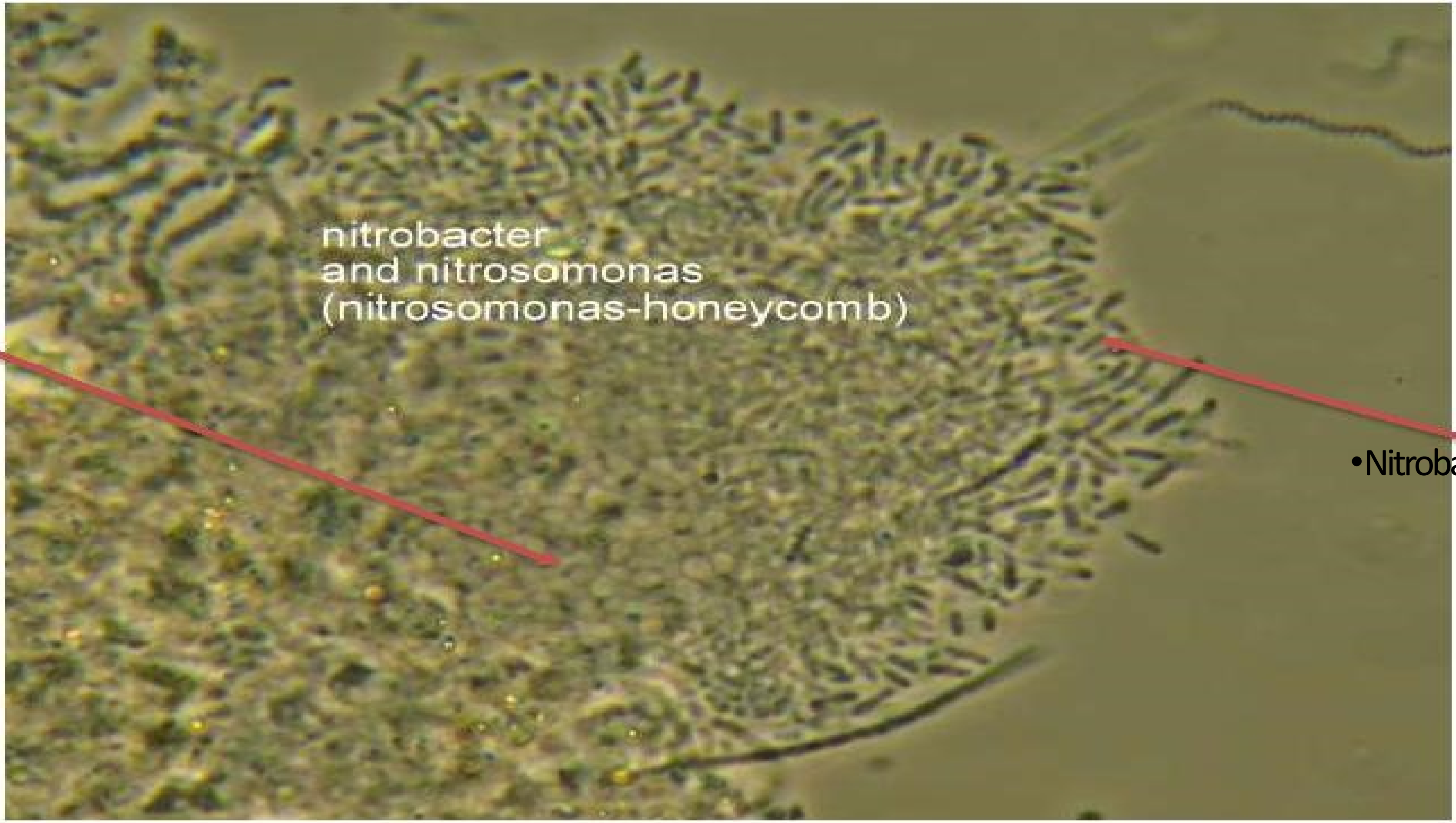
NO_2-N → NO_3-N
Nitrite N → Nitrate N

Nitrobacter

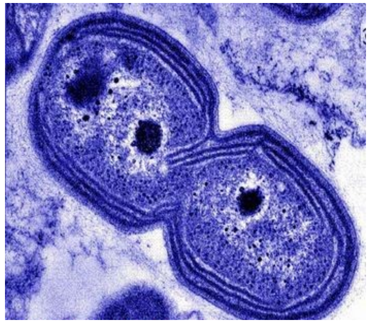
- Nitrosomonas and Nitrobacter can be
  - •visible at 1000x with phase contrast
  - •– While once believed that nitrosomonas
    - •and nitrobacter were the only nitrifying
    - •bacteria FISH has determined that
    - •Nitrospira and other nitrifying organisms
    - •perform the majority of nitrification.
  - •– Fungi can perform both steps of
    - •nitrification (slowly) and filament type 0092 can also nitrify.

fluorescence in situ hybridization (FISH)

Nitrosomonas and Nitrobacter



- Nitrosomonas
- Nitrobacter



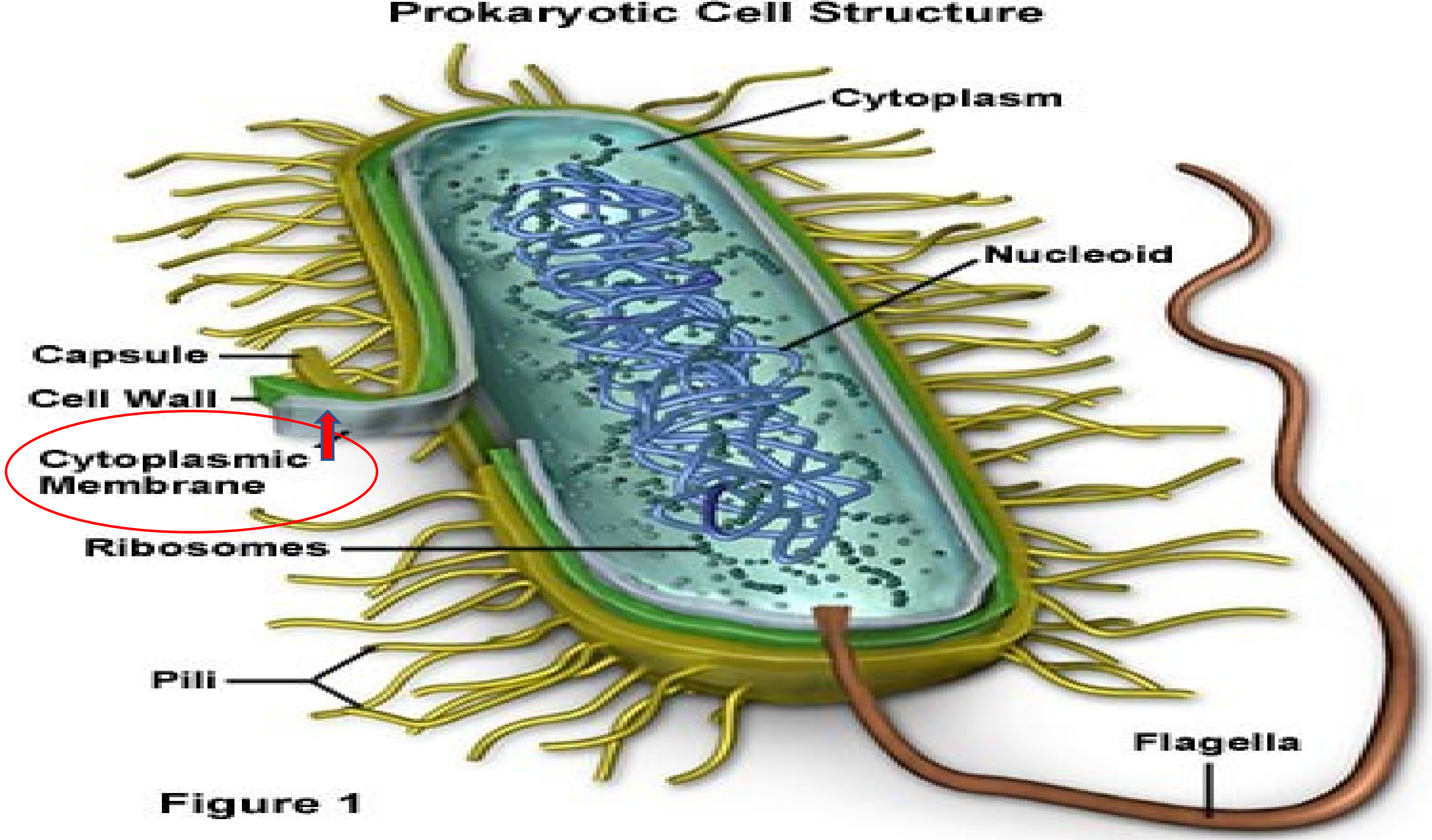


Figure 1

on the cytomembranes of Nitrosomonas and Nitrobacter, where ammonium ions and nitrite ions, respectively, come in contact with enzymes that add oxygen to each ion.

What is Nitrification ?

Nitrification is the sequential conversion of ammonium to nitrite and ultimately nitrate:

$$\text{Ammonium} \longrightarrow \text{Nitrite} \longrightarrow \text{Nitrate}$$

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

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

The overall reaction is as follows:

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

How does nitrification take place in an activated sludge system ?

It is important to note that it is the ammonium ion (NH_4^+) and not ammonia (NH_3) that is oxidized during nitrification. When proteins and organic nitrogen compounds, e.g. urea (NH_2CONH_2), are hydrolysed, and degraded amino acids are released.

The amino group is removed by bacterial activity – this is known as de-amination- and is quickly converted to the ammonium ion.

PREDOMINANTLY

NH_4

PREDOMINANTLY

NH_3

pH	Temperature													
	42.0 (°F)	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6
	6 (°C)	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617	.7929
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351	.8585
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892	.9058
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271	.9389

Ammonia Levels NH_3 mg/L

These factors are necessary for effective Nitrification!

Oxygen

- Nitrifiers are obligate aerobes, i.e. they require free molecular oxygen. Maximum nitrification occurs at a D.O. level of 3.0 mg/L. Significant nitrification occurs at a D.O. level of 2.0 to 2.9 mg/L. Nitrification ceases at D.O. levels of < 0.5 mg/L.
- Approximately, 4.6 kg of oxygen are required for every kg of ammonium ions oxidized to nitrate.

Temperature

Nitrification is temperature sensitive. The optimum temperature for nitrification is generally considered to be 86° F.

Temperature Continued

Temperature	Effect upon Nitrification
>113° F	Nitrification ceases
82 - 89° F	Optimum temperature range
61° F	Approx. 50% of nitrification rate at 86°
50° F	Significant reduction in nitrification
<41° F	Nitrification ceases

ALKALINITY

Aerobic metabolism in general, and nitrification in particular, will *decrease alkalinity* by the following reaction:

$$NH_4 + 2O_2 + 2HCO_3 \longrightarrow NO_3 + 2CO_2 + 3H_2O$$

In this reaction, two bicarbonates are consumed for every ammonium that is converted to nitrate, so for every mg/L of converted ammonium, the alkalinity decreases by 7.14 mg/L.

Nitrification (Aerobic) (-7.14)

For example:

Influent ammonia = 36 mg/L

36 mg/L ammonia ´ 7.14 mg/L alkalinity to nitrify = 257 mg/L alkalinity requirements

257 mg/L is the minimum amount of alkalinity needed to nitrify 36 mg/L of influent ammonia

Coming into aeration your NH4 is 15 mg/l and the alkalinity concentration is 60 mg/l. Exiting the aeration tank your NH4 is 8mg/l and NO3 is 7mg/L. What would be your expected alkalinity concentration?

7 mg/L converted to NO_3 x 7.14 = 50 mg/L ALK. ↓

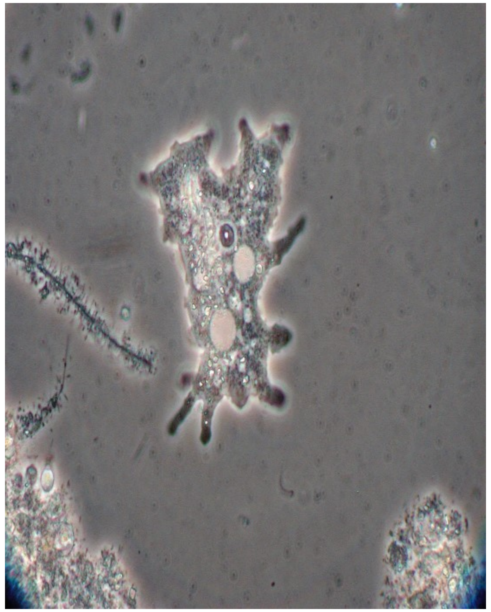
Remaining Alkalinity 10 mg/L

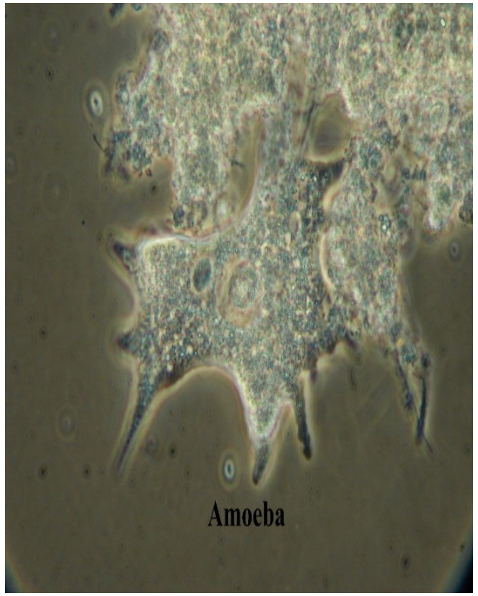
Optimal Conditions for Nitrification

CONDITION	ACCEPTABLE RANGE	OPTIMUM RANGE
Dissolved Oxygen, ppm	>1	>2
pH	6.5 – 9.0	7.5 – 8.0
Temperature,℃	10 - 40	20 - 35
Toxic Heavy Metals, ppm	<0.1	None
Toxic Organics, ppm	Trace	None
Alkalinity, ppm as $CaCO_3$	>40	>100


MICROSCOPE
Wastewater Lab
SCHOTT

Amoeba





Amoeba can only multiply when there is an abundance of nutrients in the aeration tank.

They feed on small organic particulates. When amoeba are present in large numbers in the aeration basin this usually indicates that there has been some sort of shock loading to the plant (a lot of food available). Their presence may also indicate that there is a low D.O. environment in the aeration basin, because they can tolerate very low amounts of D.O.

AMOEBA

Flagellates

Most flagellates absorb dissolved nutrients. If large amounts of flagellates are present in the later stages of the activated sludge development this usually indicates that the wastewater still contains a large amount of soluble organic nutrients.

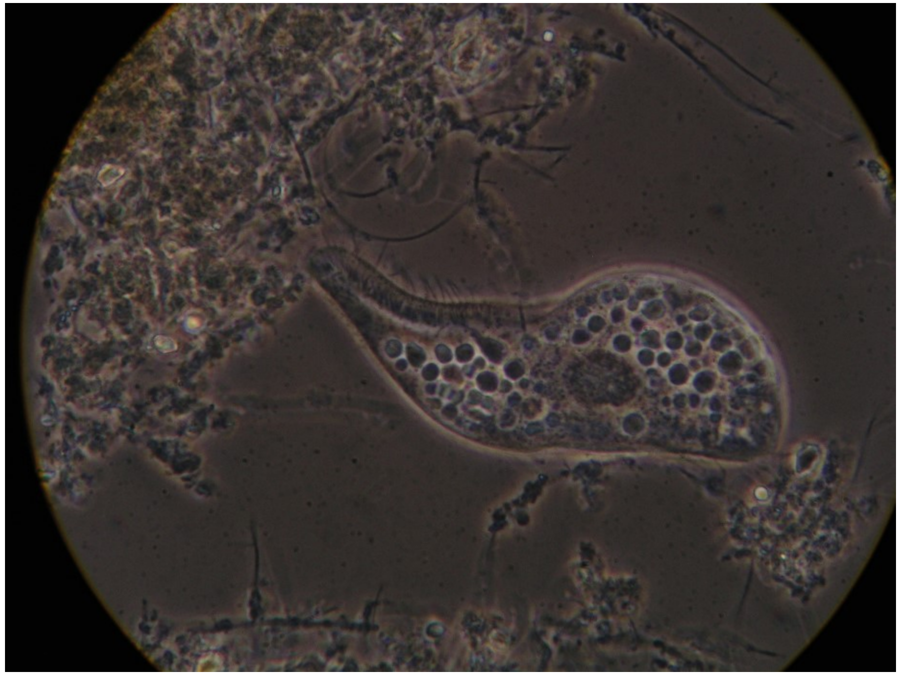
FLAGELLATES

CILIATES

Ciliates feed on bacteria not on dissolved organics. While bacteria and flagellates compete for dissolved nutrients, ciliates compete with other ciliates and rotifers for bacteria. *The presence of ciliates indicate a good sludge, because they dominate after the floc has been formed and after most of the organic nutrients have been removed.*

FREE SWIMMER

Carnivore ciliates

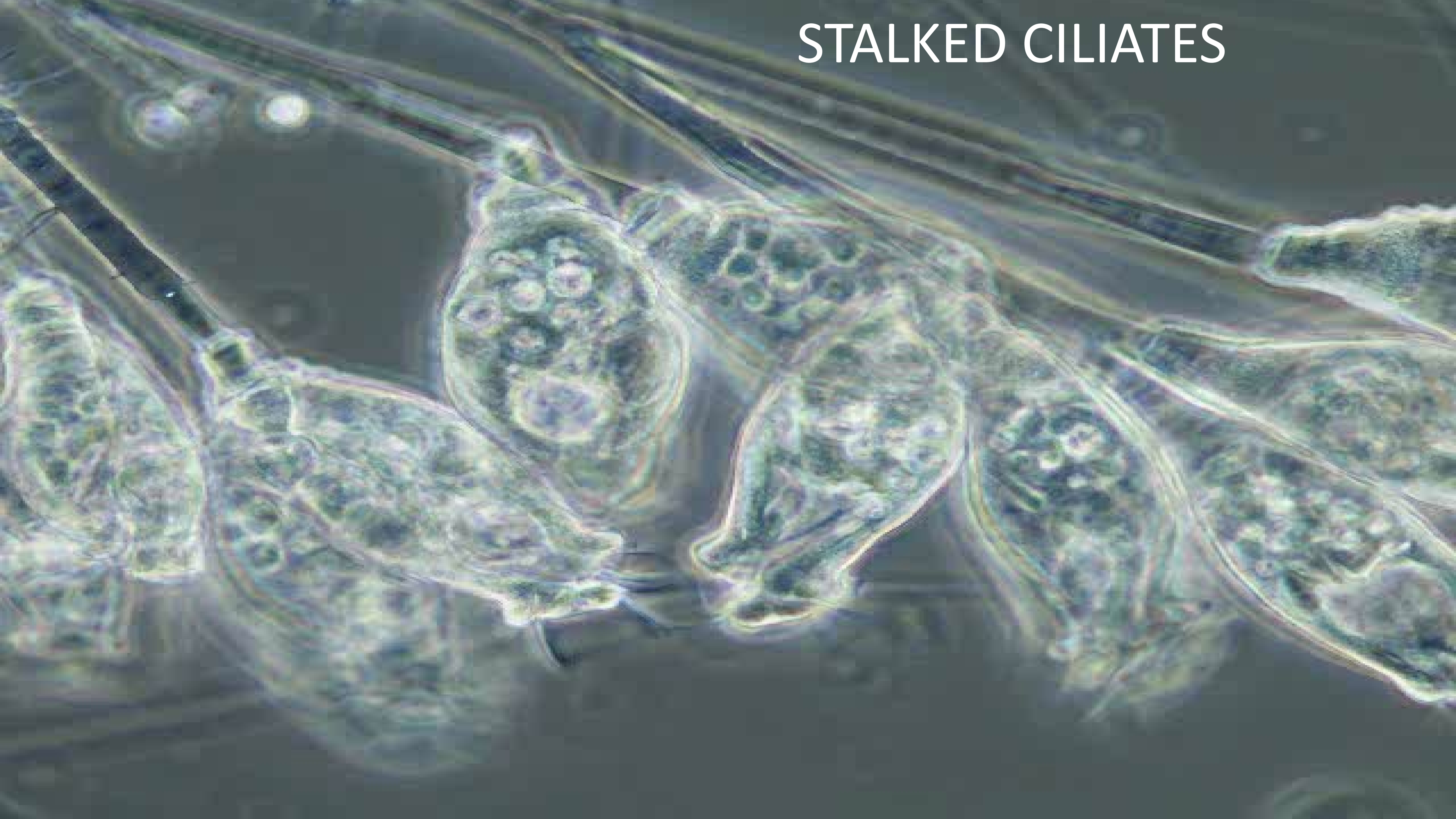


Lionotus

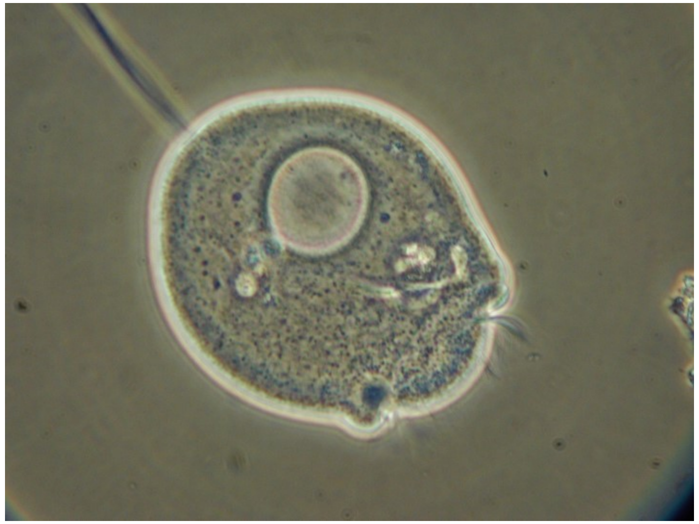
Blepharisma

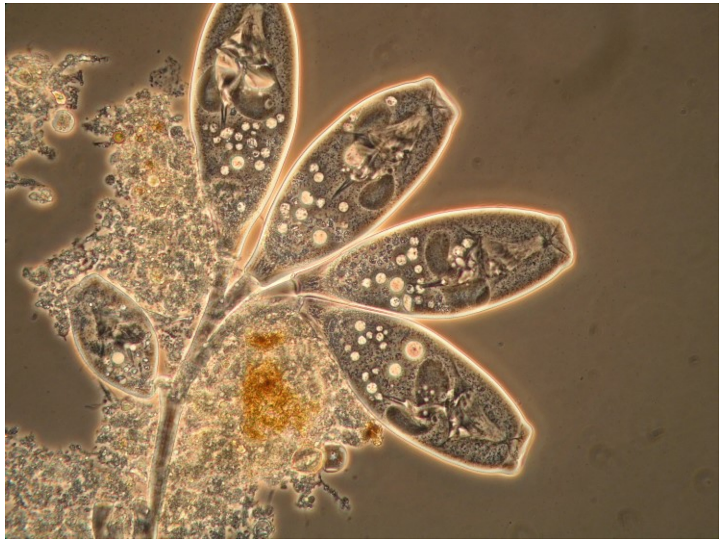
-Healthy system
-sufficient D.O.
-Low BOD & Ammonia
-Older sludge age
-Diversity

CRAWLING CILIATES


STALKED CILIATES

Stalked Ciliates

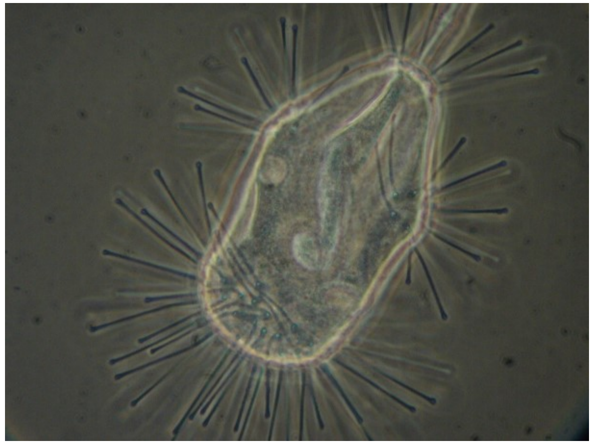


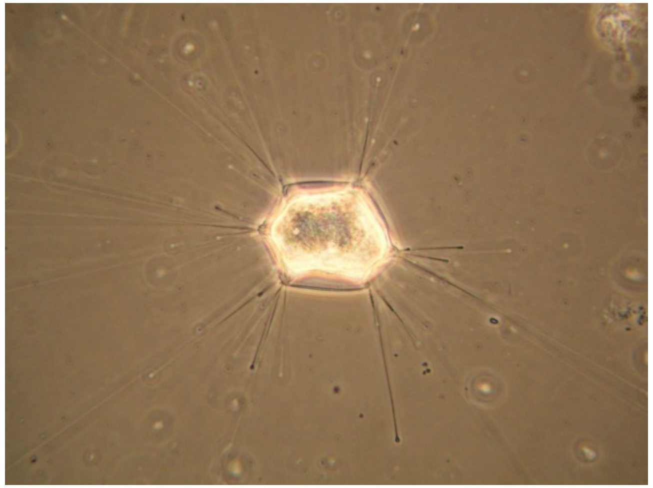


★-Indicates healthy biomass

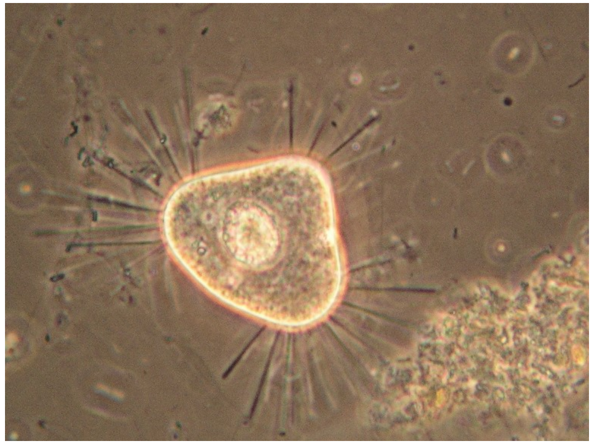
Lower BOD

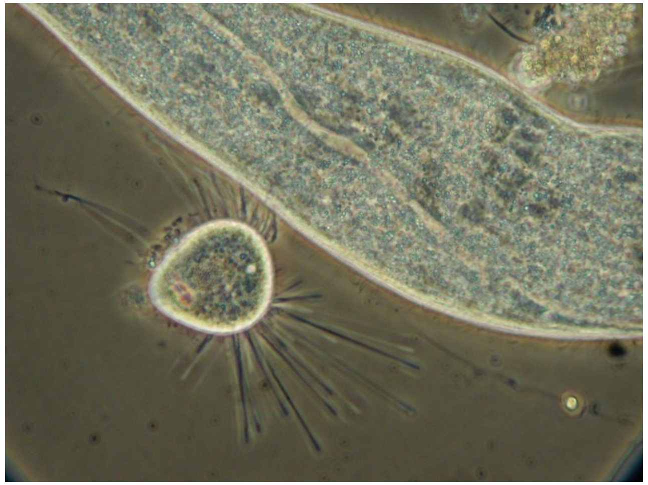
Suctoria





-Healthy biomass
-Low ammonia
-Low BOD
-sufficient D.O.





ROTIFERS

Rotifers move by swimming freely through the bulk water or crawling. They have a ciliated area at the anterior end (mouth opening) that resembles a "rotating wheel." This group of cilia at the mouth aids in the feeding and movement of the rotifer. *They feed on suspended particles and bacteria.* The food is passed into the gut via two grinding plates called "mastax". Many rotifers also have a posterior podite (foot) which allows them to attach to floc. It usually looks like a forked tail. *The main role of rotifers in wastewater systems is the removal of bacteria*. They also aid in floc formation. *Rotifers thrive in conditions with plenty of oxygen and are an indicator species for low Biochemical Oxygen Demand (BOD), low toxicity, and stable wastewater systems.*


ROTIFERS
MASTAX


SHELLED ROTIFER

Nematode (metazoa)

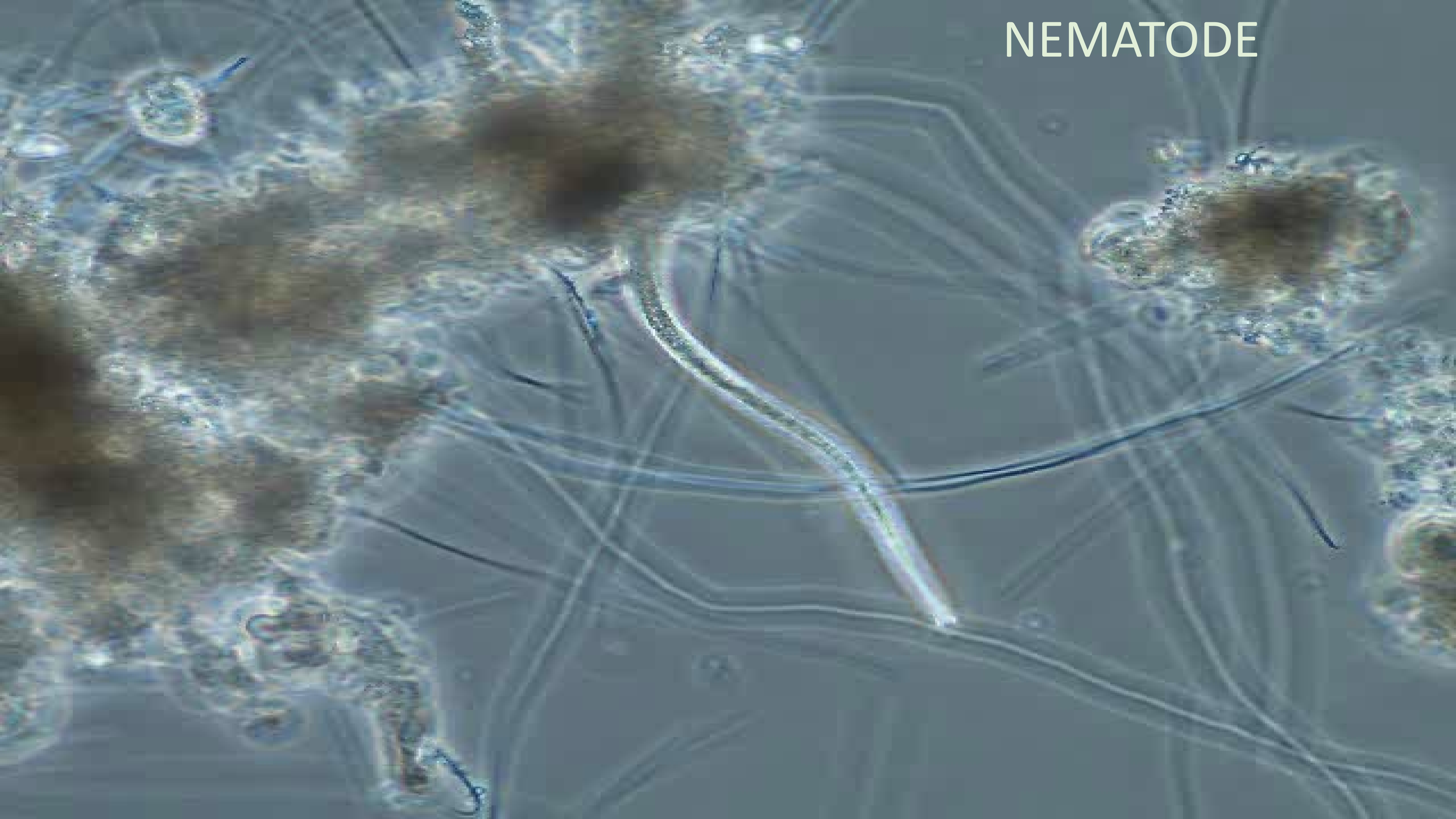
Nematodes aid the floc with oxygen utilization.

Indicative of poor operating conditions if they are found in activated sludge systems. Nematodes-Feed on **bacteria**, **fungi**, **small protozoa & other nematodes**.

The presence of nematodes in wastewater indicates:

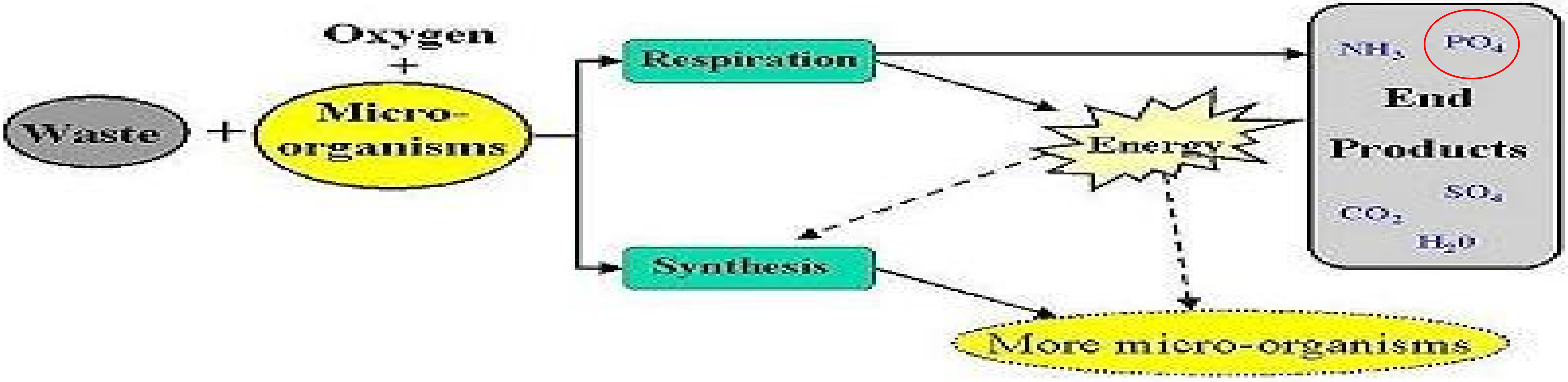
- Low dissolved oxygen
- Low sludge age

NEMATODE




WATERBEAR

WHAT ABOUT PHOSPHOROUS ??



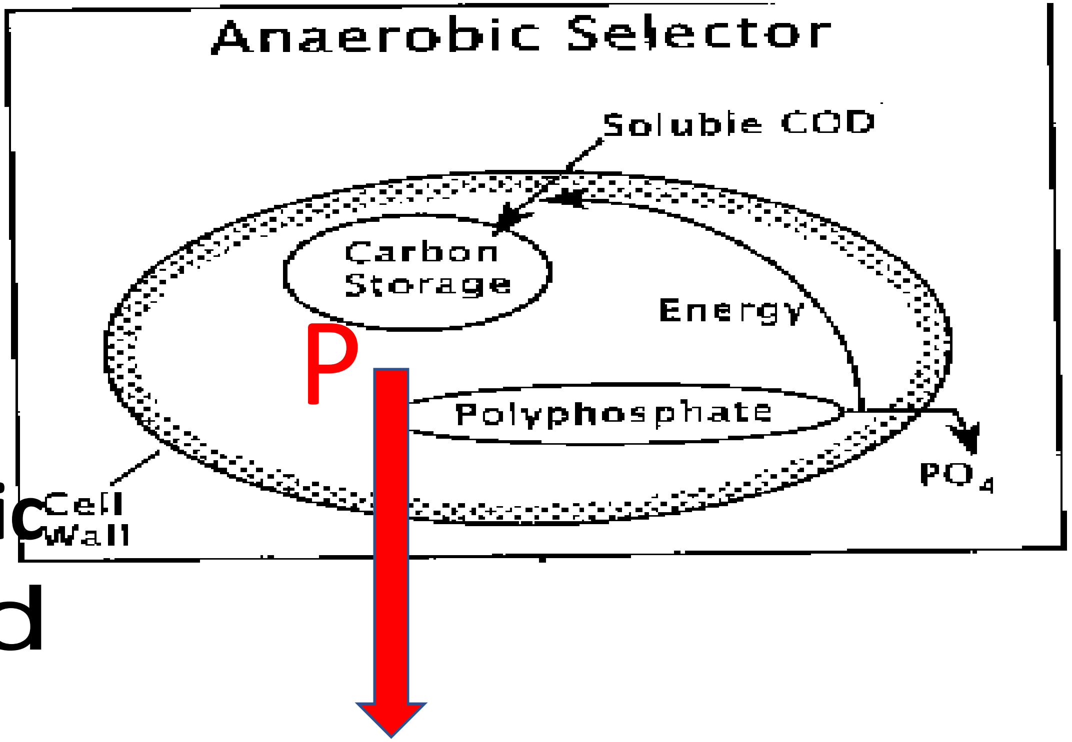
Carbon Source

$$C_6\,H_{12}\,O_6 + O_2 \longrightarrow 6CO_2 + 6H_2O + \textbf{ENERGY}$$

(glucose) (Oxygen) (Carbon Dioxide)

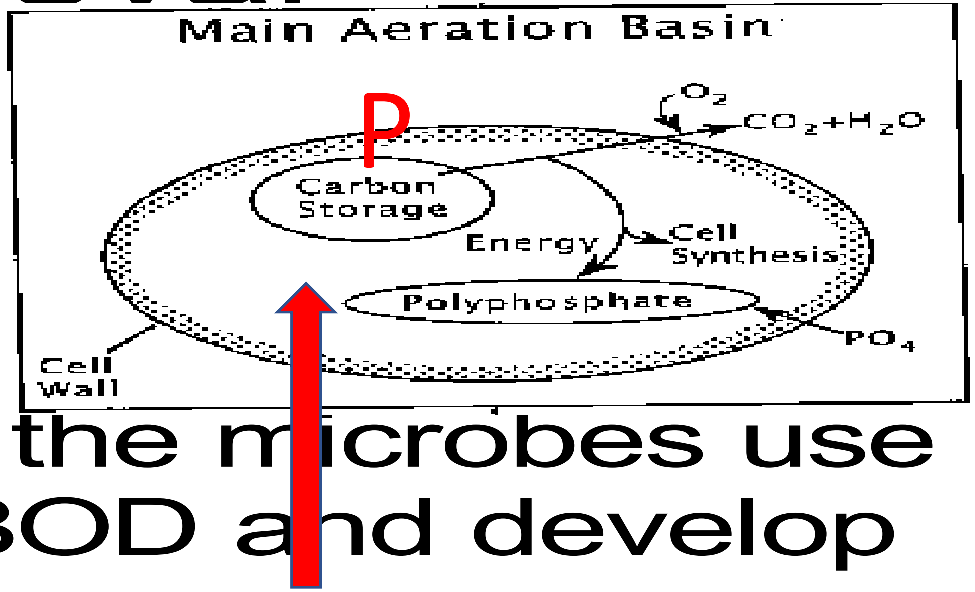
RESPIRATION PROCESS

Biological Phosphorus Removal



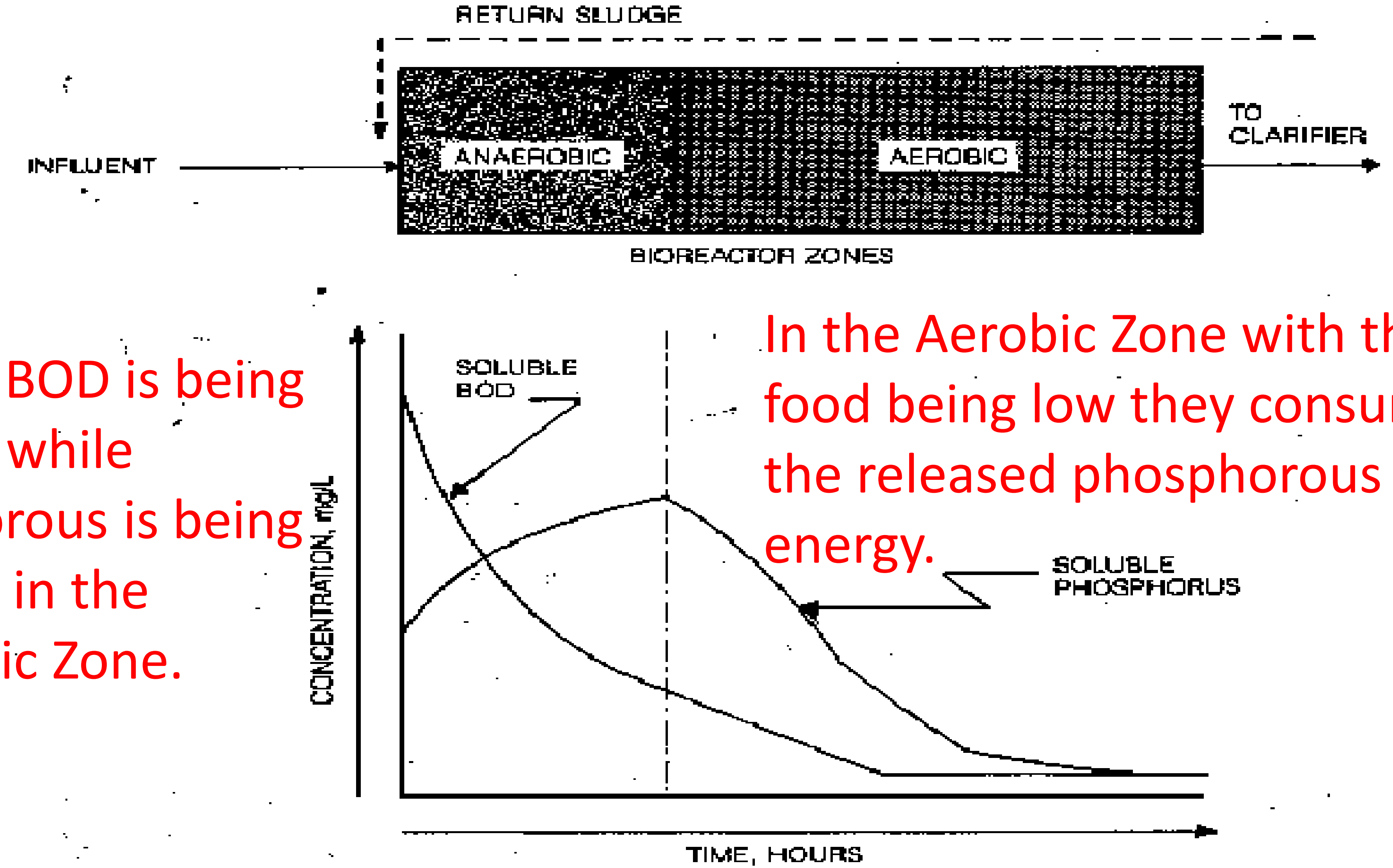
- Two Zone Process
  - 1st Zone – Anaerobic
    - Acinetobacter and Pseudomonas
    - Release Stored Phosphorus and take in Soluble BOD in the form of Acetate and Fatty Acids under Anaerobic conditions.

Biological Phosphorus Removal



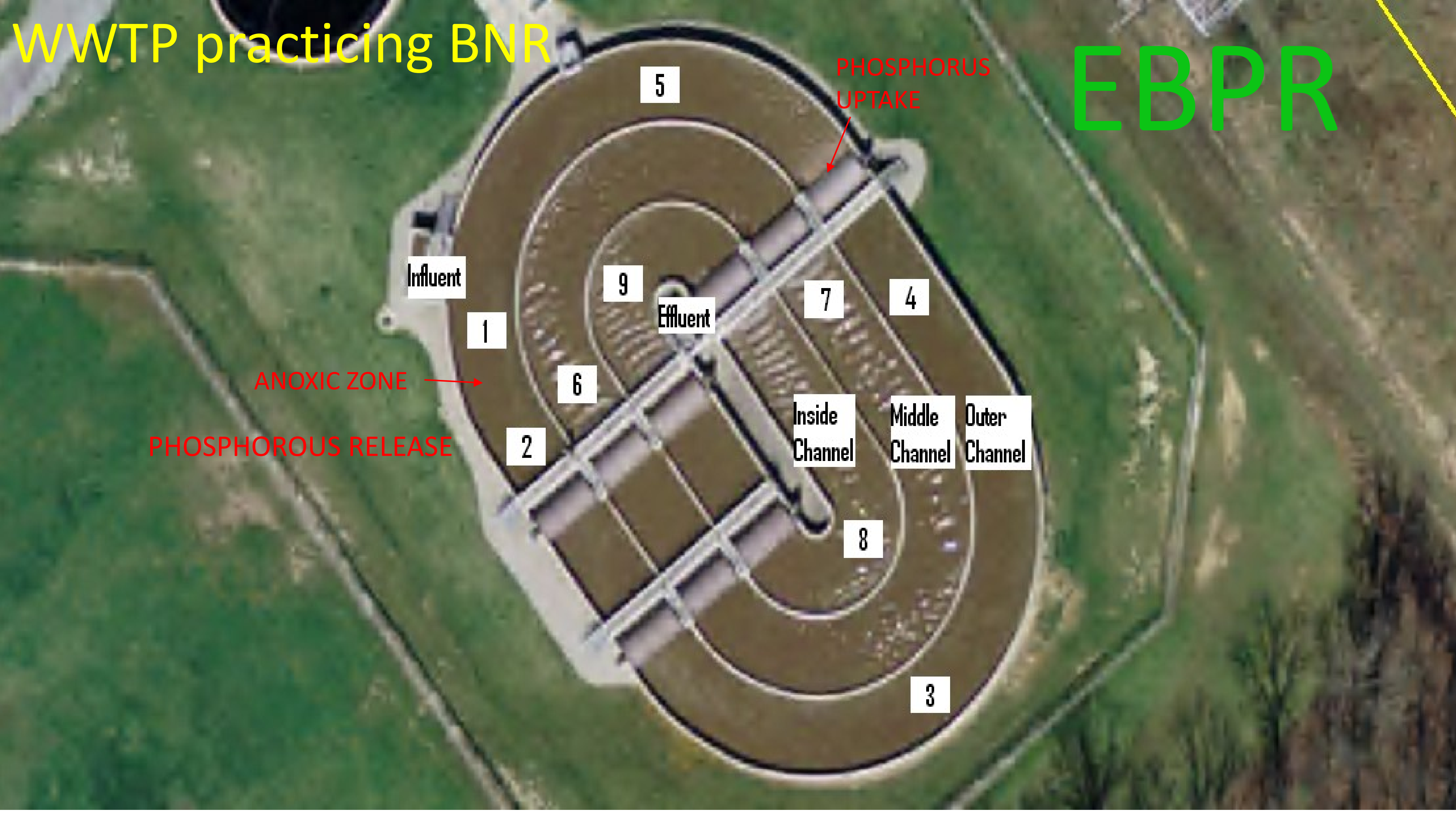
- 2^{nd} Zone – Aerobic
  - In the aerobic zone the microbes use the stored soluble BOD and develop new cells
  - With low soluble BOD, microbes consume large amounts of soluble phosphorus
  - Phosphorus contained within the microbes are wasted.

Biological Phosphorus Removal



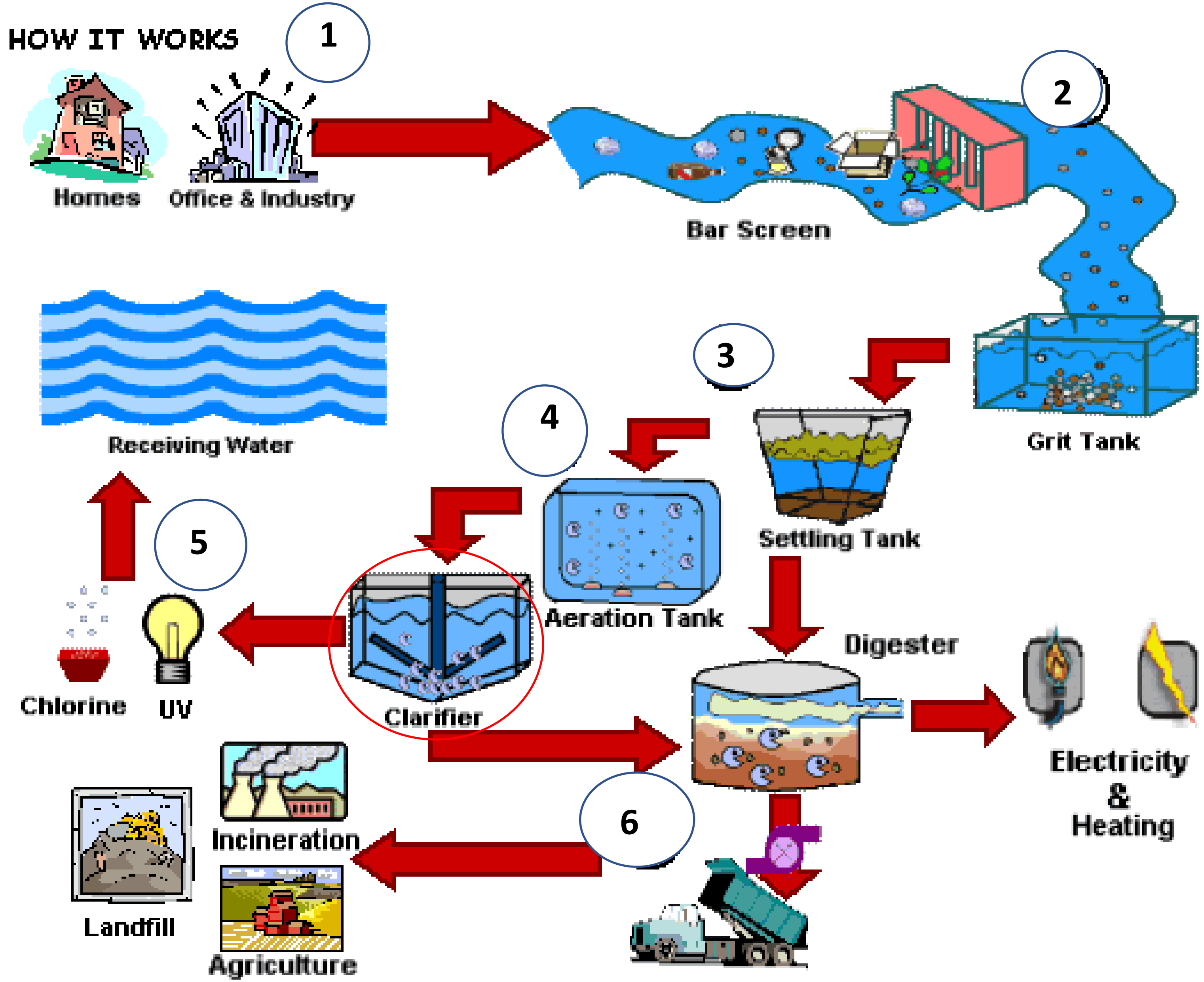
NOTICE: BOD is being reduced while phosphorous is being released in the Anaerobic Zone.

In the Aerobic Zone with the food being low they consume the released phosphorous for energy.



WWTP practicing BNR
EBPR
PHOSPHORUS UPTAKE
5
Influent
9
Effluent
7
4
1
6
ANOXIC ZONE
PHOSPHOROUS RELEASE
2
Inside Channel
Middle Channel
Outer Channel
8
3

Wastewater "Treatment"



Typical Operating Parameters — Secondary Clarifiers

Parameter	Operating Range
Detention Time	2.0 to 3.0 hours
Weir Overflow Rate > 1.0 MGD	5,000 to 15,000 gallons per day per lineal foot of weir 30,000 gpd/linear foot
Surface Settling Rate or Surface Loading Rate	300 to 1,200 gallons per day per square foot of clarifier surface area
Solids Loading Rate	12 to 30 pounds of solids per day per square foot of clarifier surface area

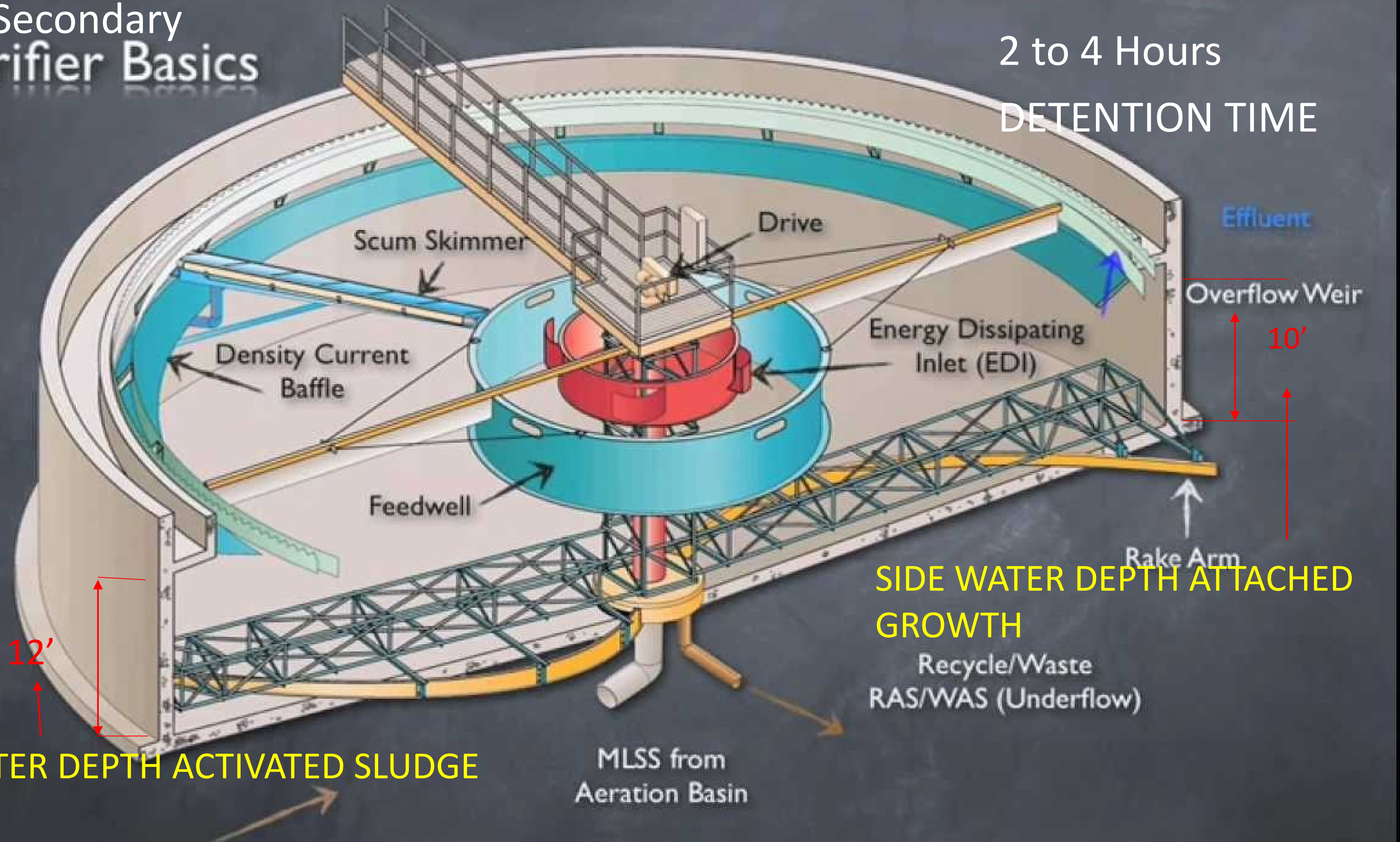
In activated sludge processes, the sludge blanket should never exceed 25% of the sidewall depth of the secondary clarifier.

Sludge Blanket 1 – 3 feet

Secondary Clarifier Basics

2 to 4 Hours

DETENTION TIME



SIDE WATER DEPTH ATTACHED GROWTH

SIDE WATER DEPTH ACTIVATED SLUDGE

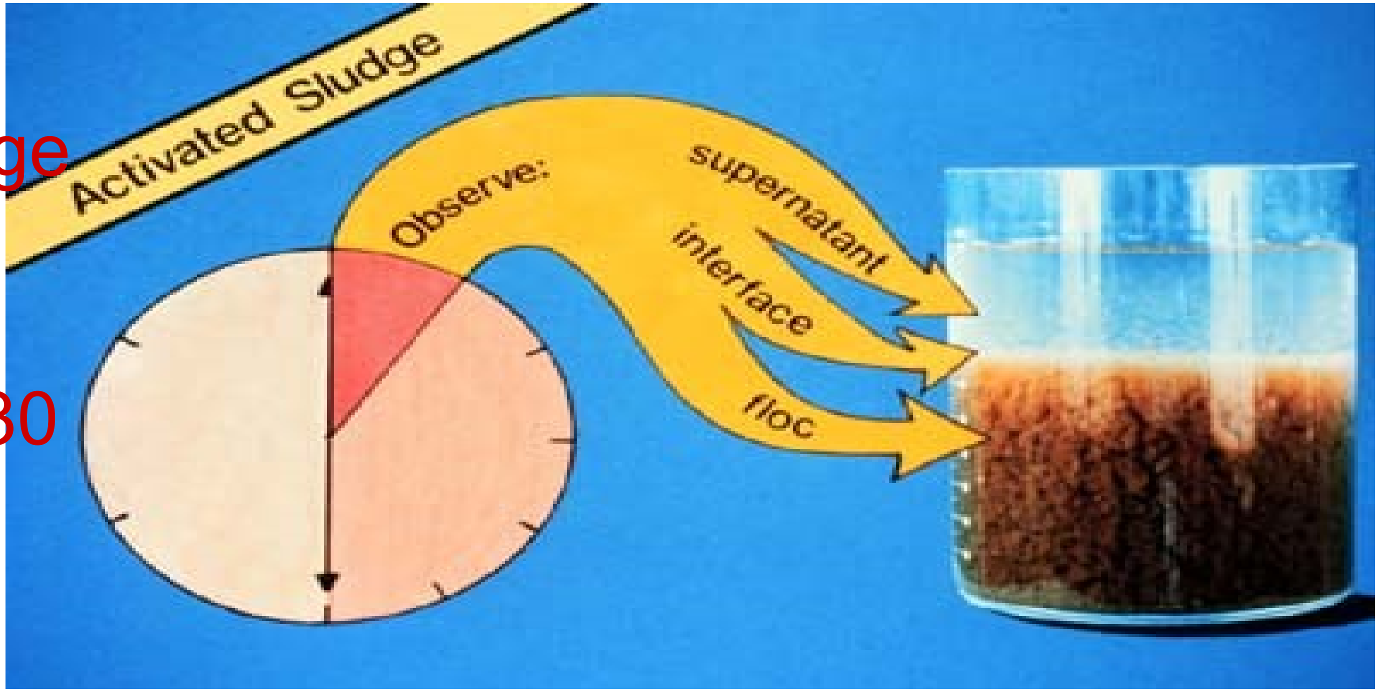
Maintain 1 to 3 Feet

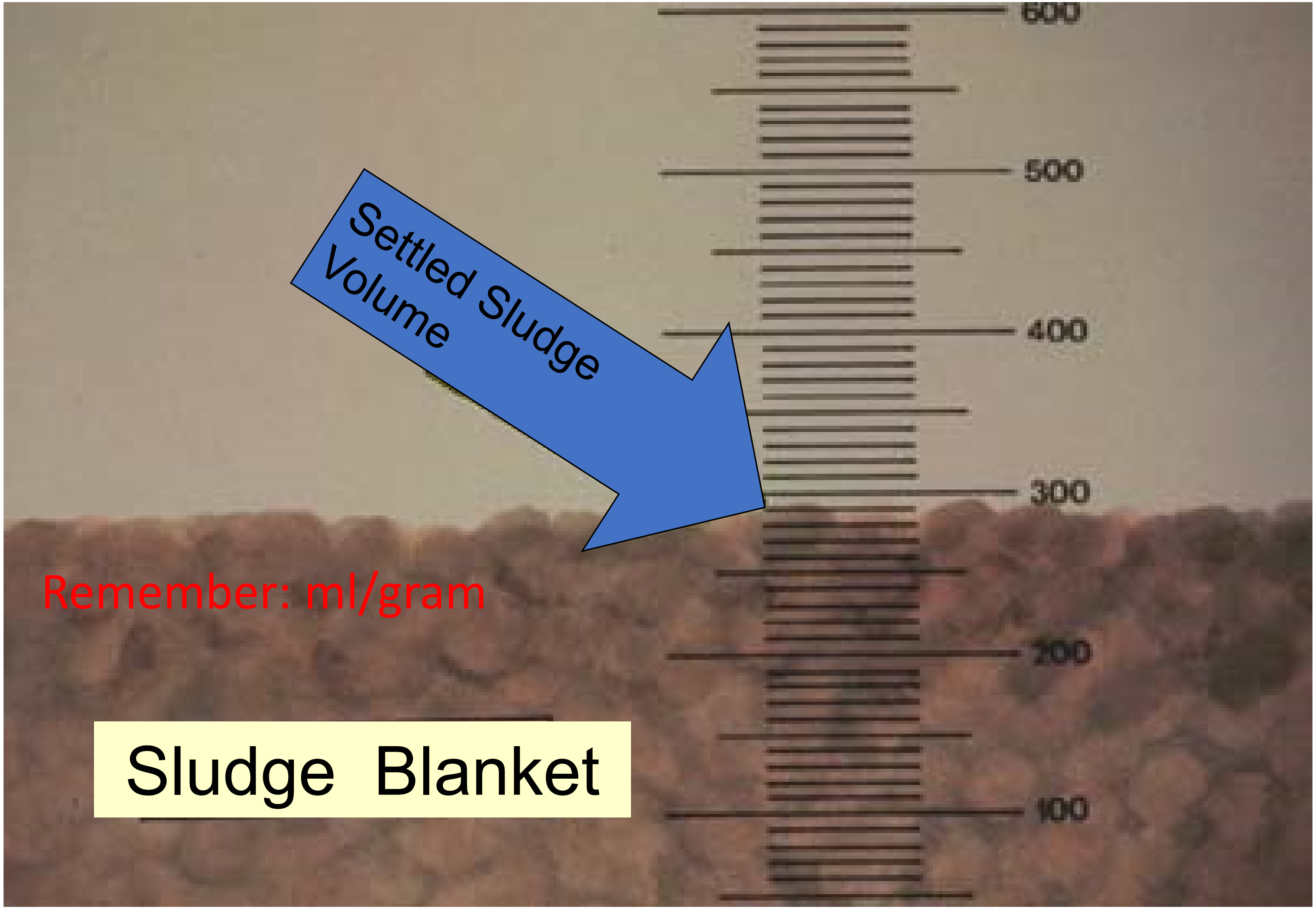
Settleometer Test - remember 1gram/ml

While Settling Observe:

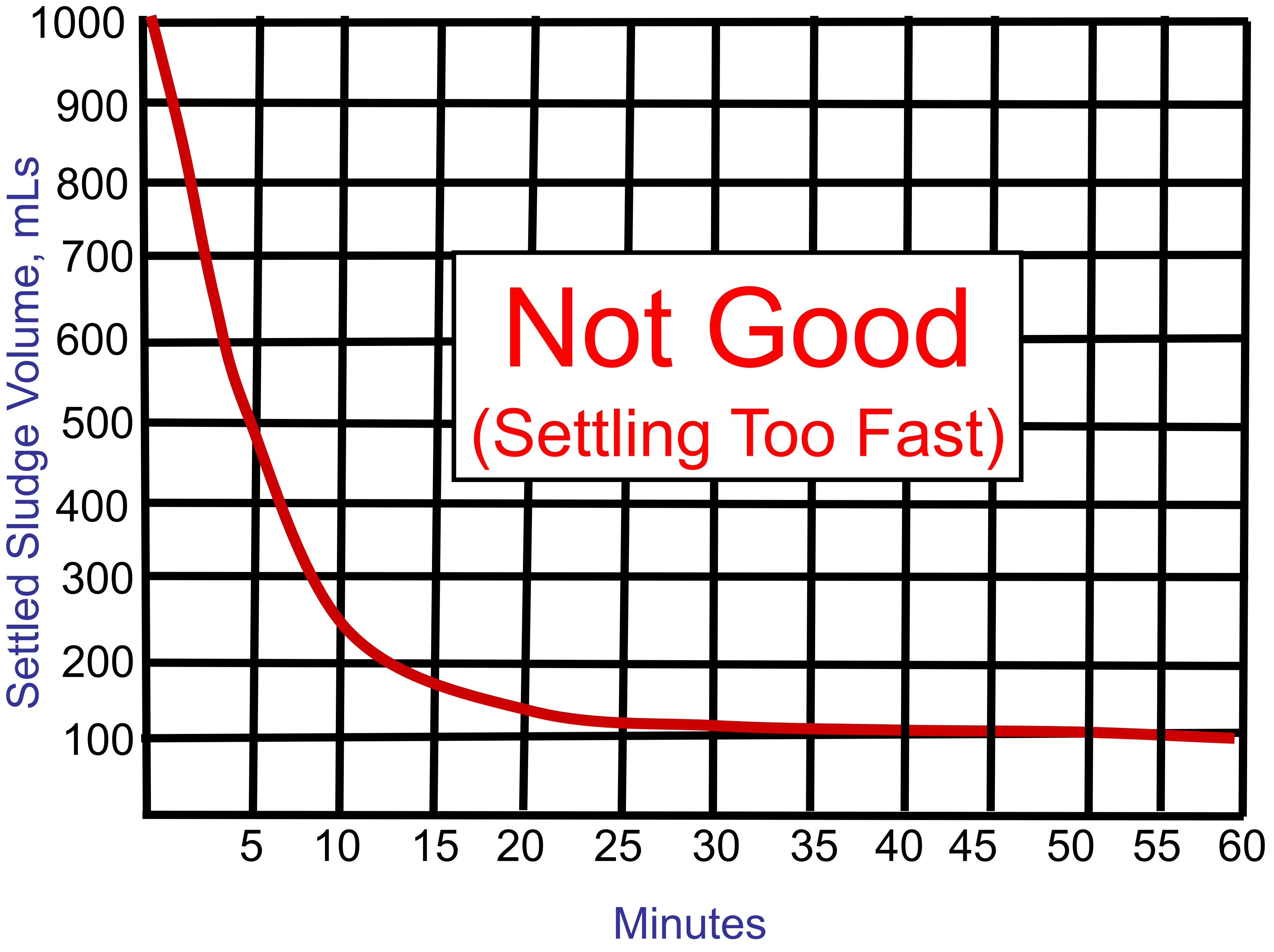
Color of ML and Supernatant
Supernatant Turbidity
Straggler Floc

Record
Settled Sludge
Volume
Every 5
Minutes for 30
Minutes




600
500
400
300
200
100
Settled Sludge Volume
Remember: ml/gram
Sludge Blanket


Good
Settled Sludge Volume, mLs
1000
900
800
700
600
500
400
300
200
100
5
10
15
20
25
30
35
40
45
50
55
60
Minutes

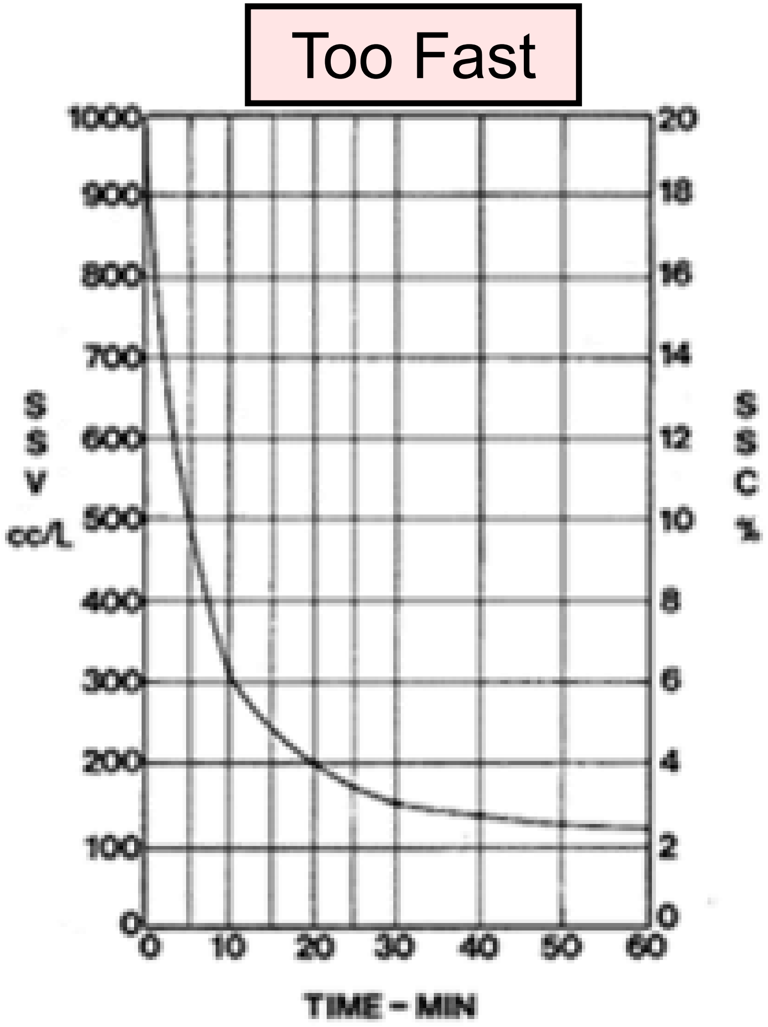


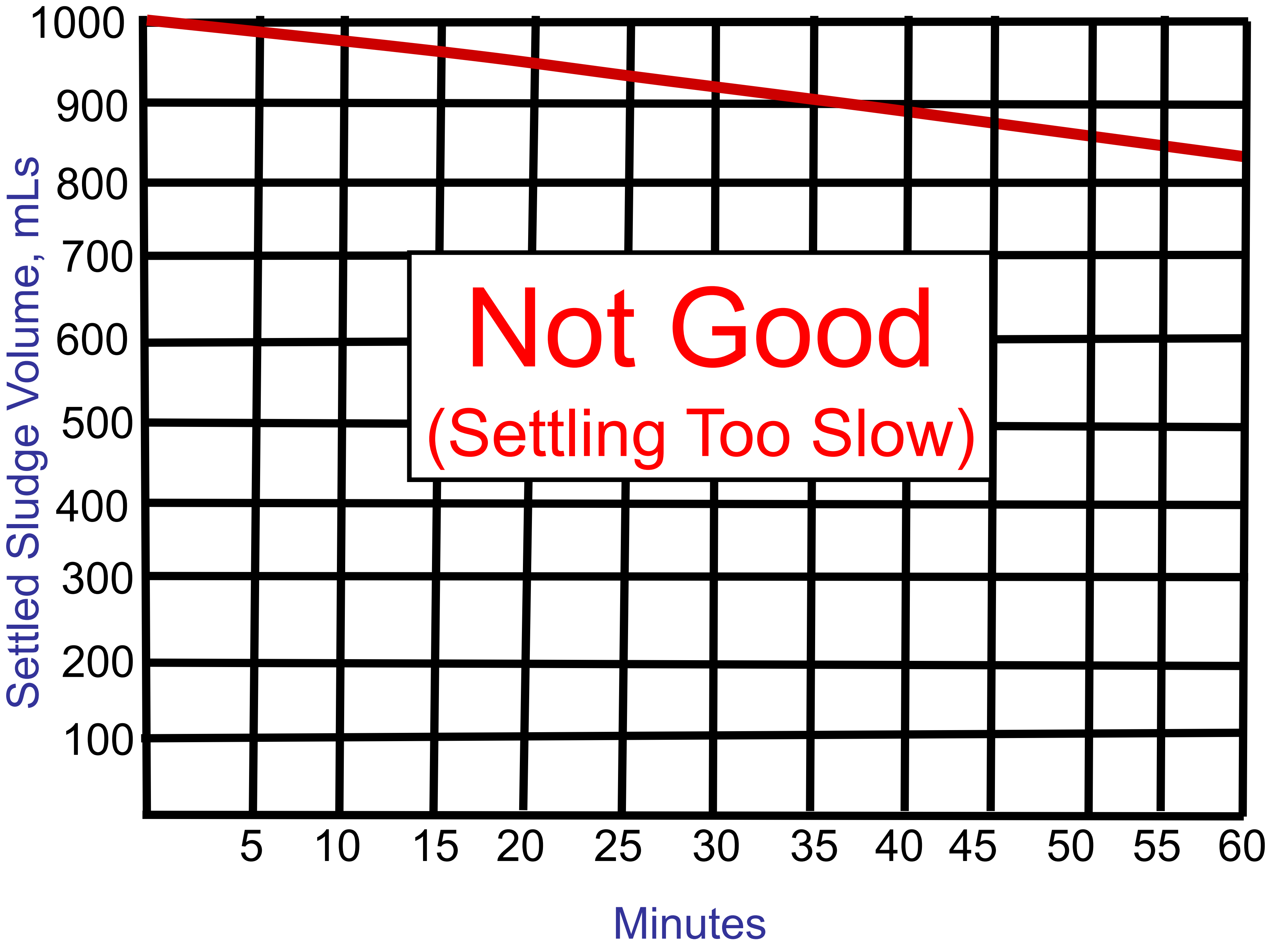
Not Good
(Settling Too Fast)
Settled Sludge Volume, mLs
1000
900
800
700
600
500
400
300
200
100
5
10
15
20
25
30
35
40
45
50
55
60
Minutes

Settleometer Test

Indication of "Old" Sludge

Leaves Straggler Floc
in Effluent





Not Good
(Settling Too Slow)
Settled Sludge Volume, mLs
1000
900
800
700
600
500
400
300
200
100
5
10
15
20
25
30
35
40
45
50
55
60
Minutes

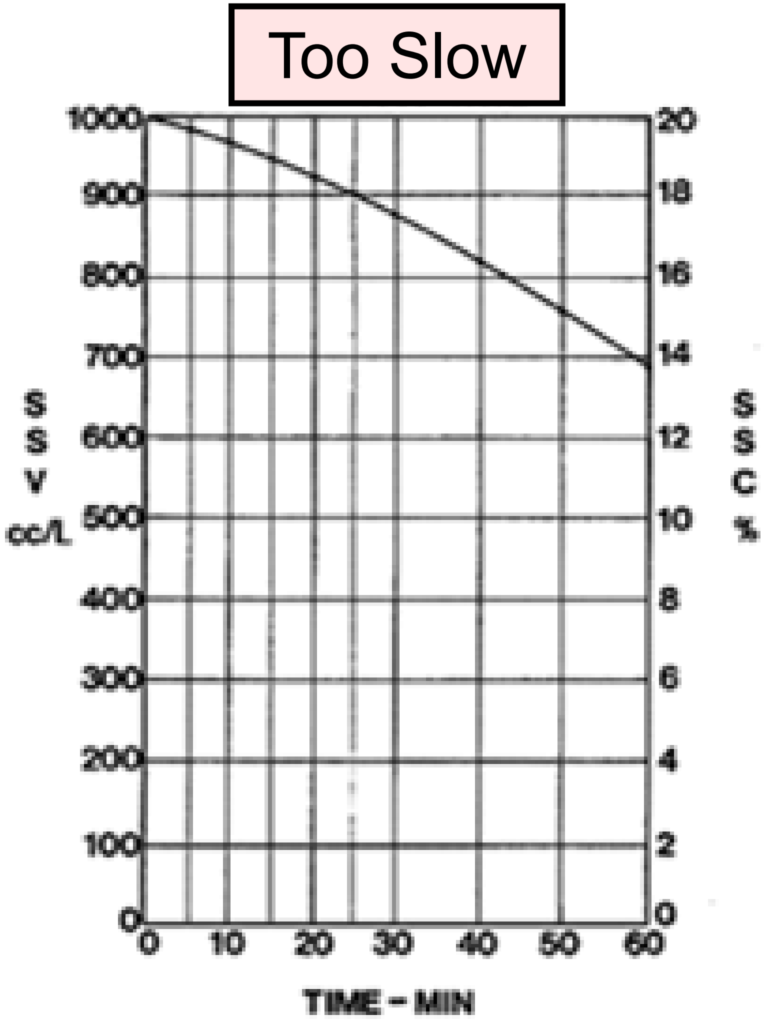
The typical sludge volume index for a sludge wastewater system that is operating as it should will be between 50 and 150 mL/g.

- If the SVI is 80 mL/g or less, the sludge will be very dense and will settle rapidly
- If the SVI is between 100 and 200 mL/g, the sludge will settle a little more slowly, trapping more particulate matter during the settling process.
- If the SVI is above 250 ml/g, the sludge is very, very slow to settle, and does not compact well. The result is a light and fluffy texture to the sludge

DENITRIFYING

Rising sludge indicates denitrification, look for small nitrogen bubbles on top of clarifier.

Settleometer Test



Not Compacting (Bulking)

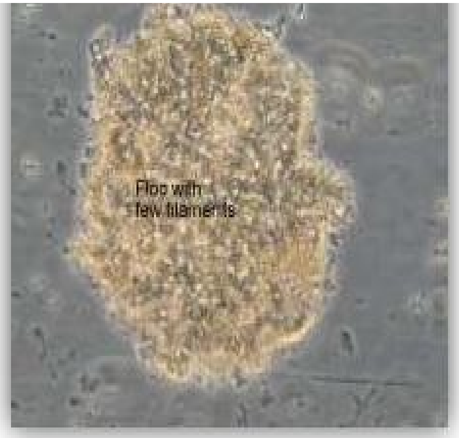
Solids Washed Out
in High Flows

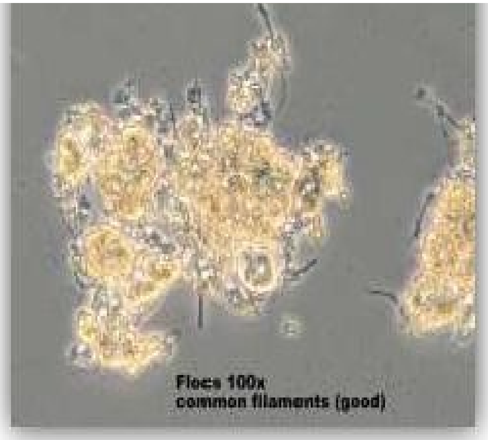
BULKING is an indicator of filamentous organisms.

- Filamentous bulking is the number one cause
  •of environmental violations
- A bulking sludge settles slowly, and has an SVI
  •>150.
- Many sludge thickening and dewatering
  •problems are actually problems due to a
  •bulking sludge
- Filaments can cause bulking due to interfloc
  •bridging, or open floc structure.

Dr. Michael Richard's Filament Ranking Guide

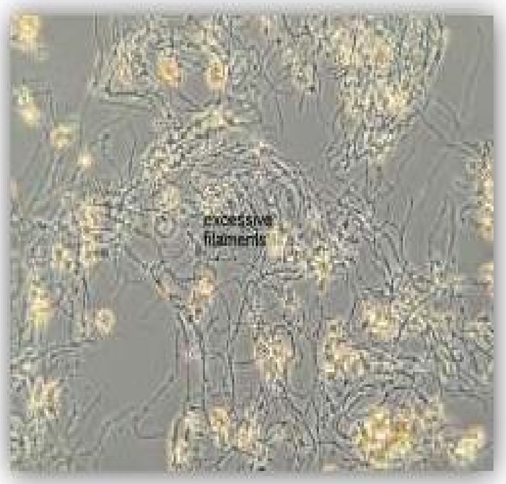
- 1 (few)- filaments observed in occasional floc
- 2 (some)- filaments observed in half the flocs
- 3 (common)- filaments observed in all the flocs, but
  - at low abundance (1-5 filaments per floc)
- 4 (very common)- filaments observed in all flocs at
  - medium density (5-20 filaments per floc)
- 5 (abundant)-filaments observed in all flocs at high
  - density (>20 filaments per floc)
- 6 (excessive) filaments dominate with little floc





Zero- Few Some

Common



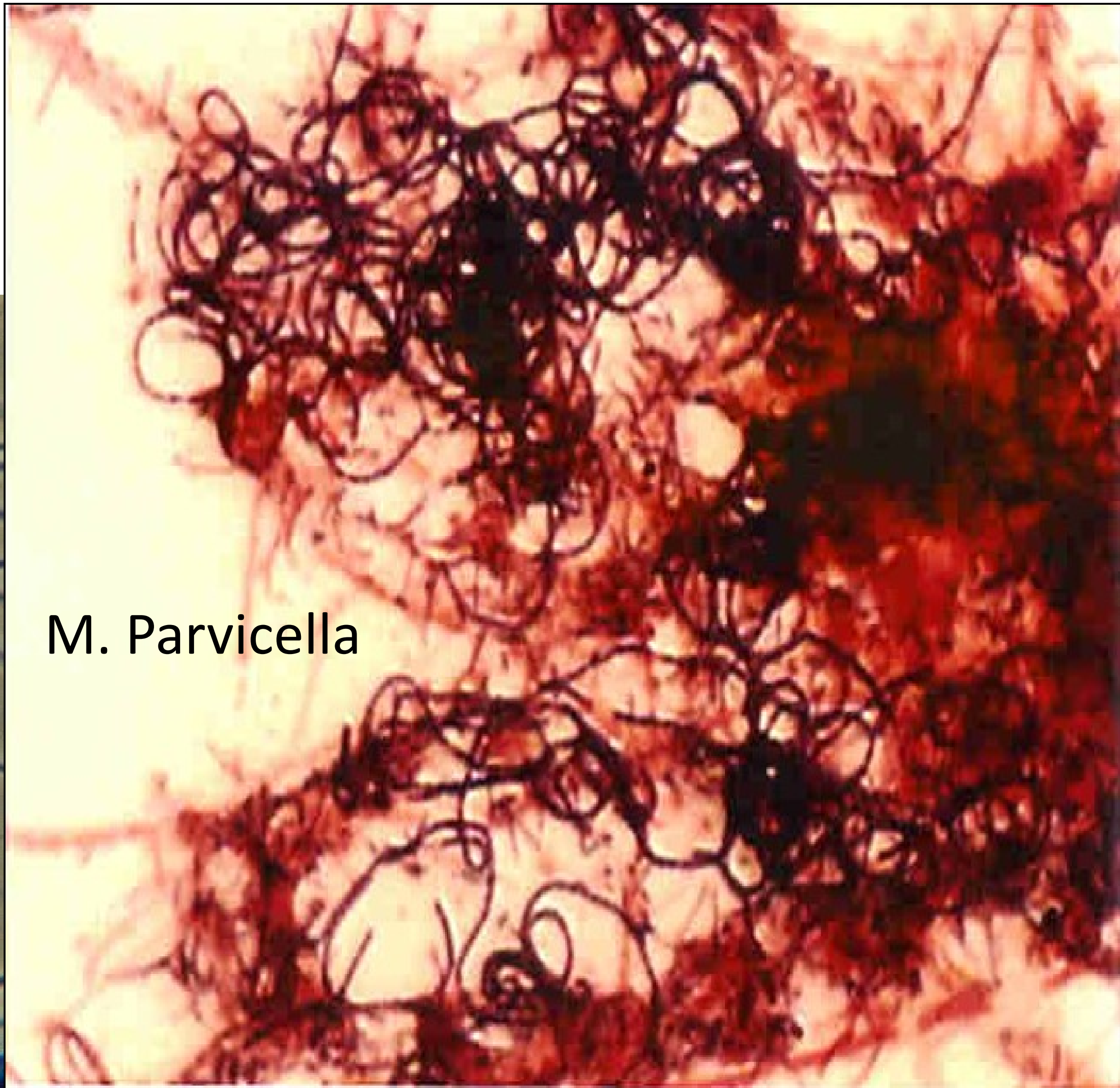
Very Common Abundant Excessive

Filament Types as Indicators of Conditions Causing Activated Sludge Bulking

Causative Condition (1)	**Filament Types**
Low Dissolved Oxygen (for the applied organic loading)	*S. natans*, type 1701 and *H. hydrossis*.
Low Organic Loading Rate >(low F/M)	*M.parvicella*, *Nocardia* spp., and types 0041, 0675, 1851 and 0803.
Septic Wastes / Sulfides(high organic acids)	*Thiothrix I* and *II*, *Beggiatoa* spp., *N. limicola II**, and types 021N, 0092*, 0914*, 0581*, 0961* and 0411.
Nutrient Deficiency - N and/or P (industrial wastes only) nitrogen - phosphorus	*Thiothrix I* and *II* and type 021N.*N. limicola III*
Low pH (<pH 6.0)	fungi.
High Grease/Oil	*Nocardia* spp., *M. parvicella* and type 1863

Filaments

- 1701, S. natans, M. parvicella
- Strains associated with poor settling



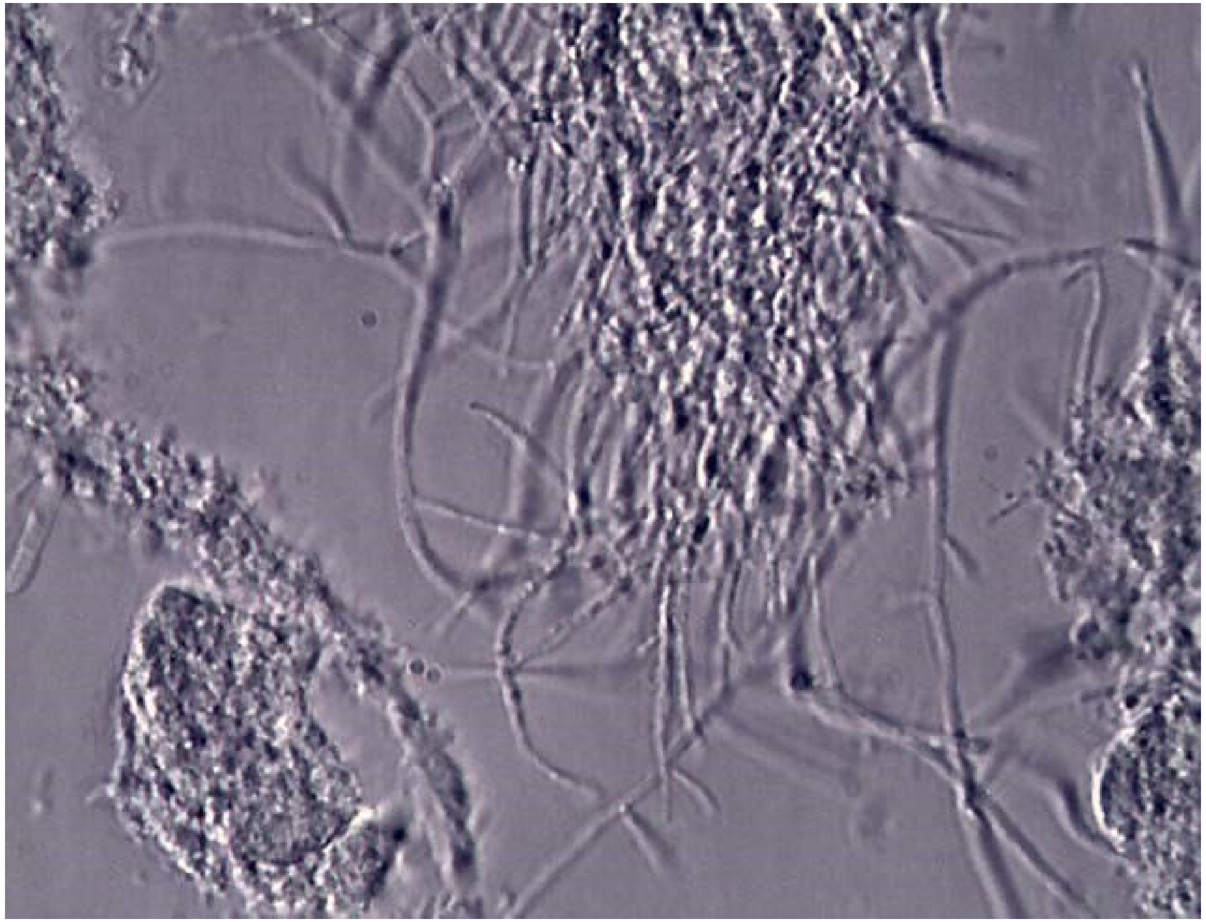
Filaments

- Major filaments
- 021N, thiothrix and Beggiatoa can use hydrogen sulfide and organic acids for substrates
- Sources are septage, nutrient deficient wastewater

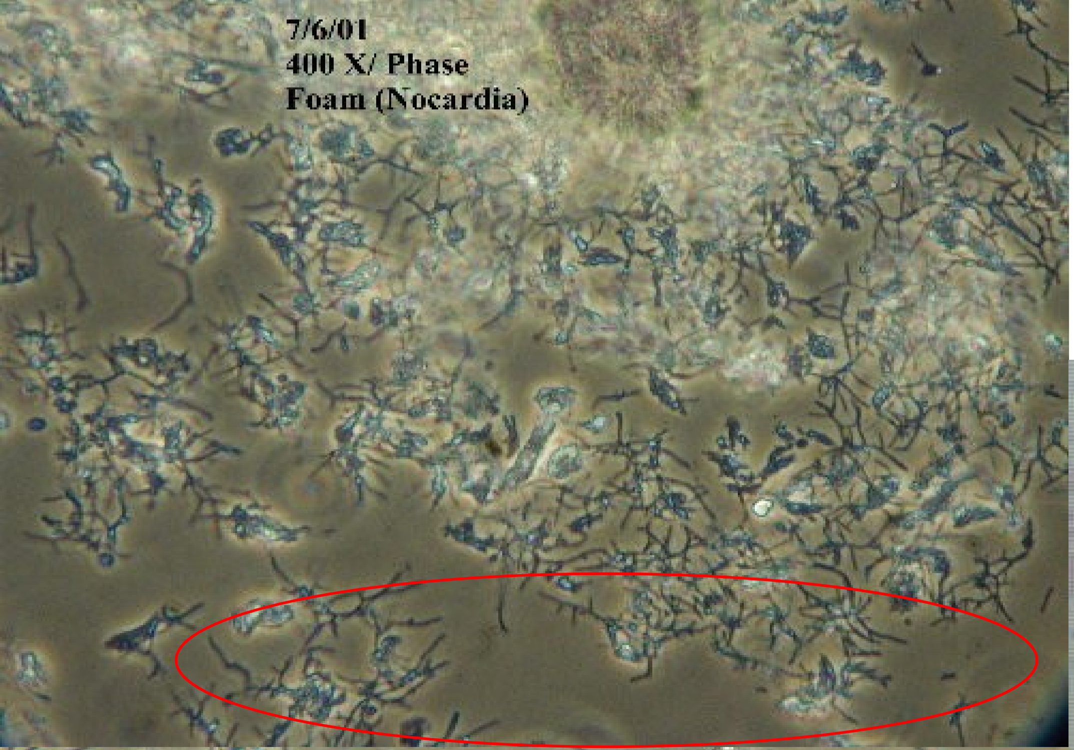
Filamentous organism	Factors promoting rapid growth
Haliscomenobacter hydrosis, Sphaerotilus natans, type 1701	Low DO
Haliscomenobactor hydrosis, Microthrix parvicella, Nocardia spp., type 021N, type 0041, type 0092, type 0581, type 0675, type 0803 and type 0961	Low F / M
Sphaerotilus natans, Thiothrix spp. fungi, type 0675 and type 021N	Low Nutrients (nitrogen or phosphorus)
Nocardia spp fungi	Low pH
Type 0041, type 0092, and *Microthrix parvicella*	Low organic load
Beggiatoa spp, Thiothrix spp and type 021N	Septic wastewater / Sulfides

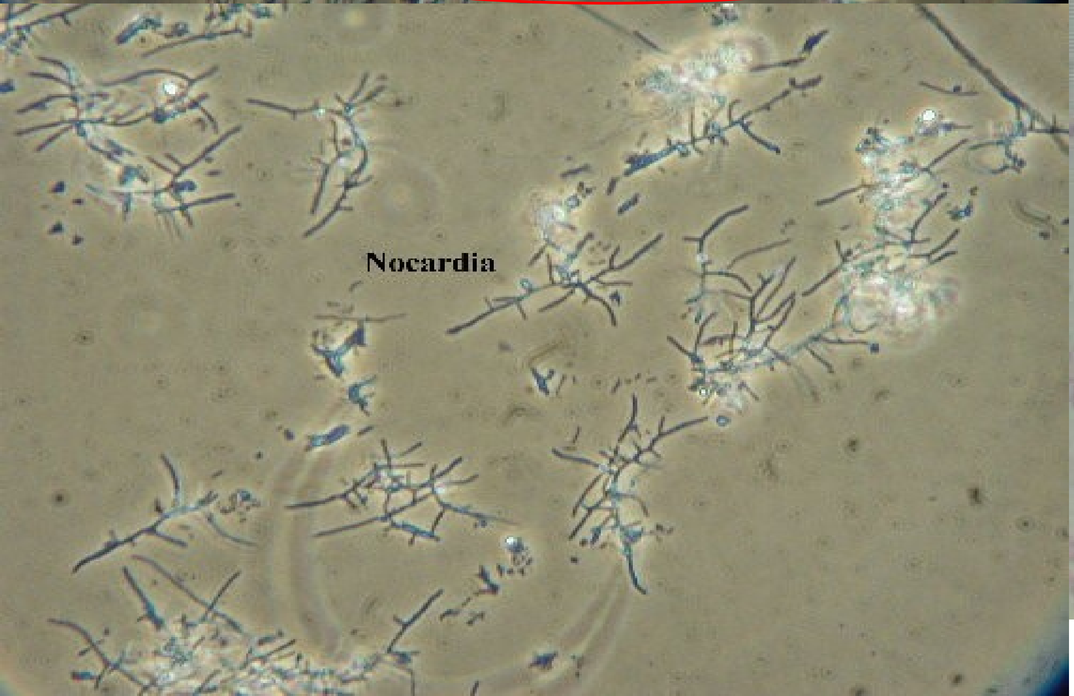
- <u>Stiff White Foam</u> – Stiff white, billowing foam, indicating a young sludge (low MCRT) is usually found in a new plant or an overloaded plant.

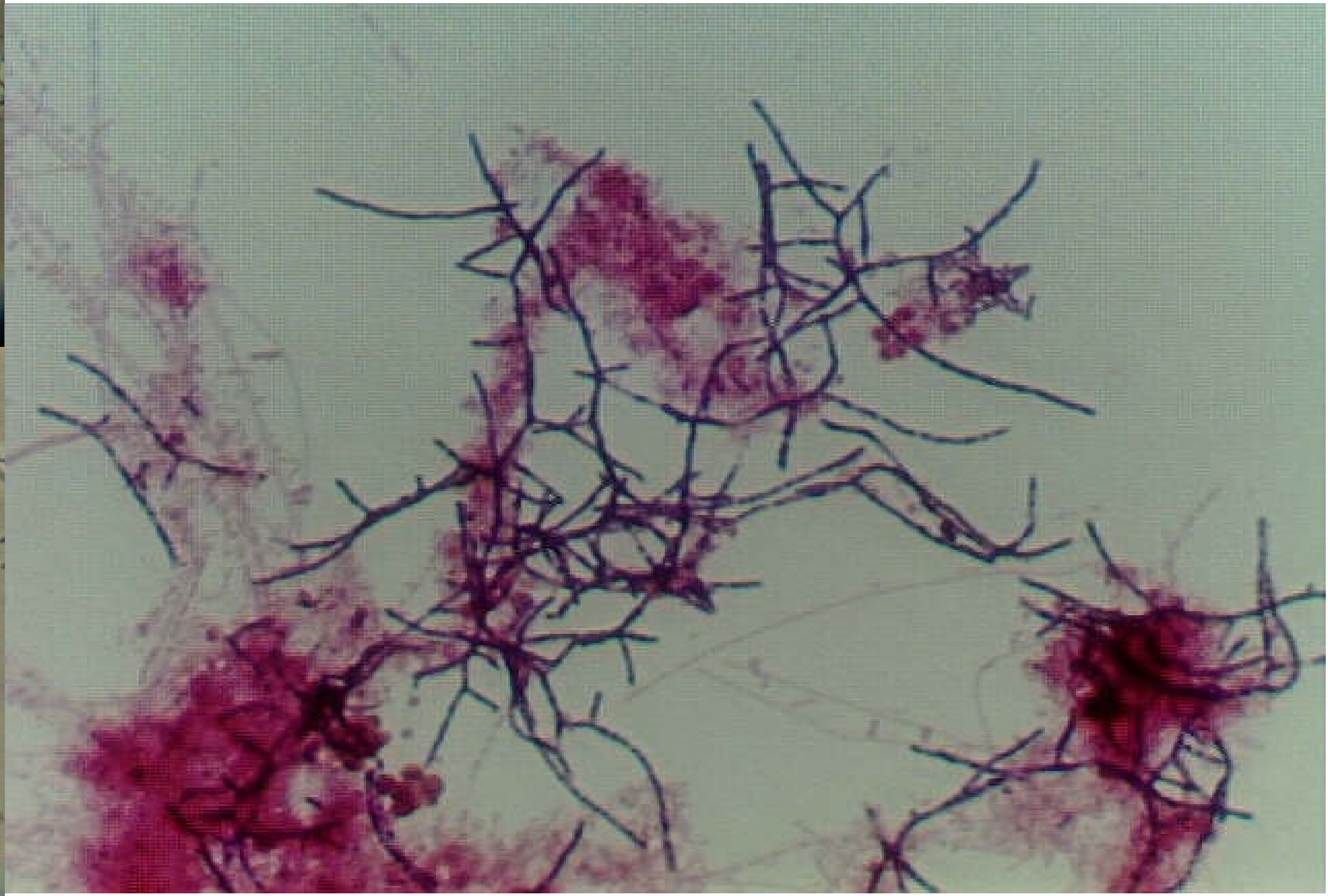
Heavy Brown Foam – A heavy dark scummy foam is typical in plants that practice sludge re-aeration. The scummy dark foam indicates an older sludge and can result is other problems downstream of the aeration tank. There could also be a presence of Nocardia in the sludge.



M parvicella foam - Stable dark brown greasy foam that can get thick enough to have a crust- *Here's a* plant with Microthrix problems due to grease problems in the lift stations, or collection systems.


7/6/01
400 X/ Phase
Foam (Nocardia)


Nocardia



pH 6.5 to 8.5 Ideally 7.0 to 7.5 for Heterotrophs

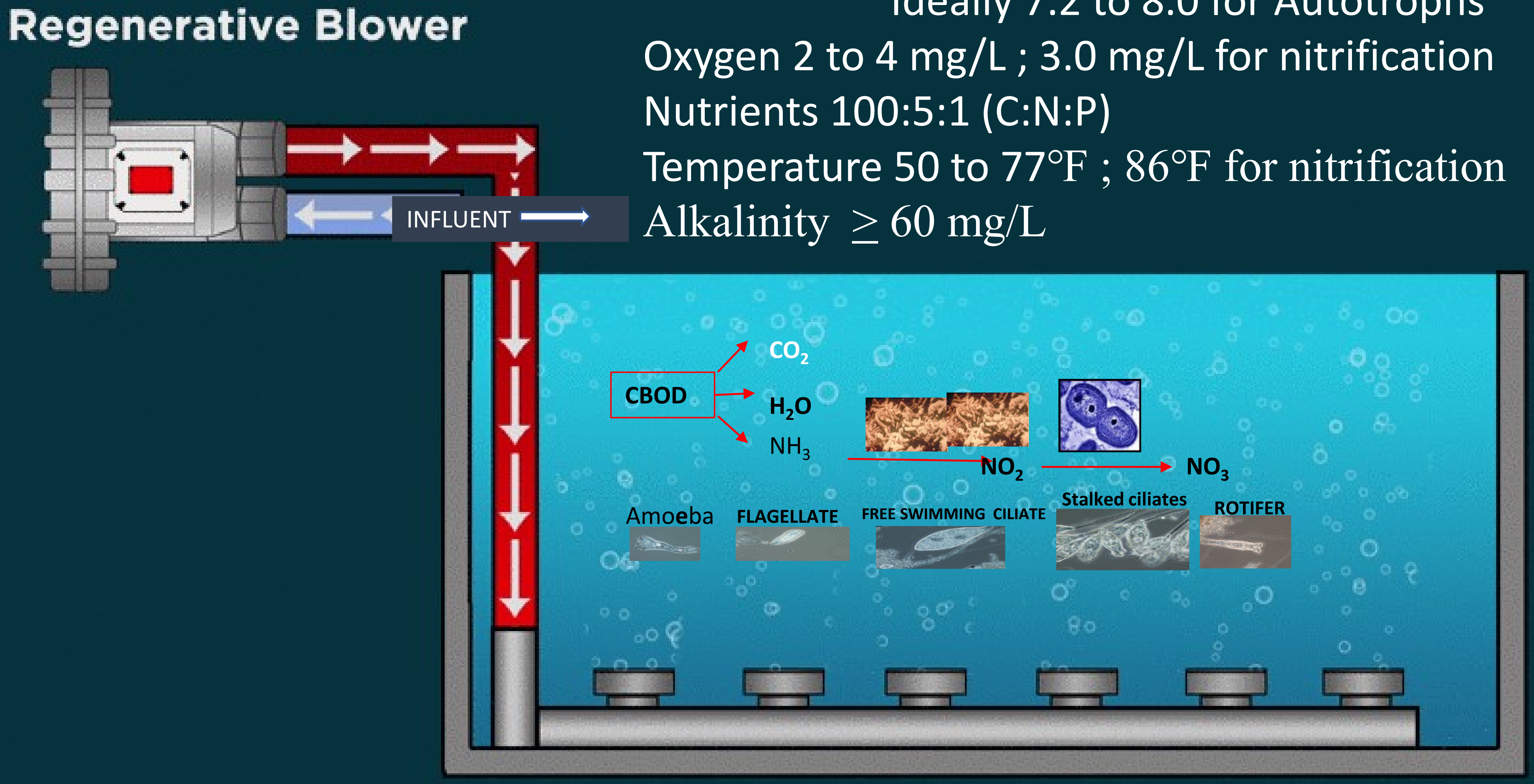
Ideally 7.2 to 8.0 for Autotrophs

Oxygen 2 to 4 mg/L ; 3.0 mg/L for nitrification

Nutrients 100:5:1 (C:N:P)

Temperature 50 to 77°F ; 86°F for nitrification

Alkalinity ≥ 60 mg/L



YOUNG (WHITE FOAM)

STRAGGLER FLOC (Underoxidized)

OLD (DARK GREASY BROWN FOAM)

PIN FLOC (Overoxidized)

WHEN YOU **LOOK AHEAD**,
ALSO LOOK BEHIND TO SEE
HOW FAR
YOU'VE COME.

June 22, in 1969, the **Cuyahoga River** burst into flames in Cleveland when sparks from a passing train set **fire** to oil-soaked debris floating on the water's surface.

EMERGING TRENDS:

WASTEWATER REUSE

Non-potable, separate distribution

Indirect potable

Direct potable

ENERGY:

Recovery of energy (biofuels, co-generation, fertilizer)

Conservation of energy (aeration, pumping, mechanical solids processing, heating, embedded materials)

Products: "Wastewater Mining"

Bioplastics

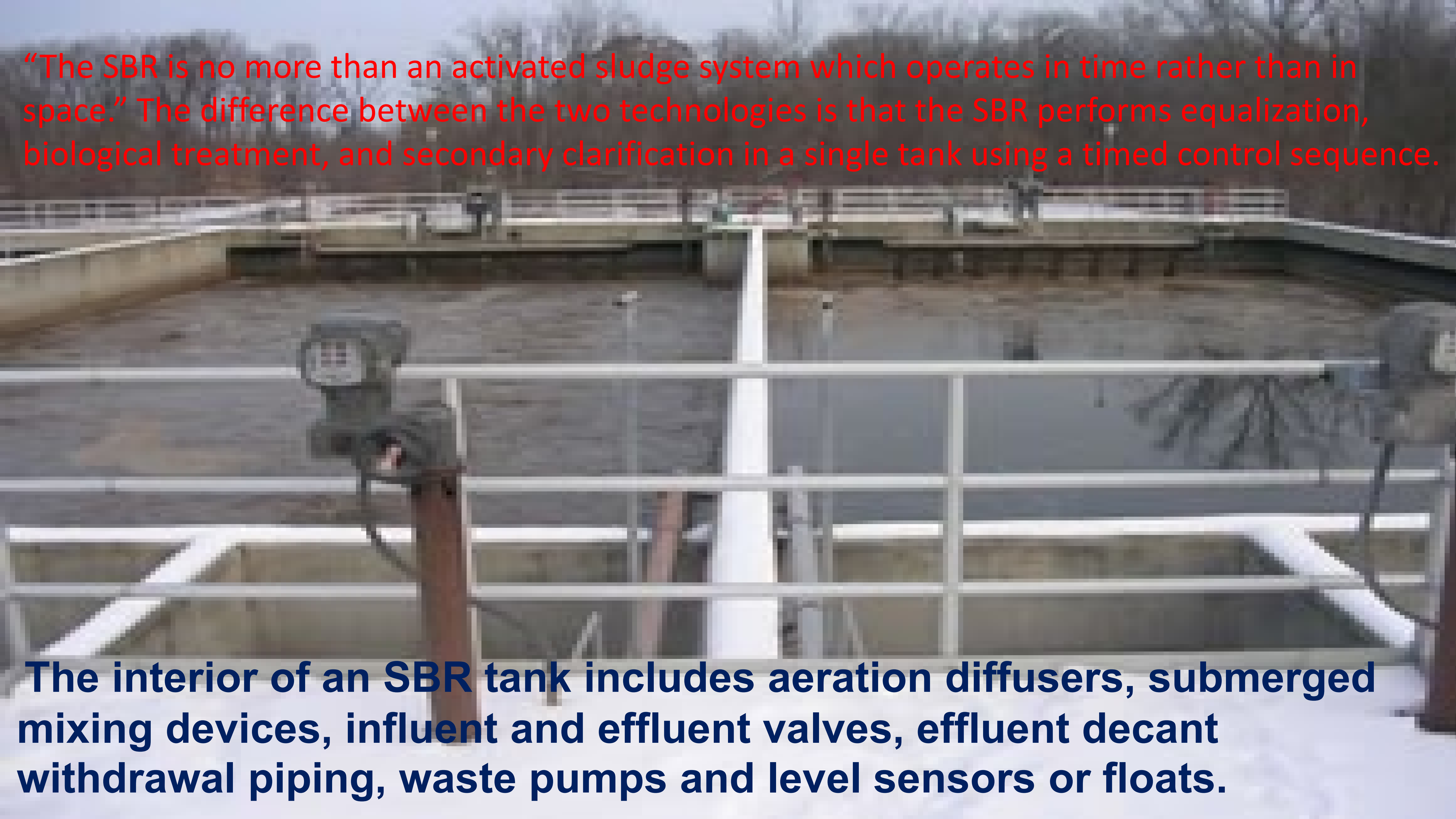
Bacterial Cellulose


Packaged Wastewater Treatment Plant
From Package Plants to
SOUTHERLY 120 MGD
We're all in this together
THANK YOU & QUESTIONS
419 – 707 - 7559
Mike Maringer
mnmaringer400@gmail.com
RELAX


SEQUENCING BATCH REACTOR
LOCATED HERE

PUT – IN – BAY WWTP DESIGN PARAMETERS

Peak WW Flow: 60,000 gpd
BOD_5 : 250 mg/L
TSS : 250 mg/L
NH_3-N : 40 mg/L
8 Lift Stations

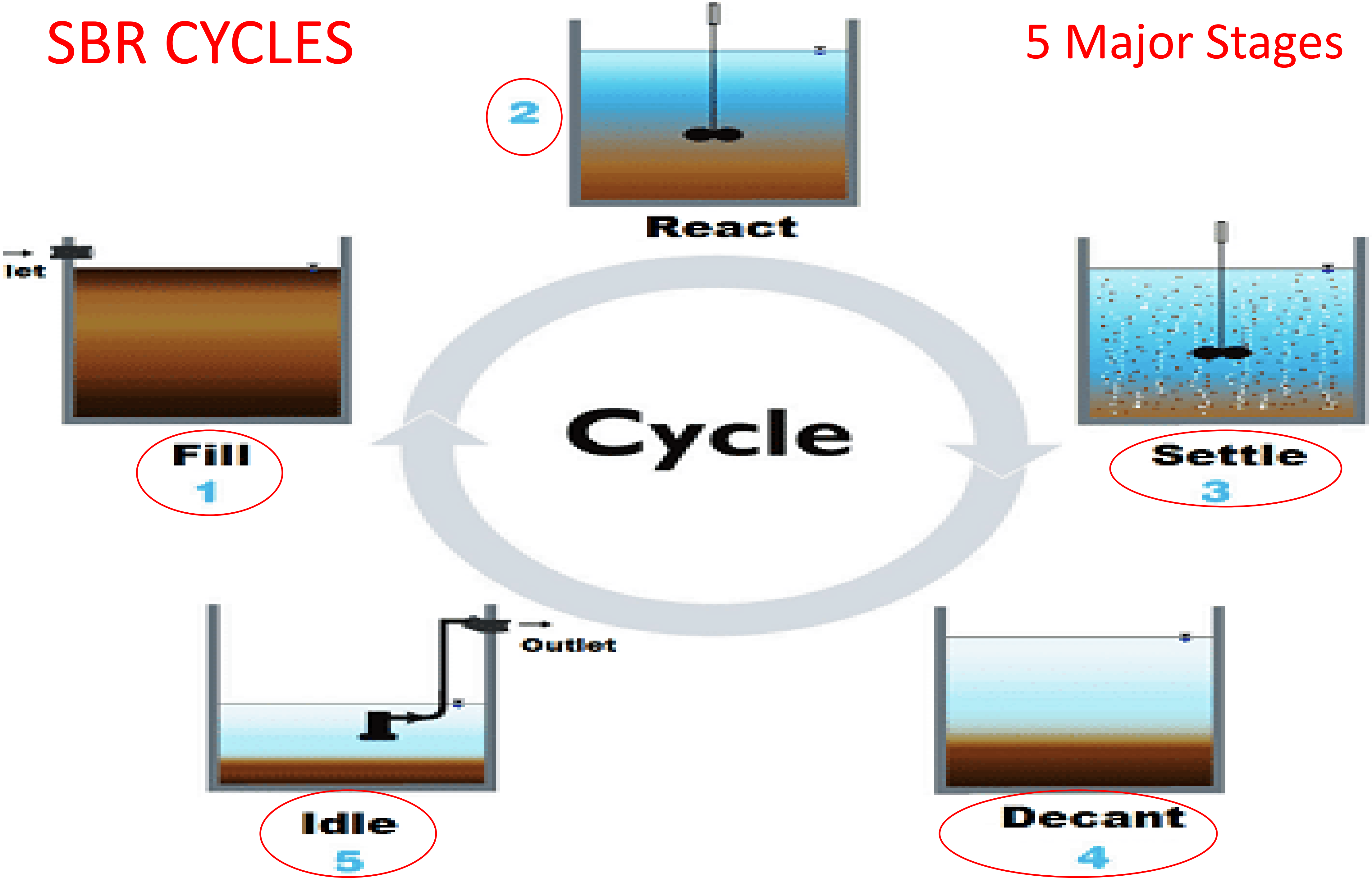

"The SBR is no more than an activated sludge system which operates in time rather than in space." The difference between the two technologies is that the SBR performs equalization, biological treatment, and secondary clarification in a single tank using a timed control sequence.
The interior of an SBR tank includes aeration diffusers, submerged mixing devices, influent and effluent valves, effluent decant withdrawal piping, waste pumps and level sensors or floats.

KEY DESIGN PARAMETERS FOR A CONVENTIONAL LOAD

	Municipal	Industrial
Food to Mass (F:M)	0.15 - 0.4/day	0.15 - 0.6/day
Treatment Cycle Duration	4.0 hours	4.0 - 24 hours
Typically Low Water Level		
Mixed Liquor Suspended Solids	2,000-2,500 mg/L	2,000 - 4,000 mg/L
Hydraulic Retention Time	6 - 14 hours	varies

SBR CYCLES

5 Major Stages



Aeration:

Theoretically you can calculate Total Biological Oxygen Demand of any influent:

1.1 mg/L x CBOD + 4.6 mg/L x TKN

Ammonia Nitrogen
+
Organic Nitrogen

Example:

Raw municipal sewage commonly has the following values:

$CBOD_5$ = 200 mg/L ; TKN = 40 mg/L

1.1 x 200 mg/L $CBOD_5$ + 4.6 x 40 mg/L TKN =

404 mg/L Total BOD_5

Using a 5.0 MGD Flow: 5.0 MGD x 8.34 x 404 mg/L = 16,847 Lbs./Day

16,847 Lbs./Day / 1440 = 11.7 Lbs./Minute

One cubic foot of Air weighs 0.0807 Lbs.

$$\frac{11.7 \text{ Lbs./Minute}}{0.0807} = 145 \text{ CFM (not including mixing)}$$

Oxygen Usage Hierarchy & Alkalinity

The Three Major Zones in WW

Free Dissolved Oxygen	*Aerobic* or Oxic Treatment
Little or No Free Oxygen, But NO_3 Present	*Anoxic* Treatment
Sulfate, SO_4 Is the next choice of the Bugs	*Anaerobic* conditions are beginning, odors forming, H_2S

ALKALINITY

7.14 mg/L ↓

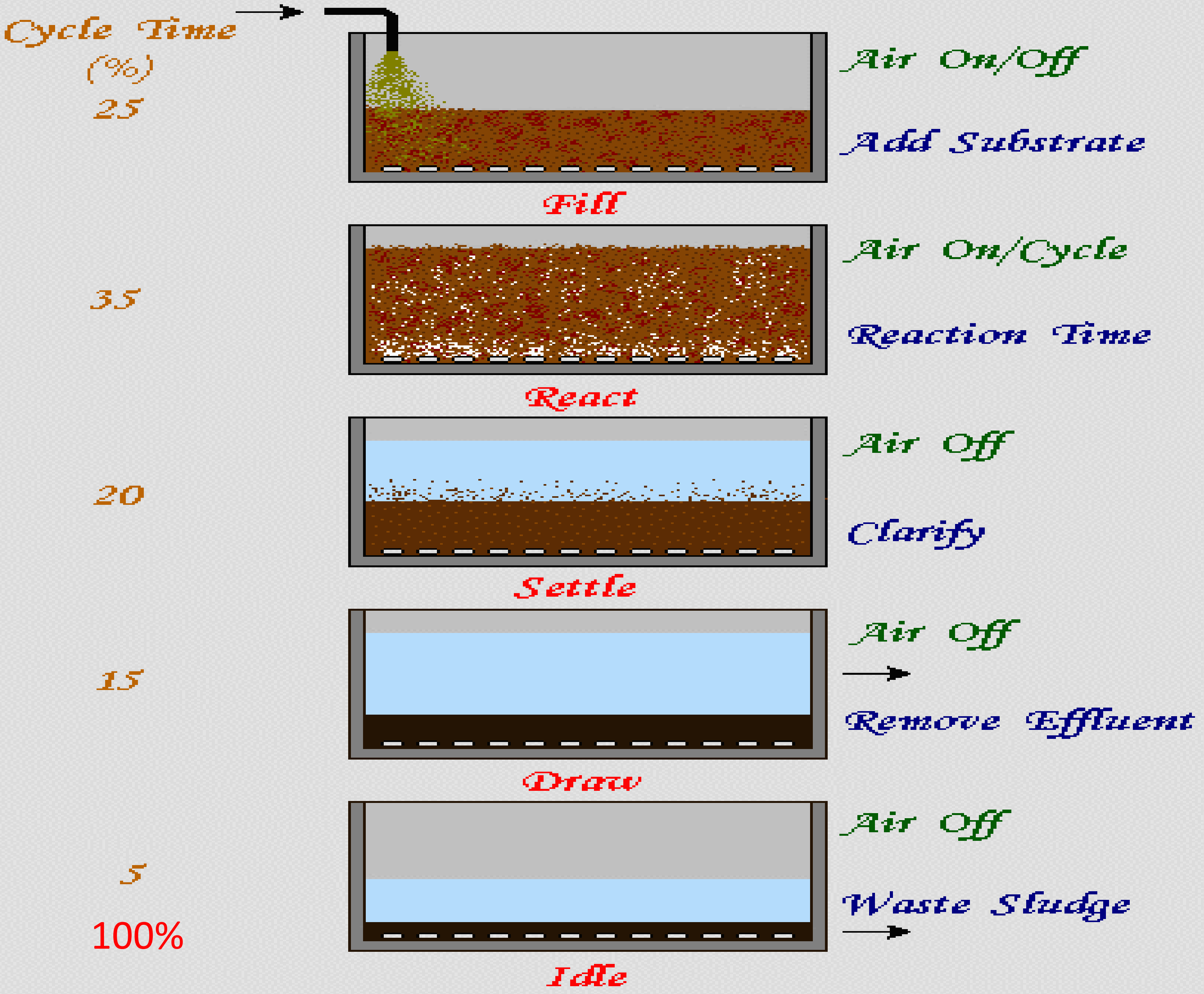
↑ **3.57 mg/L**

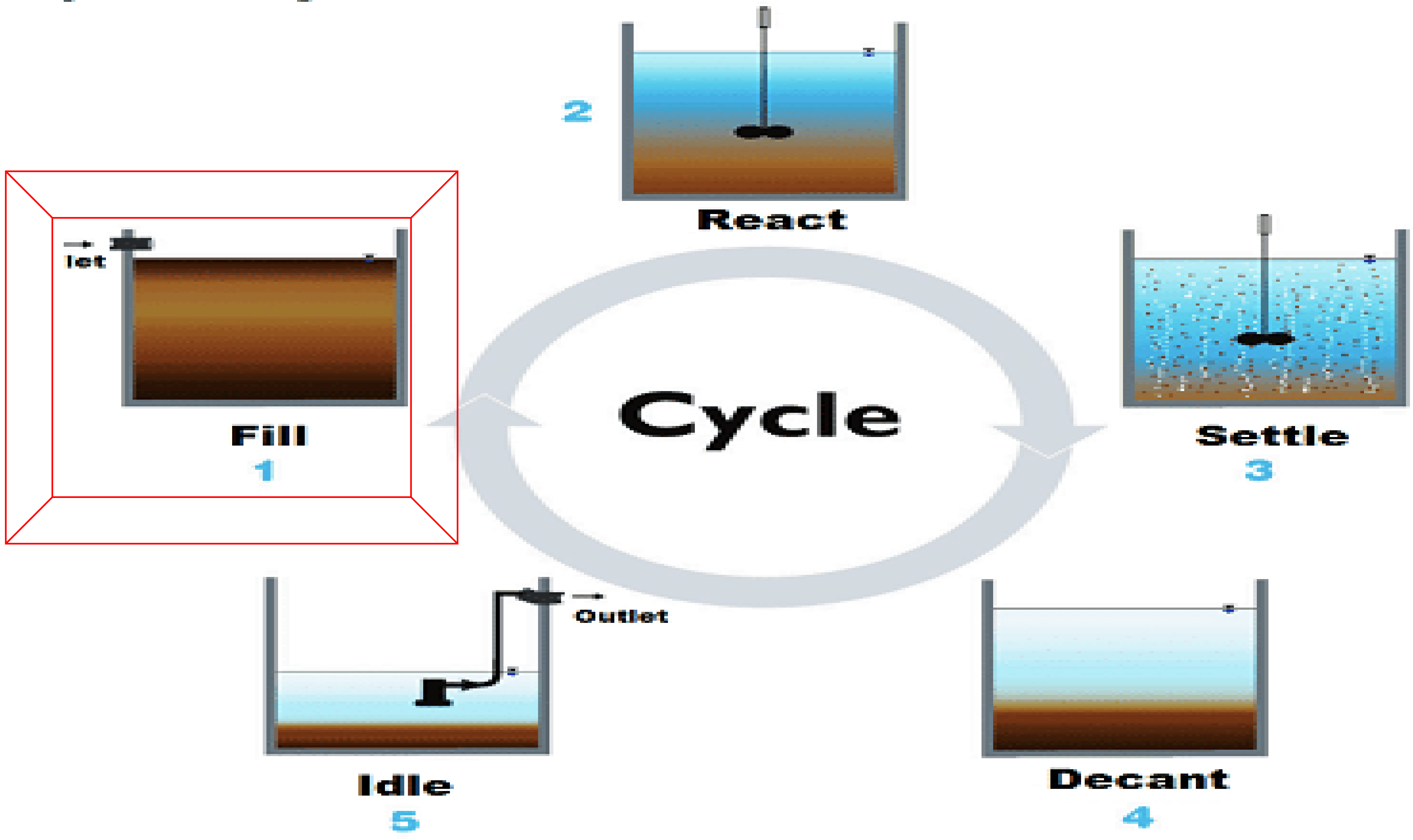
17.86 mg/L ↑

The treatment cycle can be adjusted to undergo aerobic, anaerobic, and anoxic conditions in order to achieve biological nutrient removal, including nitrification, denitrification, and some phosphorus removal. Biochemical oxygen demand (BOD) levels of less than 5 mg/L can be achieved consistently. Total nitrogen limits of less than 5 mg/L can also be achieved by aerobic conversion of ammonia to nitrates (nitrification) and anoxic conversion of nitrates to nitrogen gas (denitrification) within the same tank.

Low phosphorus limits of less than 2 mg/L can be attained by using a combination of biological treatment (anaerobic phosphorus absorbing organisms) and chemical agents (aluminum or iron salts) within the vessel and treatment cycle.

Operating Sequence for SBR





2
React
let
Settle
3
Fill
1
Cycle
Outlet
Idle
5
Decant
4

Static Fill – Under a static-fill scenario, there is no mixing or aeration while the influent wastewater is entering the tank. Static fill is used during the initial start-up phase of a facility, at plants that do not need to nitrify or denitrify, and during low flow periods to save power.

Because the mixers and aerators remain off, this scenario has an energy-savings component.

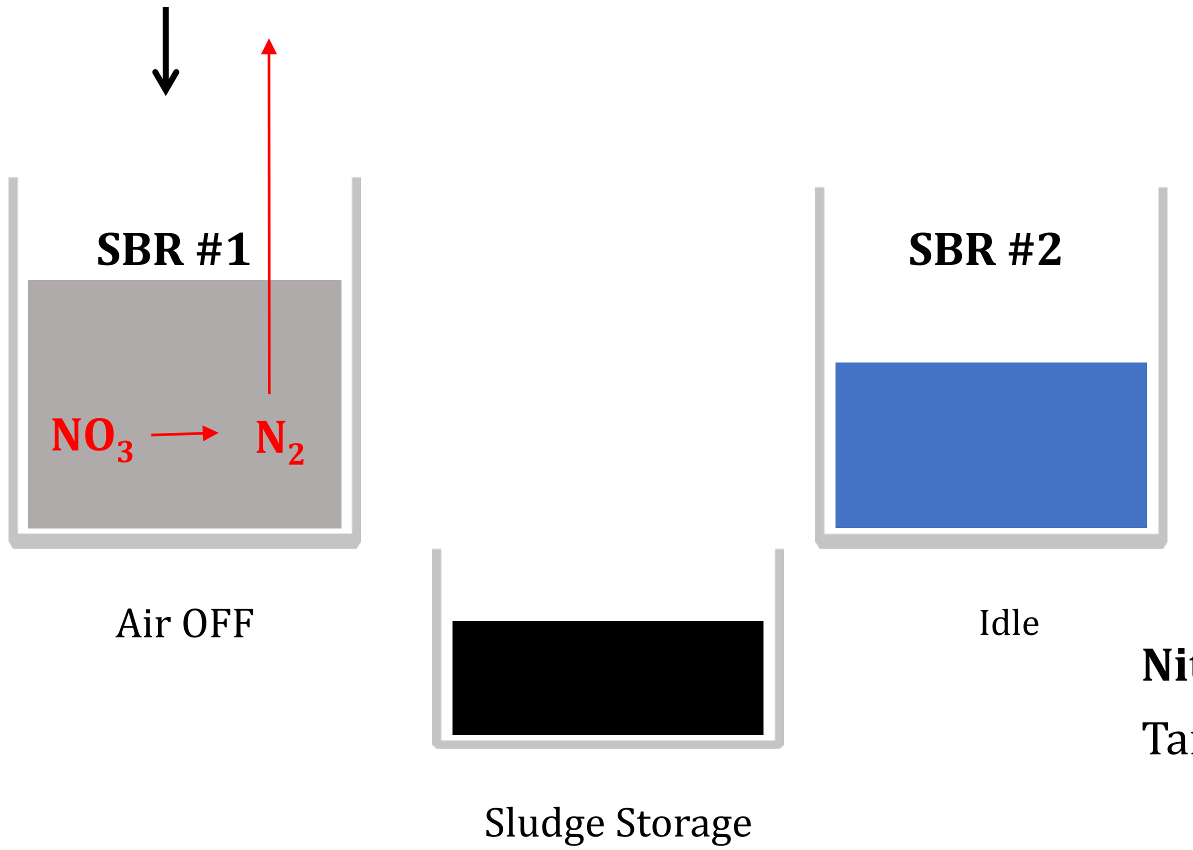
Mixed Fill – Under a mixed-fill scenario, mechanical mixers are active, but the aerators remain off. The mixing action produces a uniform blend of influent.

- Because there is no aeration, an *anoxic* condition is present, which promotes denitrification.

- Anaerobic conditions can also be achieved during the mixed-fill phase. Under *anaerobic conditions* the biomass undergoes a release of phosphorous. This release is reabsorbed by the biomass once aerobic conditions are reestablished. ***This phosphorous release will not happen with anoxic conditions.***

Sequencing Batch Reactor (SBR)
Nitrate (NO_3) Removal: Denitrification

MIXED FILL PHASE:



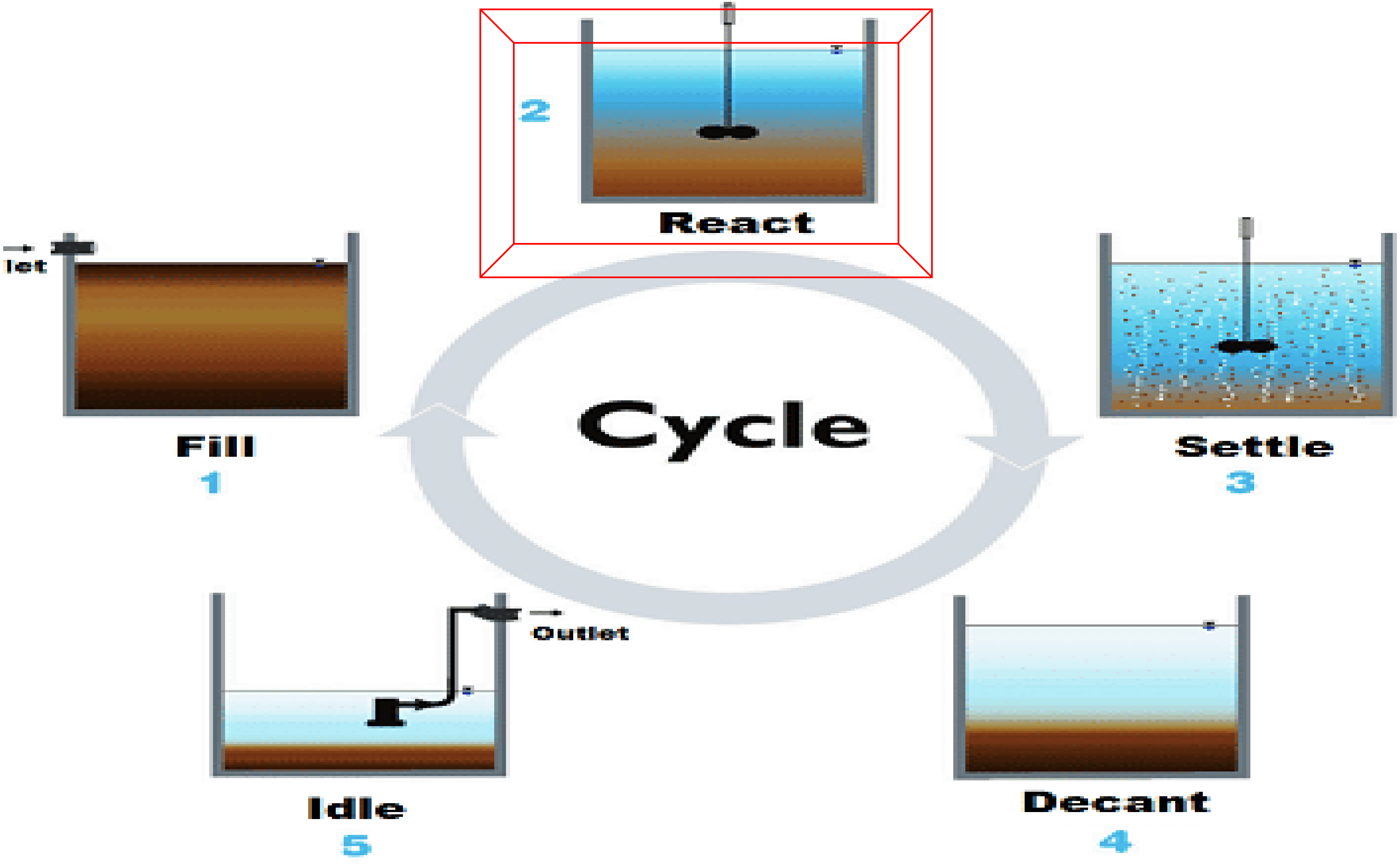
Nitrate (NO_3) Removal

Target: $NO_3 < 4$ mg/L

Aerated Fill – Under an aerated-fill scenario, both the aerators and the mechanical mixing unit are activated. The contents of the basin are aerated to convert the anoxic or anaerobic zone over to an aerobic zone. No adjustments to the aerated-fill cycle are needed to reduce organics and achieve nitrification.

However, to achieve denitrification, it is necessary to switch the oxygen off to promote anoxic conditions for denitrification. By switching the oxygen on and off during this phase with the blowers, oxic and anoxic conditions are created, allowing for nitrification and denitrification.

Dissolved oxygen (DO) should be monitored during this phase so it does not go over 0.2 mg/L. This ensures that an anoxic condition will occur during the idle phase.



2
React
let
Fill
1
Cycle
Settle
3
Outlet
Idle
5
Decant
4

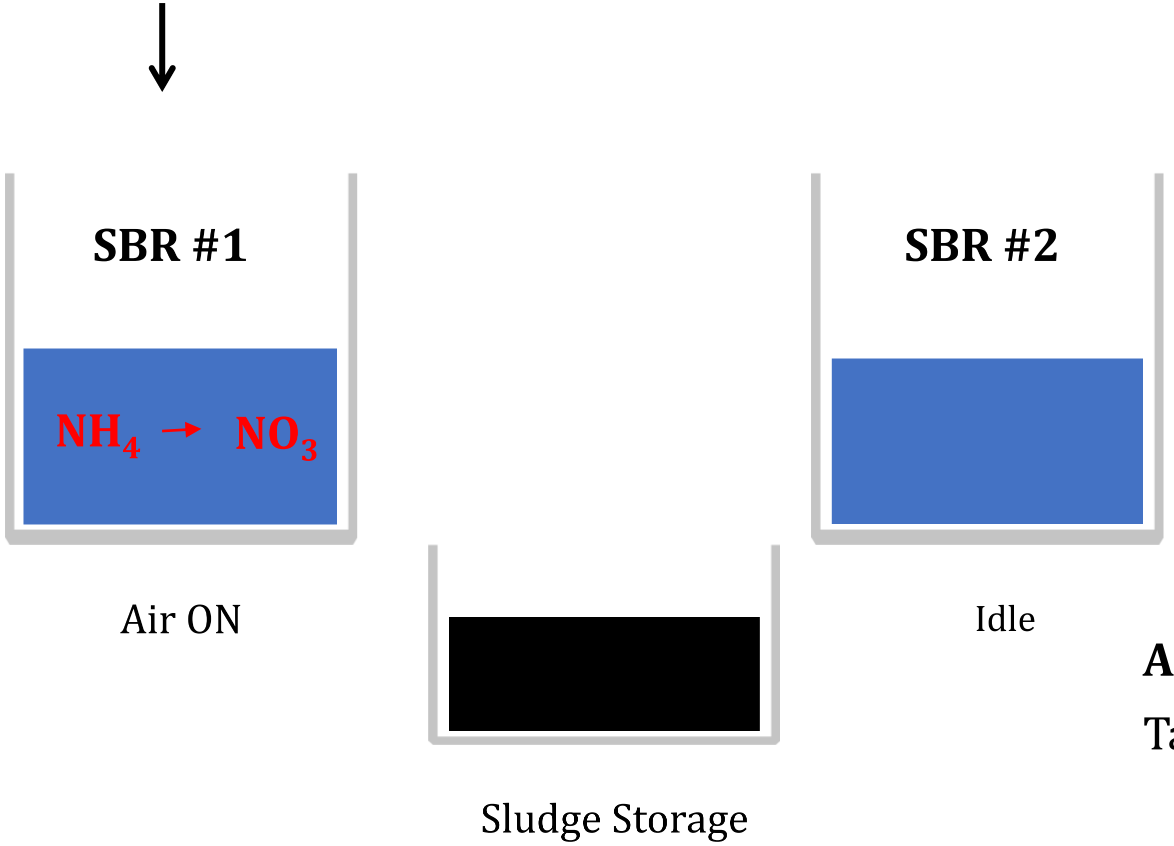
React

This phase allows for further reduction or "polishing" of wastewater parameters. During this phase, no wastewater enters the basin and the mechanical mixing and aeration units are on. Because there are no additional volume and organic loadings, the rate of organic removal increases dramatically.

Most of the carbonaceous BOD removal occurs in the react phase. Further nitrification occurs by allowing the mixing and aeration to continue—the majority of denitrification takes place in the mixed-fill phase. The phosphorus released during mixed fill, plus some additional phosphorus, is taken up during the react phase.

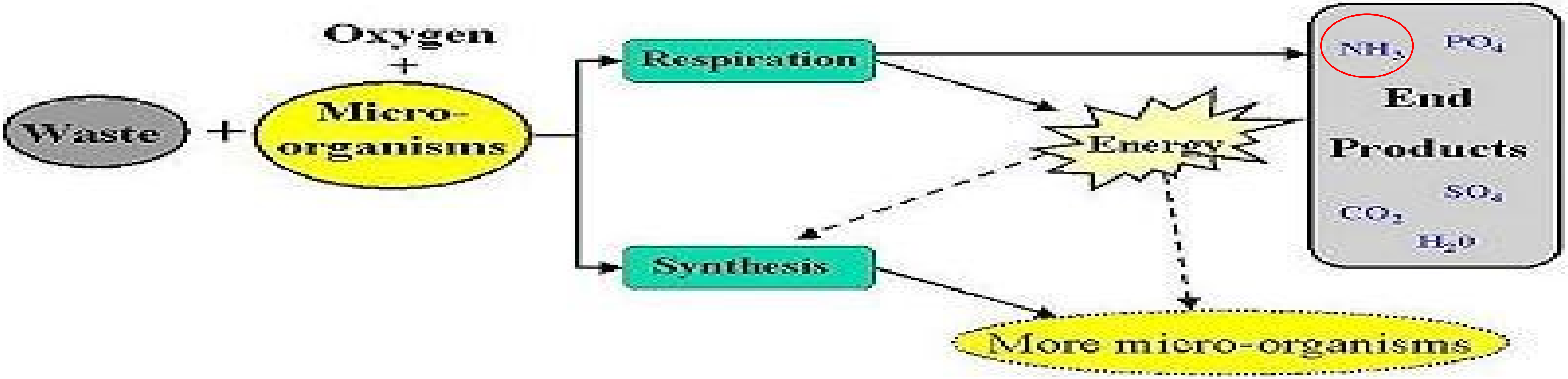
Sequencing Batch Reactor (SBR)
Ammonia (NH_4) Removal: Nitrification

REACT Phase: Lower CBOD to <40 mg/L, continue aeration to convert NH_4 to NO_3



Ammonia (NH_4) Removal

Target: $NH_4 < 0.5$ mg/L



Carbon Source

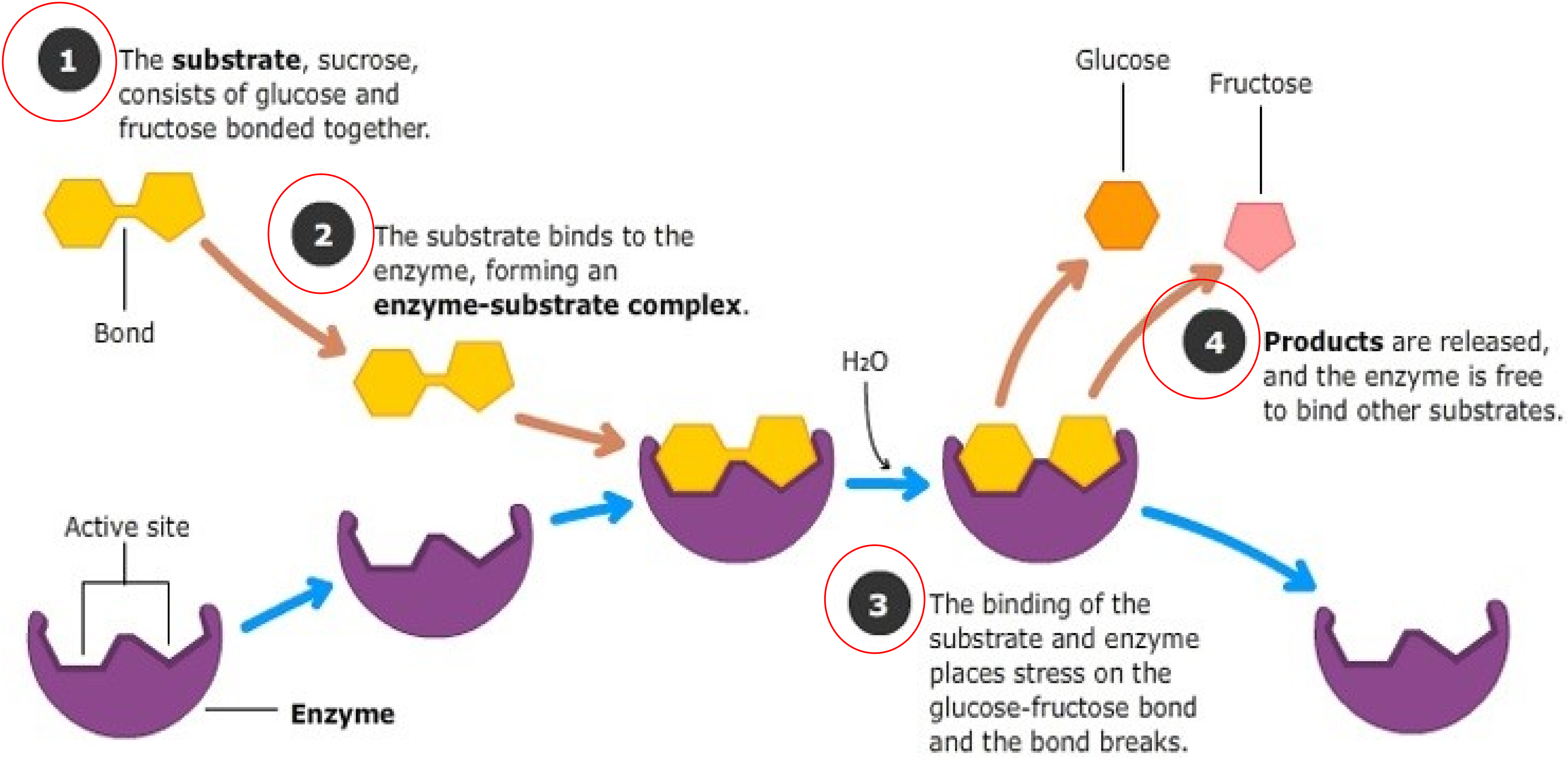
$$C_6H_{12}O_6 + O_2 \longrightarrow 6CO_2 + 6H_2O + \textbf{ENERGY}$$

(glucose) (Oxygen) (Carbon Dioxide)

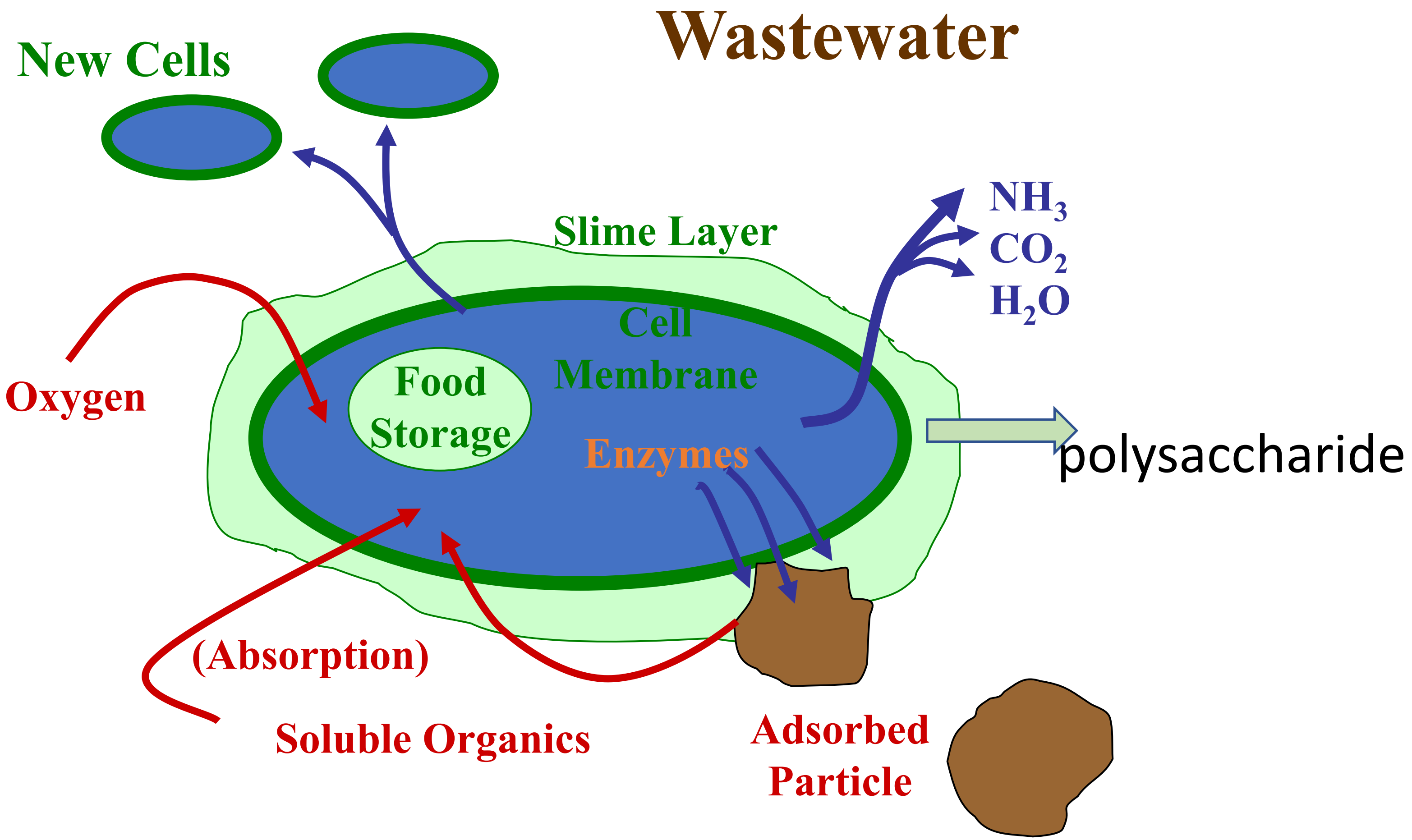
RESPIRATION PROCESS

The Effects of pH

The enzymes which regulate many of the biochemical reaction in bacteria are very pH dependent. The optimum pH should be between 7.0 and 7.5 for the proper activated sludge microorganisms to dominate.



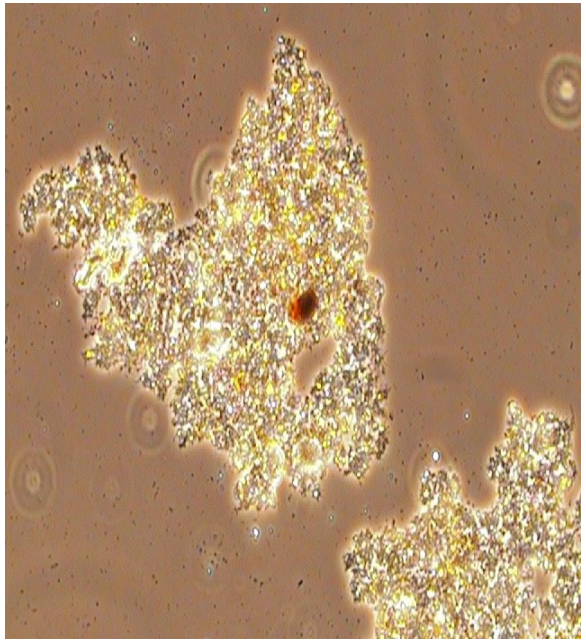
This is why pH is so important !



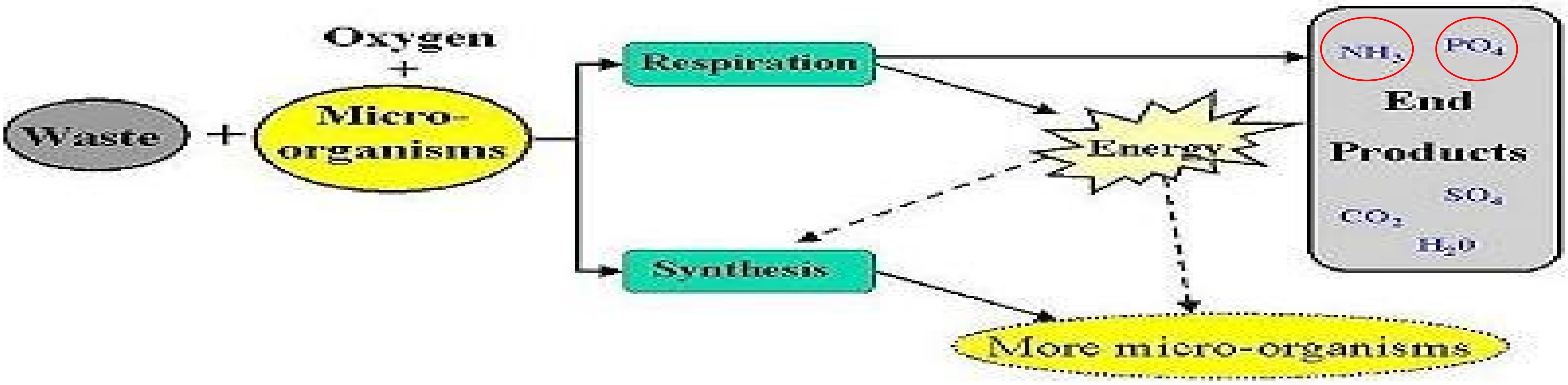
Wastewater
New Cells
Slime Layer
Cell Membrane
Food Storage
Enzymes
NH_3
CO_2
H_2O
polysaccharide
Oxygen
(Absorption)
Soluble Organics
Adsorbed Particle

Need Food to create Polysaccharide so they can stick together

Biomass 400X



7200X



Let's Look at the two nutrients N&P

pH 6.5 to 8.5 Ideally 7.0 to 7.5 for Heterotrophs

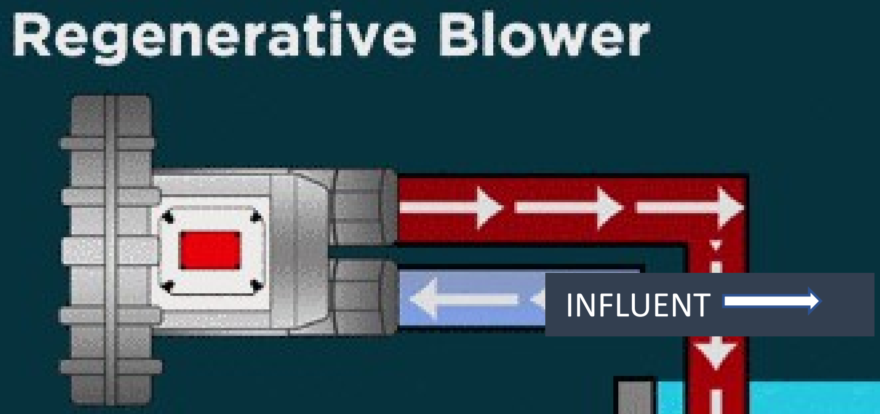
Ideally 7.2 to 8.0 for Autotrophs

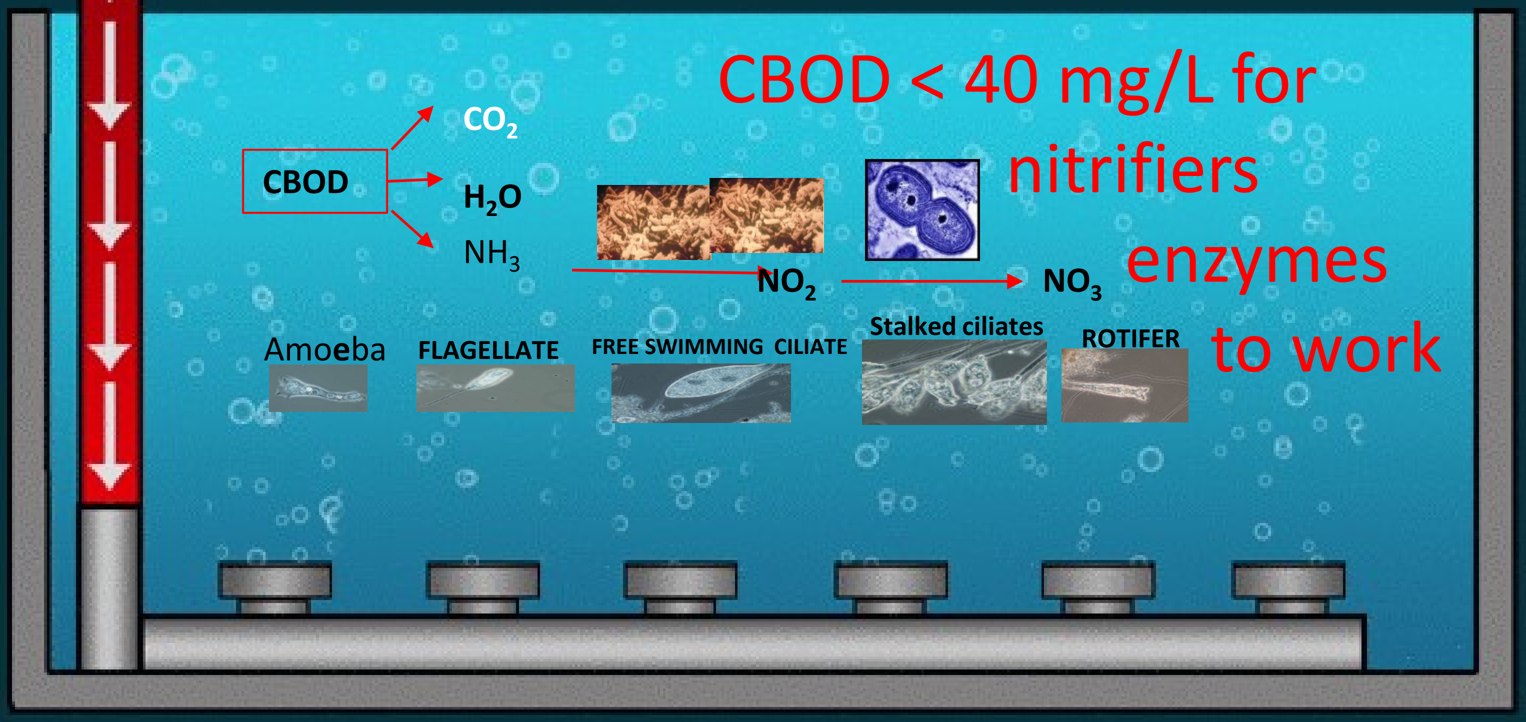
Oxygen 2 to 4 mg/L ; 3.0 mg/L for nitrification

Nutrients 100:5:1 (C:N:P)

Temperature 50 to 77°F ; 86°F for nitrification

Alkalinity $\geq$ 60 mg/L





Alkalinity and pH

Alkalinity is lost in an activated sludge process during nitrification. Nitrifiers use alkalinity as a carbon source i.e. they use an inorganic form of carbon. (CO_3 ; HCO_3 ; CO_2)

Hydrogen ions (H^+) are produced when ammonium ions are oxidized to nitrite:

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

Nitrous acid (NHO_2) is also produced during the oxidation of ammonium ions, destroying alkalinity:

$$H^+ + NO_2 \longrightarrow NHO_2$$

How does nitrification take place in an activated sludge system ?

It is important to note that it is the ammonium ion (NH_4^+) and not ammonia (NH_3) that is oxidized during nitrification. When proteins and organic nitrogen compounds, e.g. urea (NH_2CONH_2), are hydrolysed, and degraded amino acids are released.

The amino group is removed by bacterial activity – this is known as de-amination- and is quickly converted to the ammonium ion.

PREDOMINANTLY

NH_4

PREDOMINANTLY

NH_3

pH	Temperature													
	42.0 (°F)	46.4	50.0	53.6	57.2	60.8	64.4	68.0	71.6	75.2	78.8	82.4	86.0	89.6
	6 (°C)	8	10	12	14	16	18	20	22	24	26	28	30	32
7.0	.0013	.0016	.0018	.0022	.0025	.0029	.0034	.0039	.0046	.0052	.0060	.0069	.0080	.0093
7.2	.0021	.0025	.0029	.0034	.0040	.0046	.0054	.0062	.0072	.0083	.0096	.0110	.0126	.0150
7.4	.0034	.0040	.0046	.0054	.0063	.0073	.0085	.0098	.0114	.0131	.0150	.0173	.0198	.0236
7.6	.0053	.0063	.0073	.0086	.0100	.0116	.0134	.0155	.0179	.0206	.0236	.0271	.0310	.0369
7.8	.0084	.0099	.0116	.0135	.0157	.0182	.0211	.0244	.0281	.0322	.0370	.0423	.0482	.0572
8.0	.0133	.0156	.0182	.0212	.0247	.0286	.0330	.0381	.0438	.0502	.0574	.0654	.0743	.0877
8.2	.0210	.0245	.0286	.0332	.0385	.0445	.0514	.0590	.0676	.0772	.0880	.0998	.1129	.1322
8.4	.0328	.0383	.0445	.0517	.0597	.0688	.0790	.0904	.1031	.1171	.1326	.1495	.1678	.1948
8.6	.0510	.0593	.0688	.0795	.0914	.1048	.1197	.1361	.1541	.1737	.1950	.2178	.2422	.2768
8.8	.0785	.0909	.1048	.1204	.1376	.1566	.1773	.1998	.2241	.2500	.2774	.3062	.3362	.3776
9.0	.1190	.1368	.1565	.1782	.2018	.2273	.2546	.2836	.3140	.3456	.3783	.4116	.4453	.4902
9.2	.1763	.2008	.2273	.2558	.2861	.3180	.3512	.3855	.4204	.4557	.4909	.5258	.5599	.6038
9.4	.2533	.2847	.3180	.3526	.3884	.4249	.4618	.4985	.5348	.5702	.6045	.6373	.6685	.7072
9.6	.3496	.3868	.4249	.4633	.5016	.5394	.5762	.6117	.6456	.6777	.7078	.7358	.7617	.7929
9.8	.4600	.5000	.5394	.5778	.6147	.6499	.6831	.7140	.7428	.7692	.7933	.8153	.8351	.8585
10.0	.5745	.6131	.6498	.6844	.7166	.7463	.7735	.7983	.8207	.8408	.8588	.8749	.8892	.9058
10.2	.6815	.7152	.7463	.7746	.8003	.8234	.8441	.8625	.8788	.8933	.9060	.9173	.9271	.9389

Ammonia Levels NH_3 mg/L

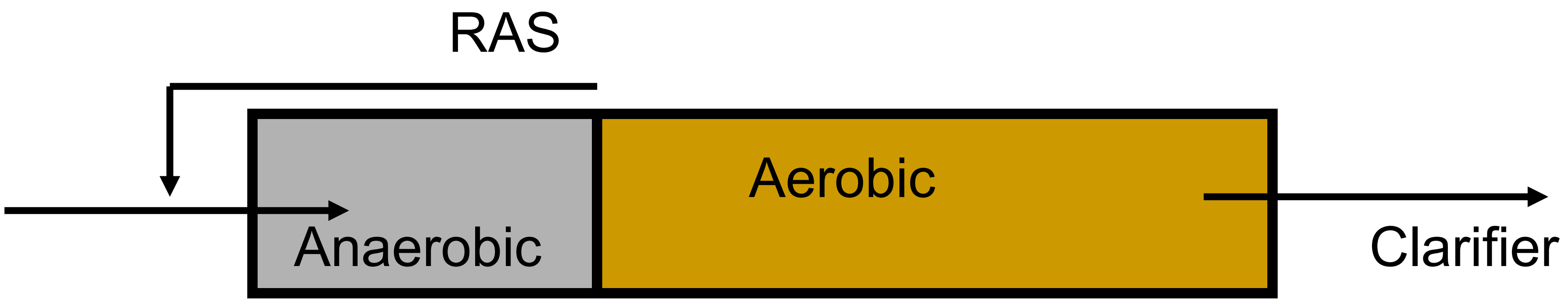
To Handle High Ammonia (NH_3): From You Know Where???

The Village installed fine bubble diffusers in 2009

- Major improvement to Ammonia reduction

Let's look at Phosphorous Removal

The MLSS in Those Facilities Cycled From Anaerobic to Aerobic



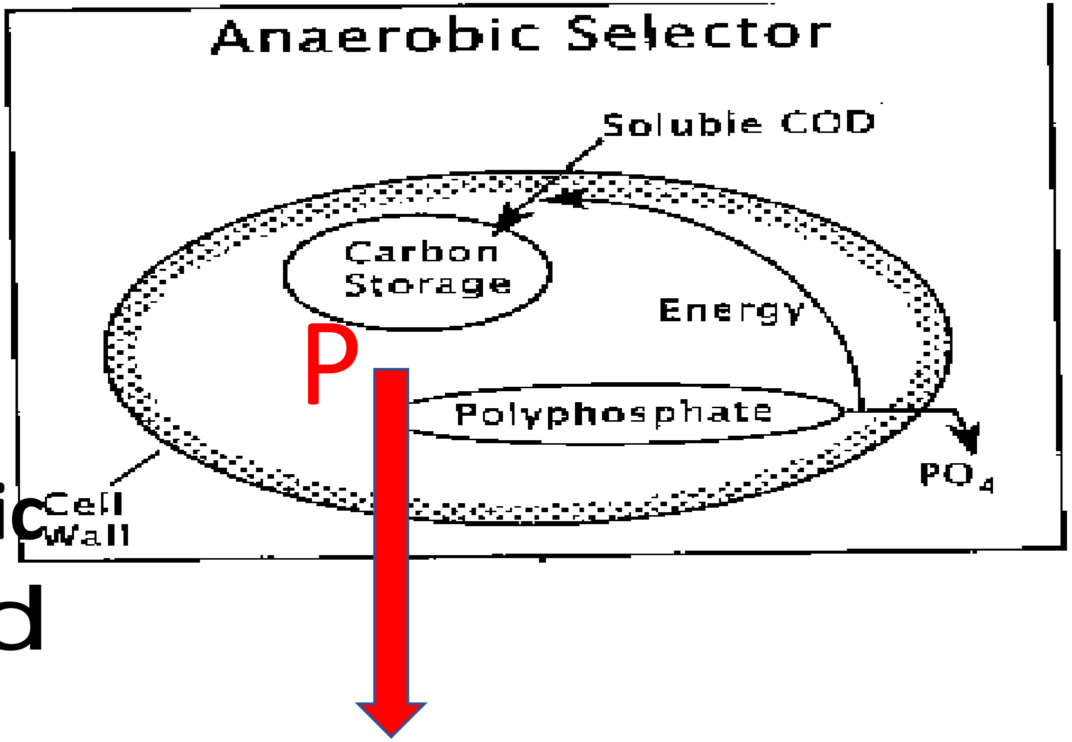
This Promoted the Accumulation of Bacteria that Uses P as an Energy Storage Mechanism

Acinetobacter (Assin Eato Back Ter)

& Other

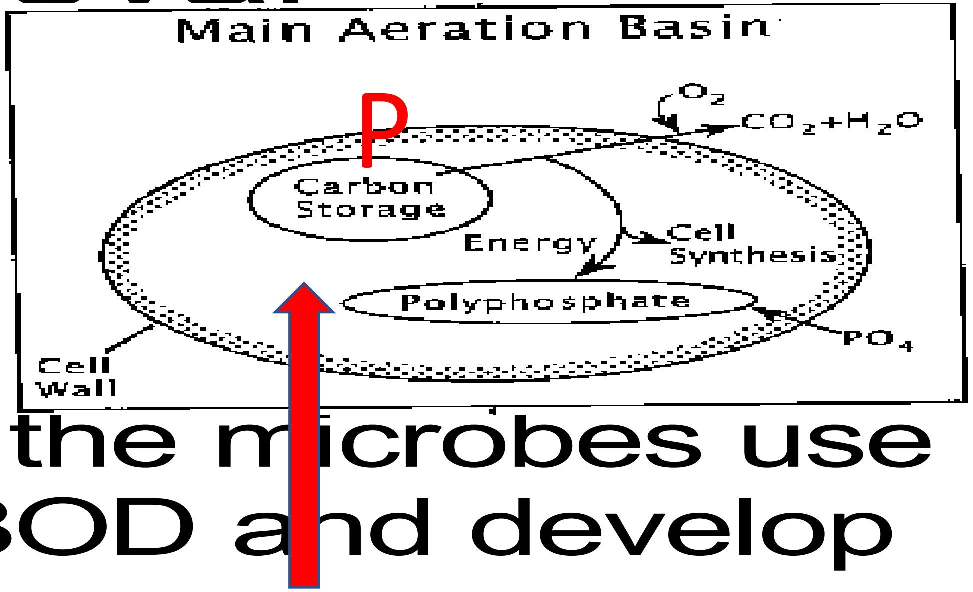
Phosphate Accumulating Organisms (PAO)

Biological Phosphorus Removal



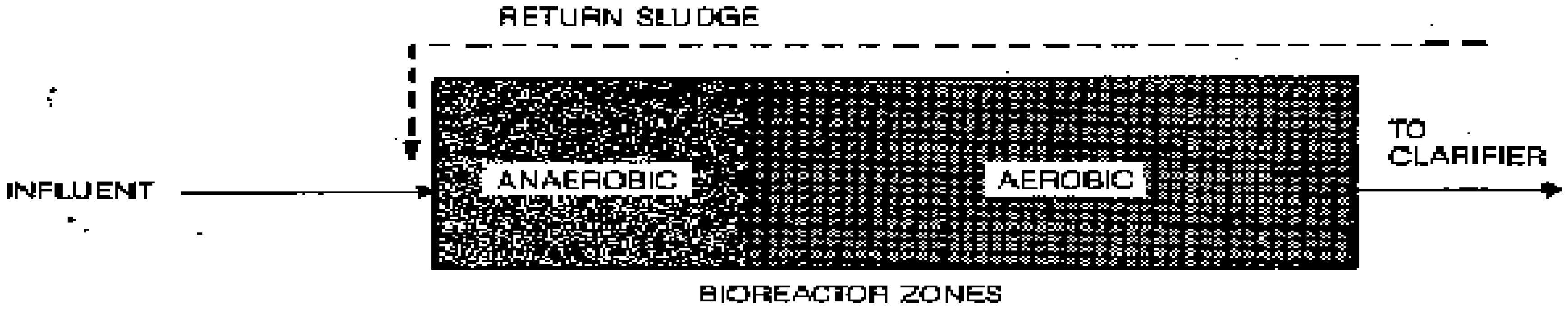
- Two Zone Process
  - 1st Zone – Anaerobic
    - Acinetobacter and Pseudomonas
    - Release Stored Phosphorus and take in Soluble BOD in the form of Acetate and Fatty Acids under Anaerobic conditions.

Biological Phosphorus Removal

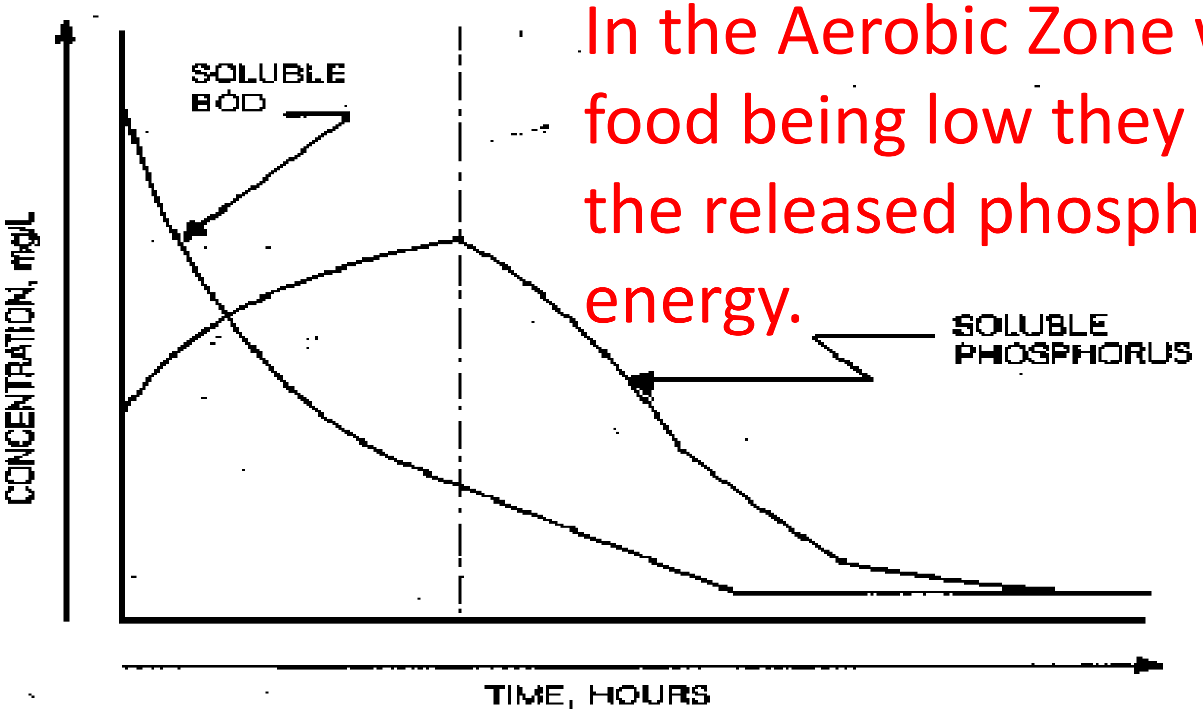


- 2^{nd} Zone – Aerobic
  - In the aerobic zone the microbes use the stored soluble BOD and develop new cells
  - With low soluble BOD, microbes consume large amounts of soluble phosphorus
  - Phosphorus contained within the microbes are wasted.

Biological Phosphorus Removal



NOTICE: BOD is being reduced while phosphorous is being released in the Anaerobic Zone.



In the Aerobic Zone with the food being low they consume the released phosphorous for energy.

ORP

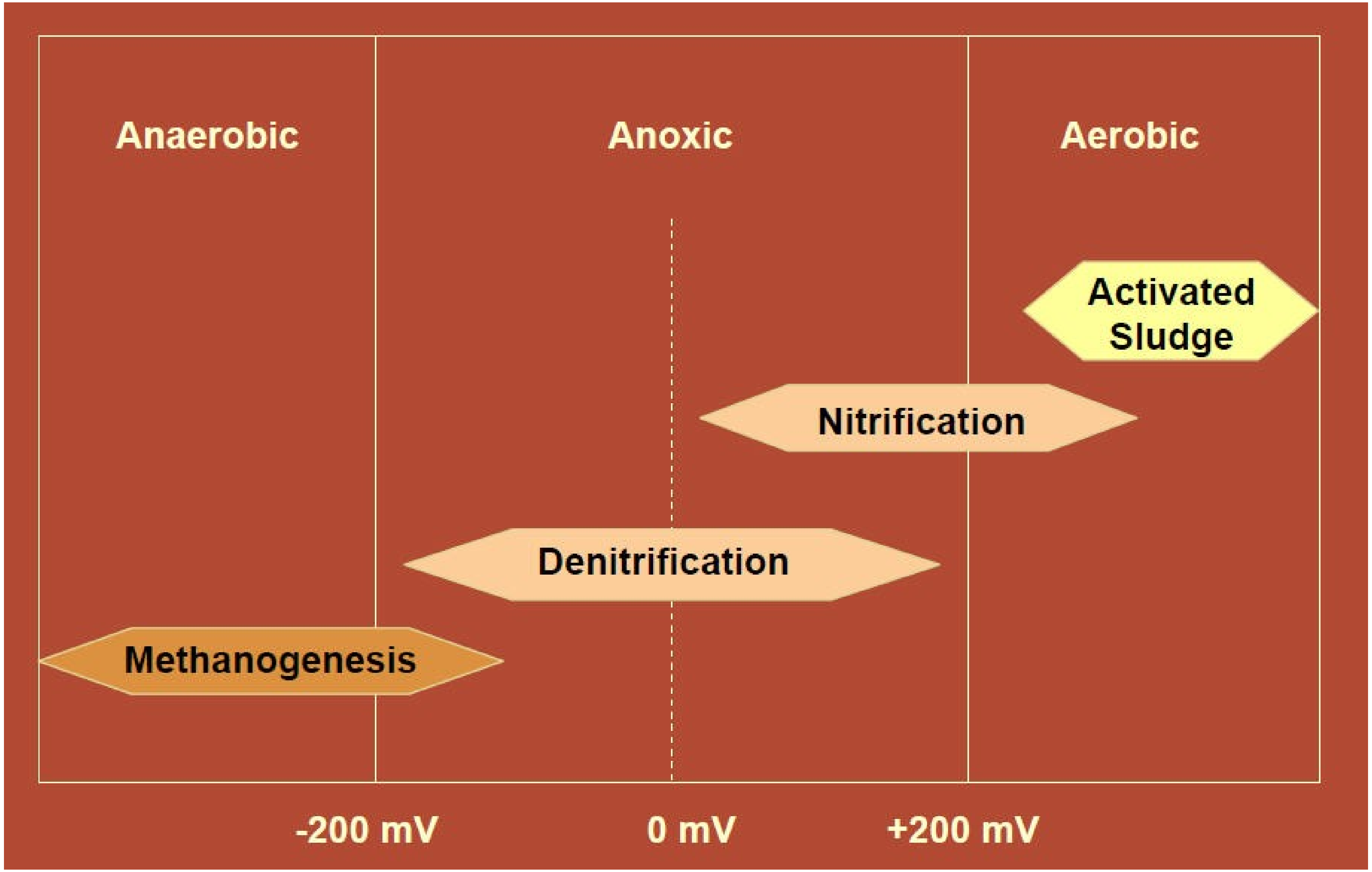
Consider this probe for nutrient removal !

Oxidation-Reduction Potential

The electrical potential (mv) required to transfer electrons from one compound to another.

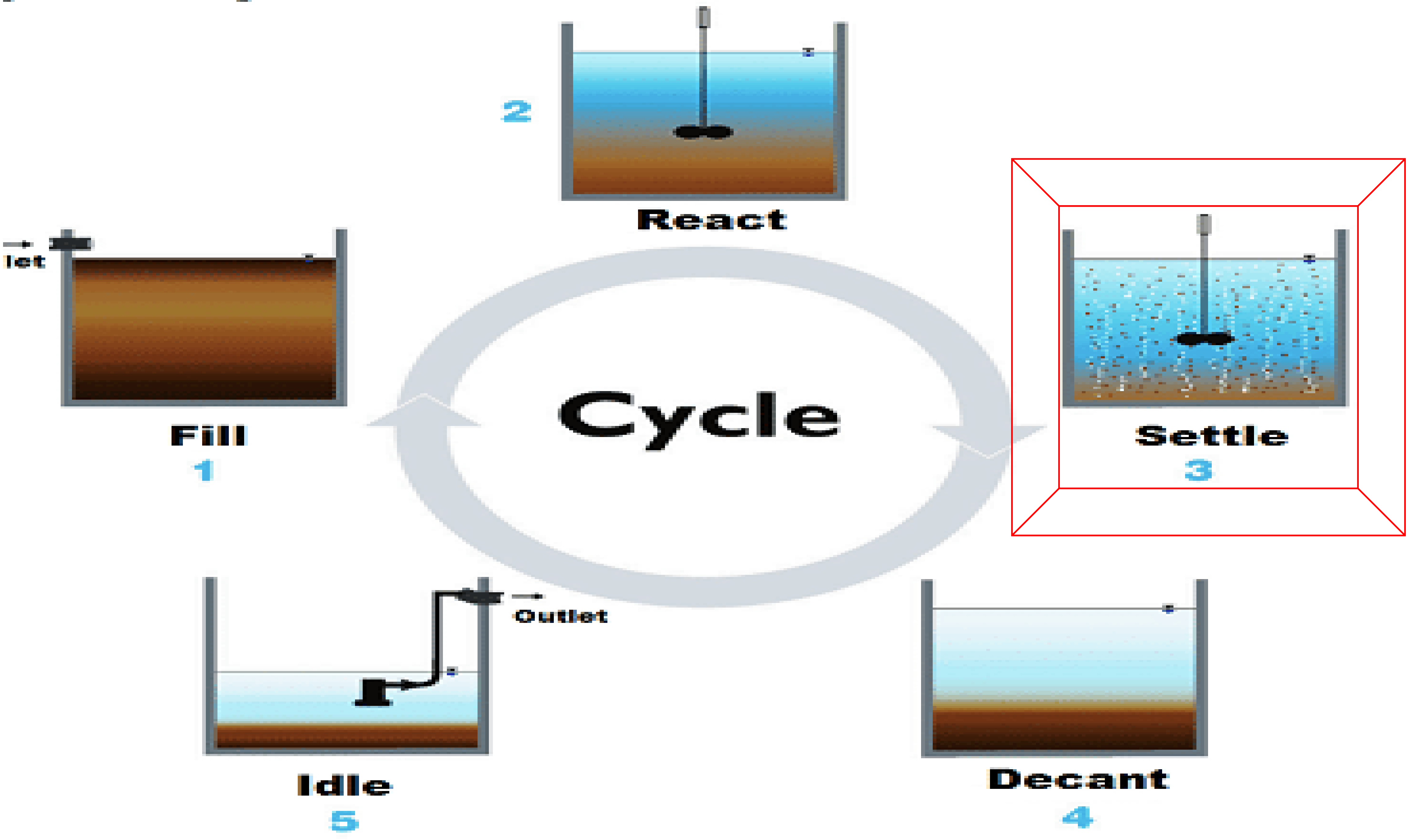
Used as a qualitative measure of the state of oxidation.

ORP


Anaerobic
Anoxic
Aerobic
Activated Sludge
Nitrification
Denitrification
Methanogenesis
-200 mV
0 mV
+200 mV

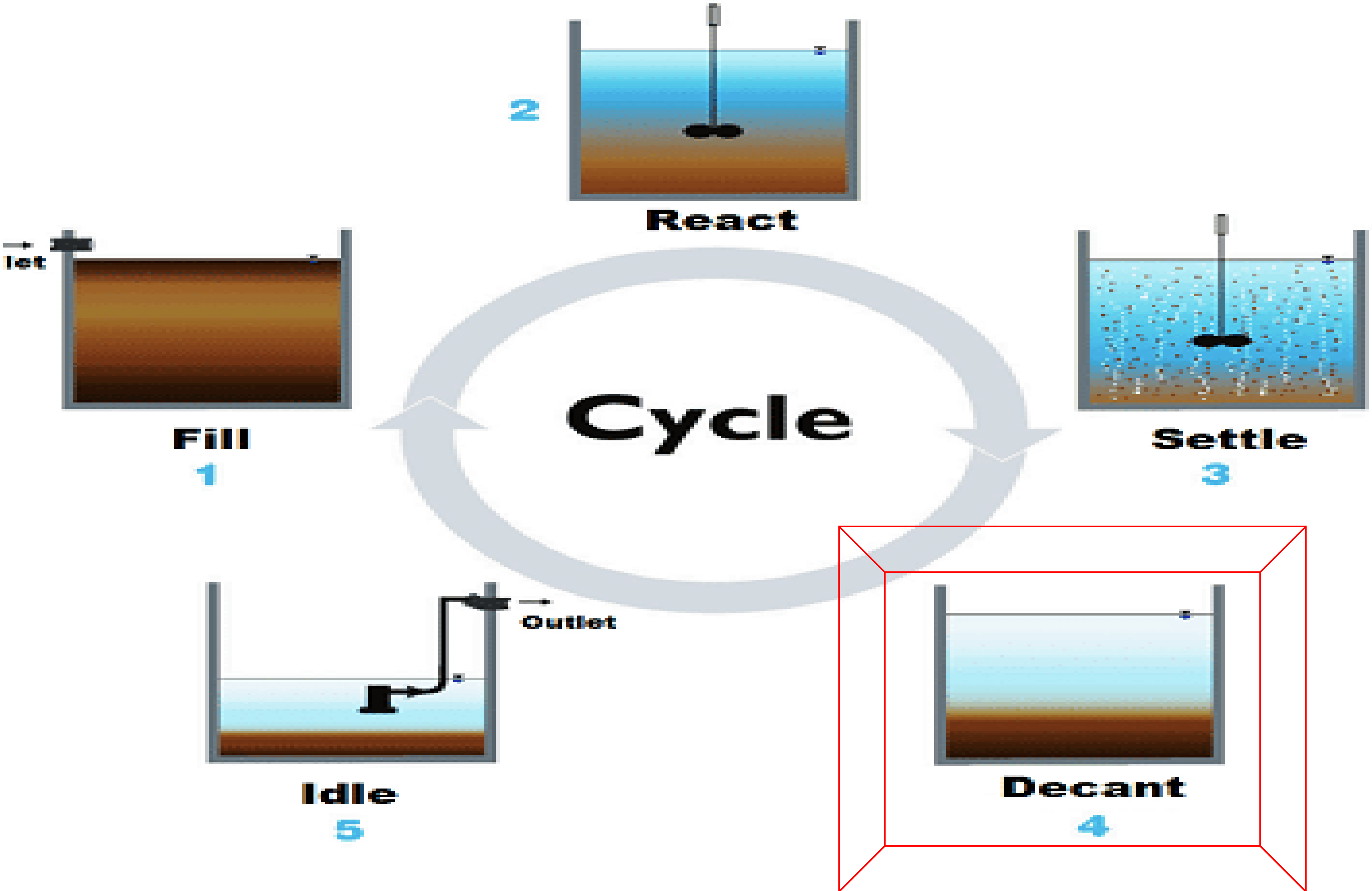
Biochemical Reactions and Corresponding ORP Values

Biochemical Reaction	ORP, mV
Nitrification	+100 to +350
cBOD degradation with free molecular oxygen	+50 to +250
Biological phosphorus removal	+25 to +250
Denitrification	+50 to -50
Sulfide (H_2S) formation	-50 to -250
Biological phosphorus release	-100 to -250
Acid formation (fermentation)	-100 to -225
Methane production	-175 to -400


let
Fill
1
2
React
Settle
3
Cycle
Outlet
Idle
5
Decant
4

Settle During this phase, activated sludge is allowed to settle under quiescent conditions—no flow enters the basin and no aeration and mixing takes place. The activated sludge tends to settle as a flocculent mass, forming a distinctive interface with the clear supernatant. The sludge mass is called the sludge blanket.

This phase is a critical part of the cycle, because if the solids do not settle rapidly, some sludge can be drawn off during the subsequent decant phase and thereby degrade effluent quality.

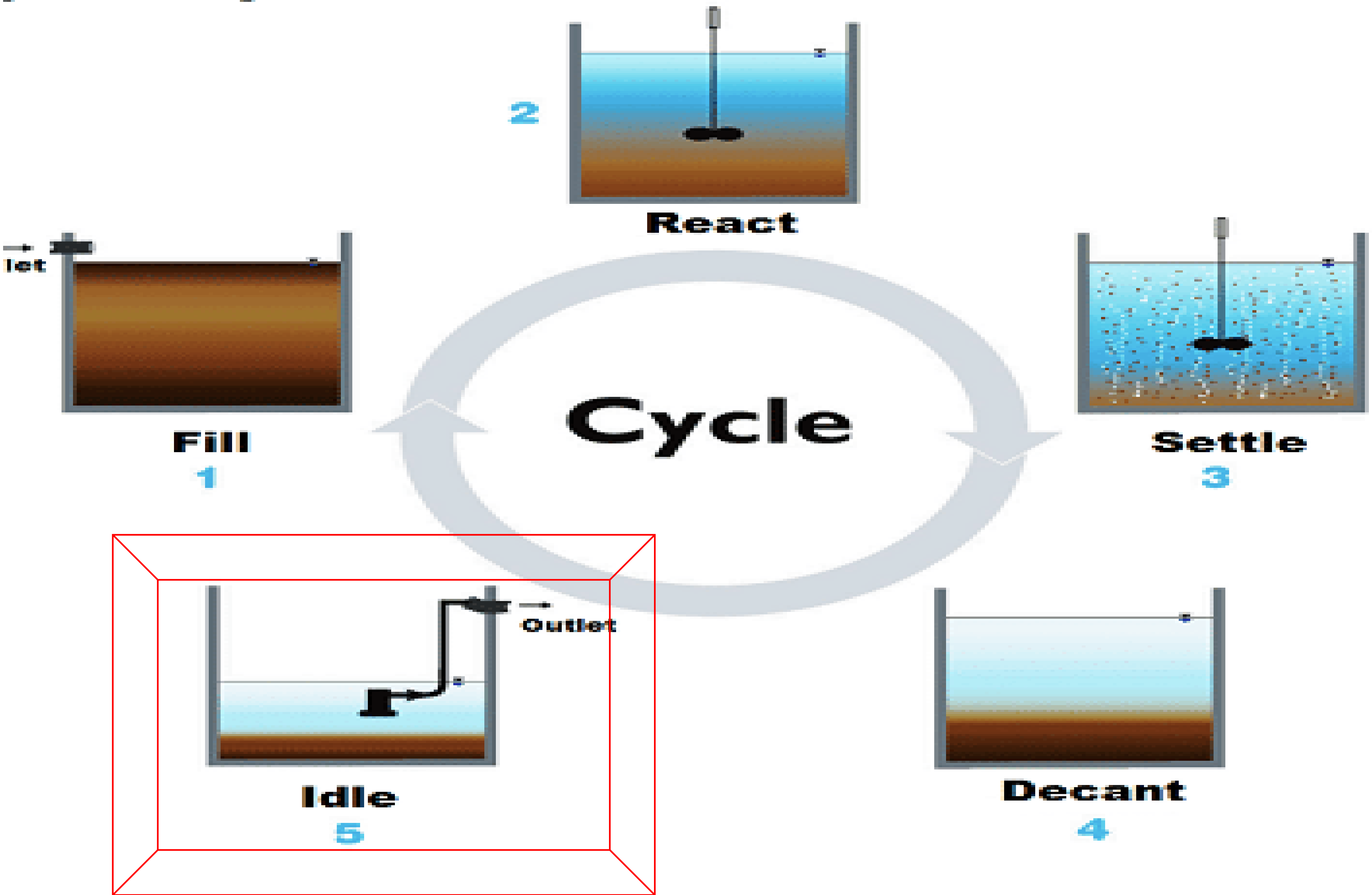


2
React
let
Fill
1
Cycle
Settle
3
Outlet
Idle
5
Decant
4

Decant *During this phase, a decanter is used to remove the clear supernatant effluent*. Once the settle phase is complete, a signal is sent to the decanter to initiate the opening of an effluent-discharge valve. There are floating and fixed-arm decanters. Floating decanters maintain the inlet orifice slightly below the water surface to minimize the removal of solids in the effluent removed during the decant phase. Floating decanters offer the operator flexibility to vary fill and draw volumes.

Fixed-arm decanters are less expensive and can be designed to allow the operator to lower or raise the level of the decanter. It is optimal that the decanted volume is the same as the volume that enters the basin during the fill phase. It is also important that no surface foam or scum is decanted. The vertical distance from the decanter to the bottom of the tank should be maximized to avoid disturbing the settled biomass.

FLOATING DECANTER


React
2
let
Fill
1
Cycle
Settle
3
Outlet
Idle
5
Decant
4

Idle This step occurs between the decant and the fill phases. The time varies, based on the influent flow rate and the operating strategy. During this phase, a small amount of activated sludge at the bottom of the SBR basin is pumped out – wasting.

An advantage to the SBR system, is Membrane Filtration can be added onto the existing Plant

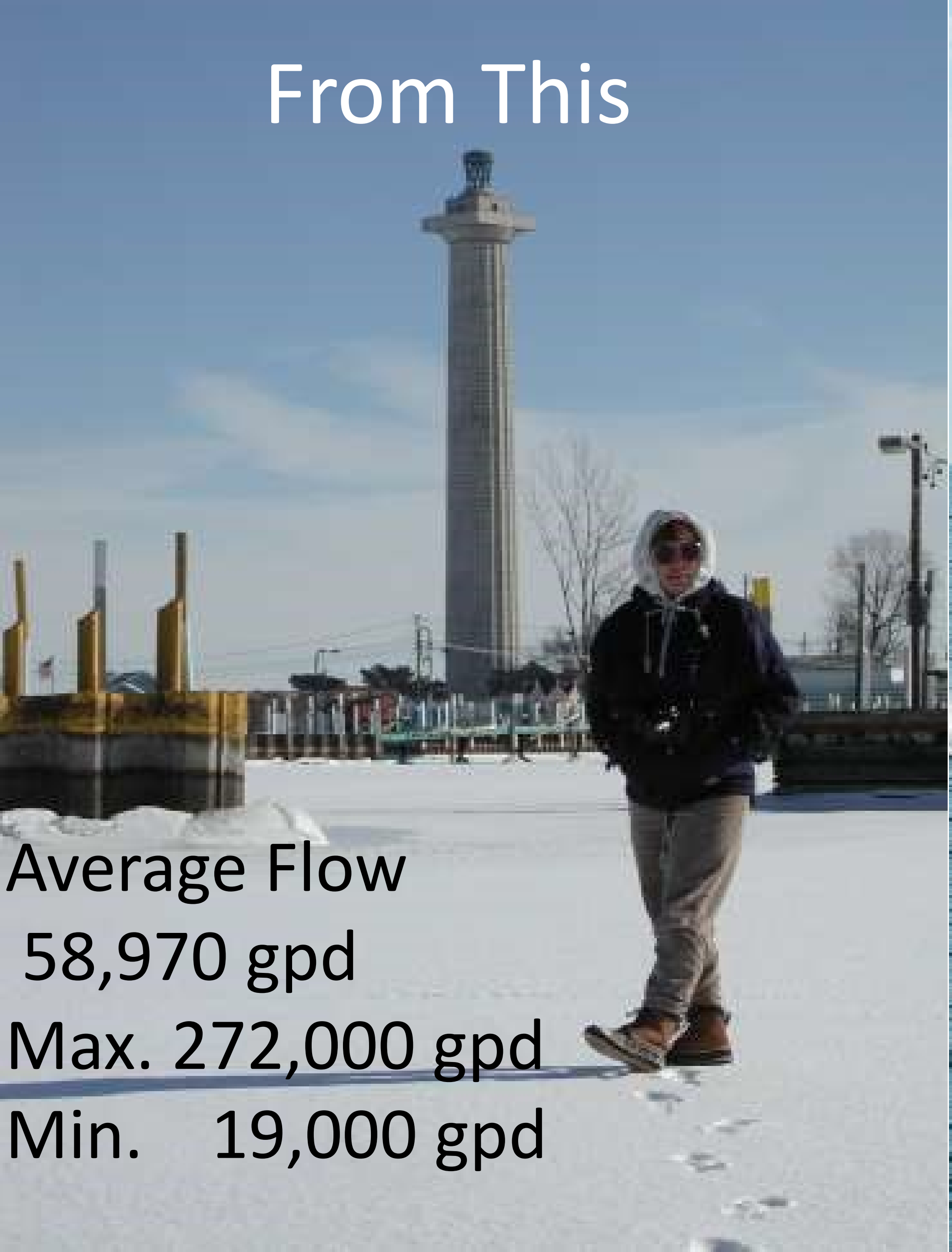
Limitations of SBR

- A higher level of sophistication is required especially for larger systems, of timing units and controls.
- Higher level of maintenance associated with more sophisticated controls, automated switches, and automated valves.
- Potential plugging of aeration devices during selected operating cycles, depending on the aeration system used by the manufacturer.


Aerobic Digestion


Comes in at 1.0% Total Solids


Store and air dries to
14% Total Solids
$1500/Load to transport to
Mainland

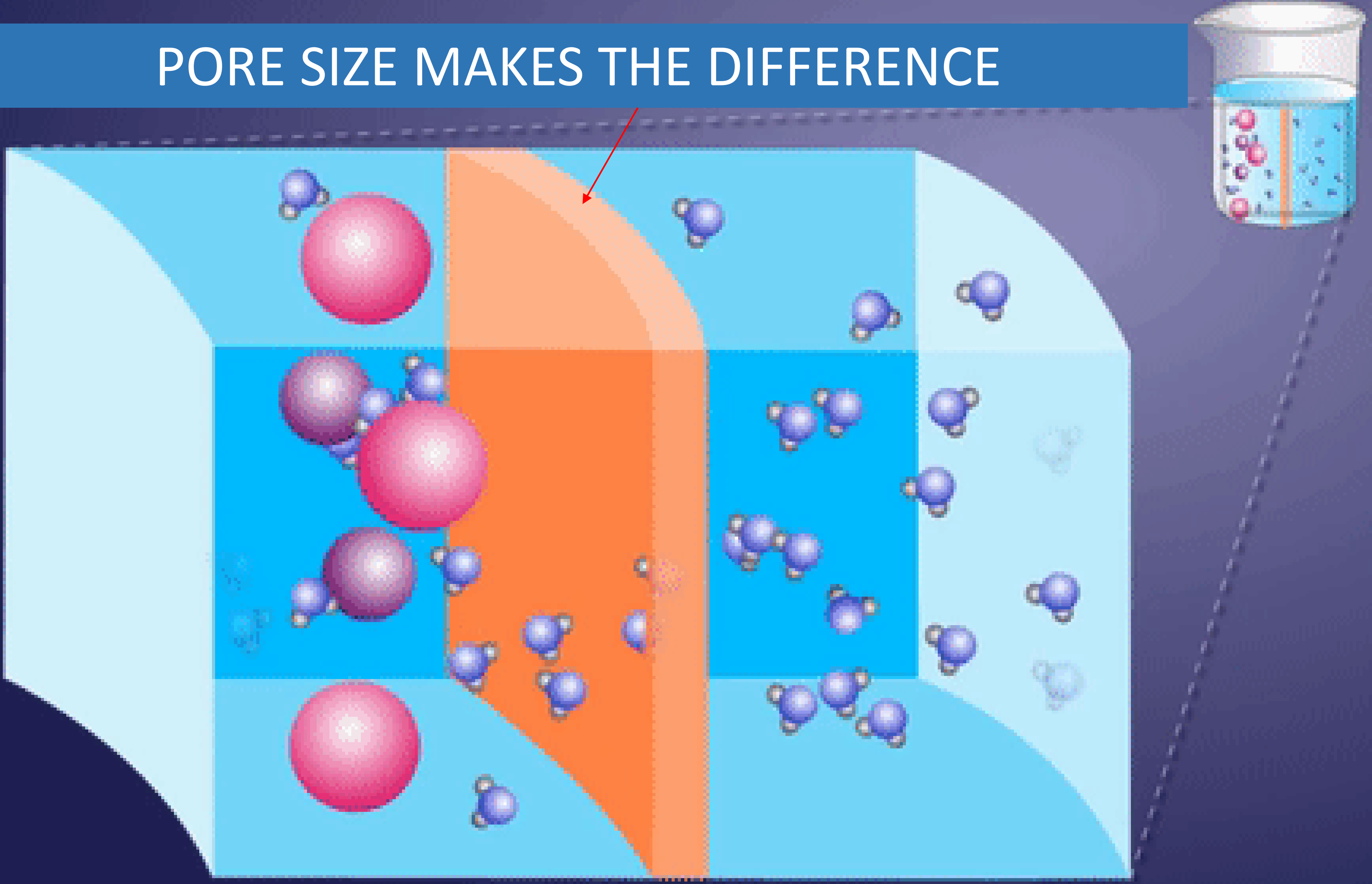

From This
Average Flow
58,970 gpd
Max. 272,000 gpd
Min. 19,000 gpd


To This
JET EXPRESS
PUT-IN-BAY
Average Flow 181,650 gpd
Maximum 333,000 gpd
Mimimum 124,000 gpd

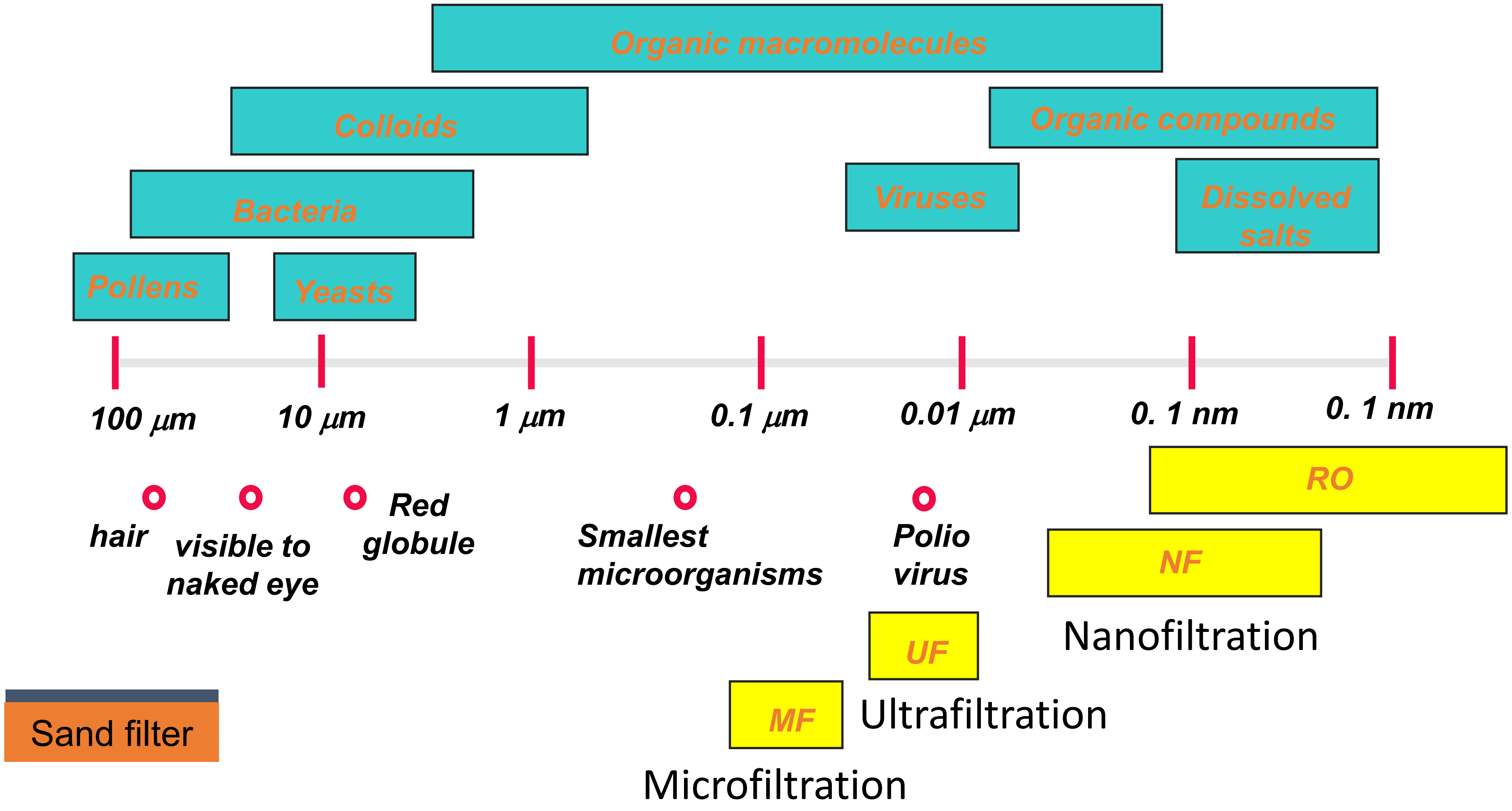
High Water and Noreaster Winds

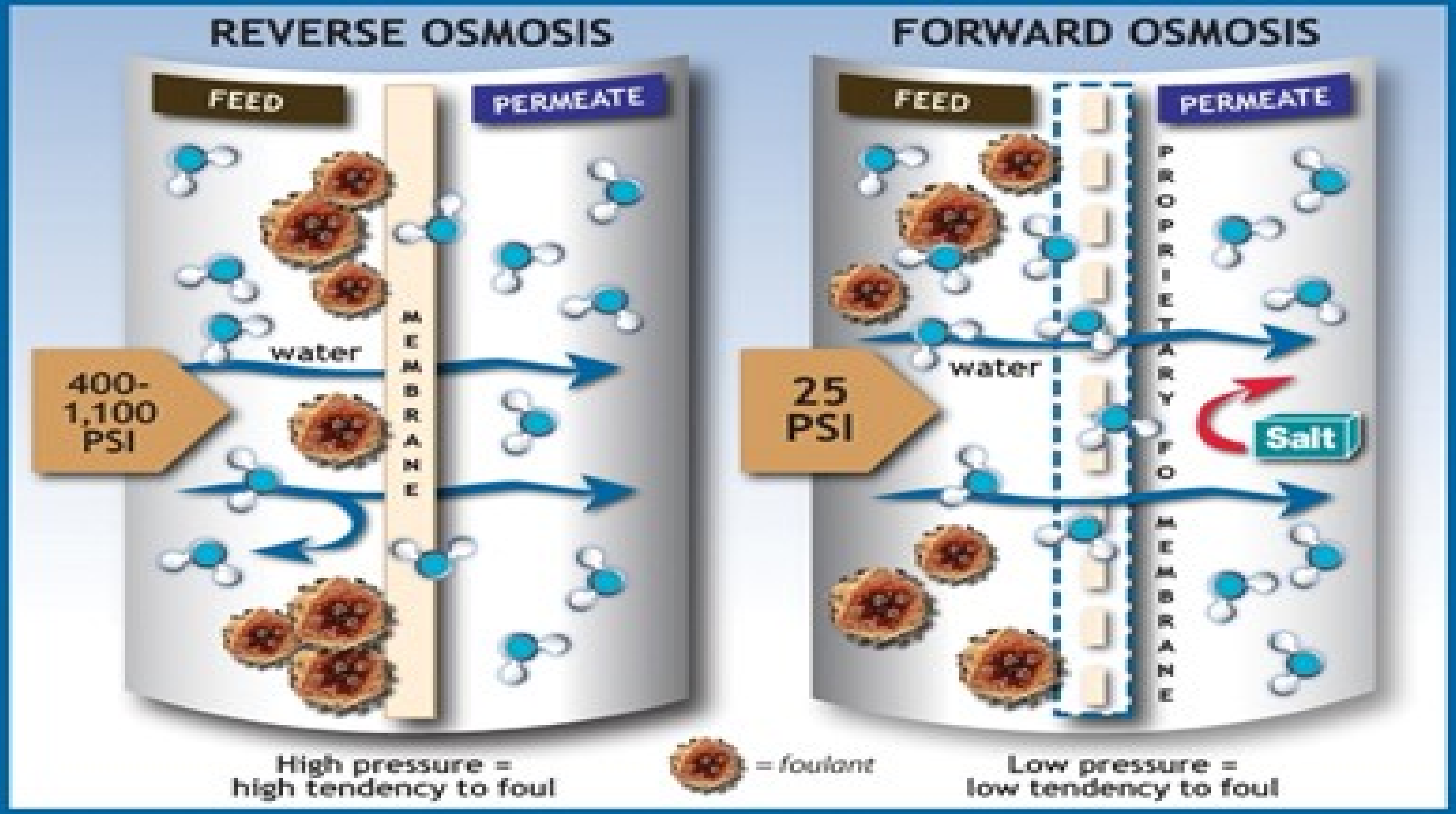

Special Thanks to Mike Mewhorter, Chris Ladd, Ann Auger
THANK YOU AND COME VISIT

PORE SIZE MAKES THE DIFFERENCE



Membrane Classifications
(Pore Size)




REVERSE OSMOSIS
FEED
PERMEATE
MEMBRANE
water
400-
1,100
PSI
High pressure =
high tendency to foul
= foulant
FORWARD OSMOSIS
FEED
PERMEATE
PROPRIETARY FO MEMBRANE
water
25
PSI
Salt
Low pressure =
low tendency to foul


FORWARD
OSMOSIS
3% TS
Fout
400mL
PYREX