# Activated Sludge What Can an Operator Control

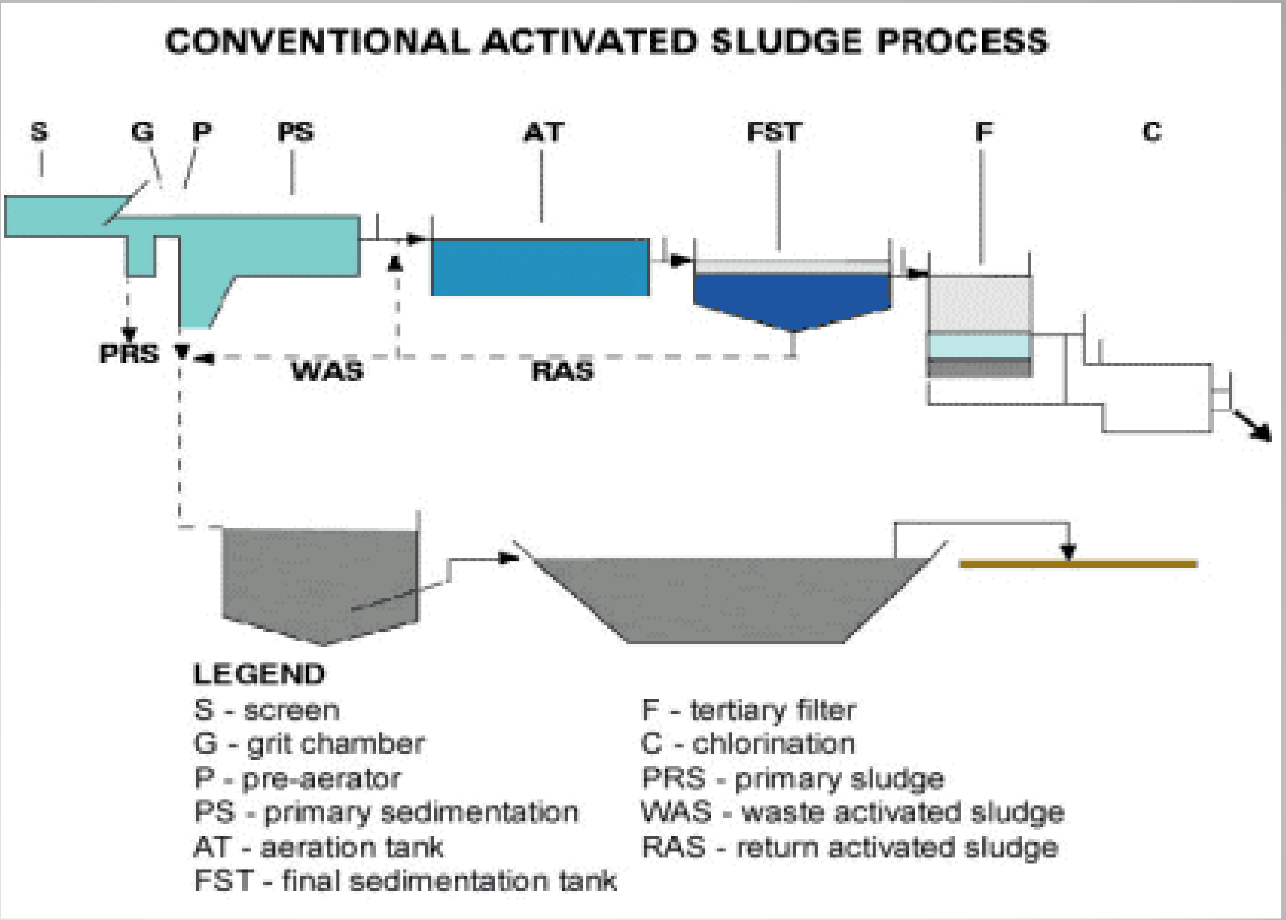
In the operation of an activated sludge wastewater treatment plant, the operator has little or no control over the amount, timing and characteristic of the flow entering the plant, as well as the size and type of the unit processes in the plant. This presentation looks at what the operator can control to promote operational conditions favorable to the production of an effluent that meets design standards. It will also look at the importance of good data collection.

# Introduction

We will begin with a quick look at some of the different types of activated sludge systems to show that not all the same controls can be applied. We will then review basic process design and see how engineering standards are used to set the initial operational parameters. Next the process controls we can use are examined. Finally we will show the importance of quality data collection, observations, and record keeping

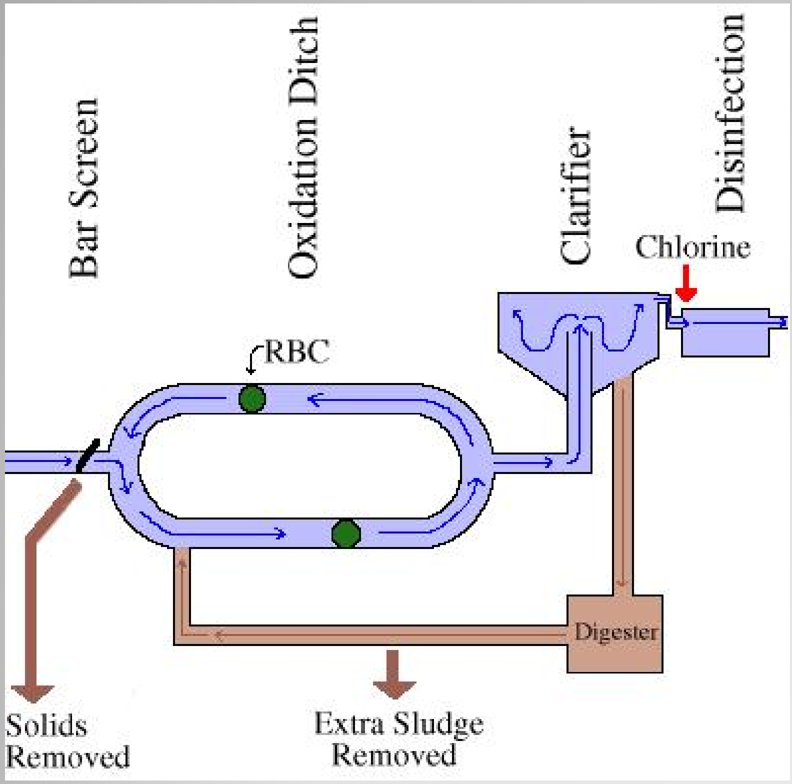
# Types of Activated Sludge Plants

## Conventional




# Types of Activated Sludge Plants

## Oxidation Ditch

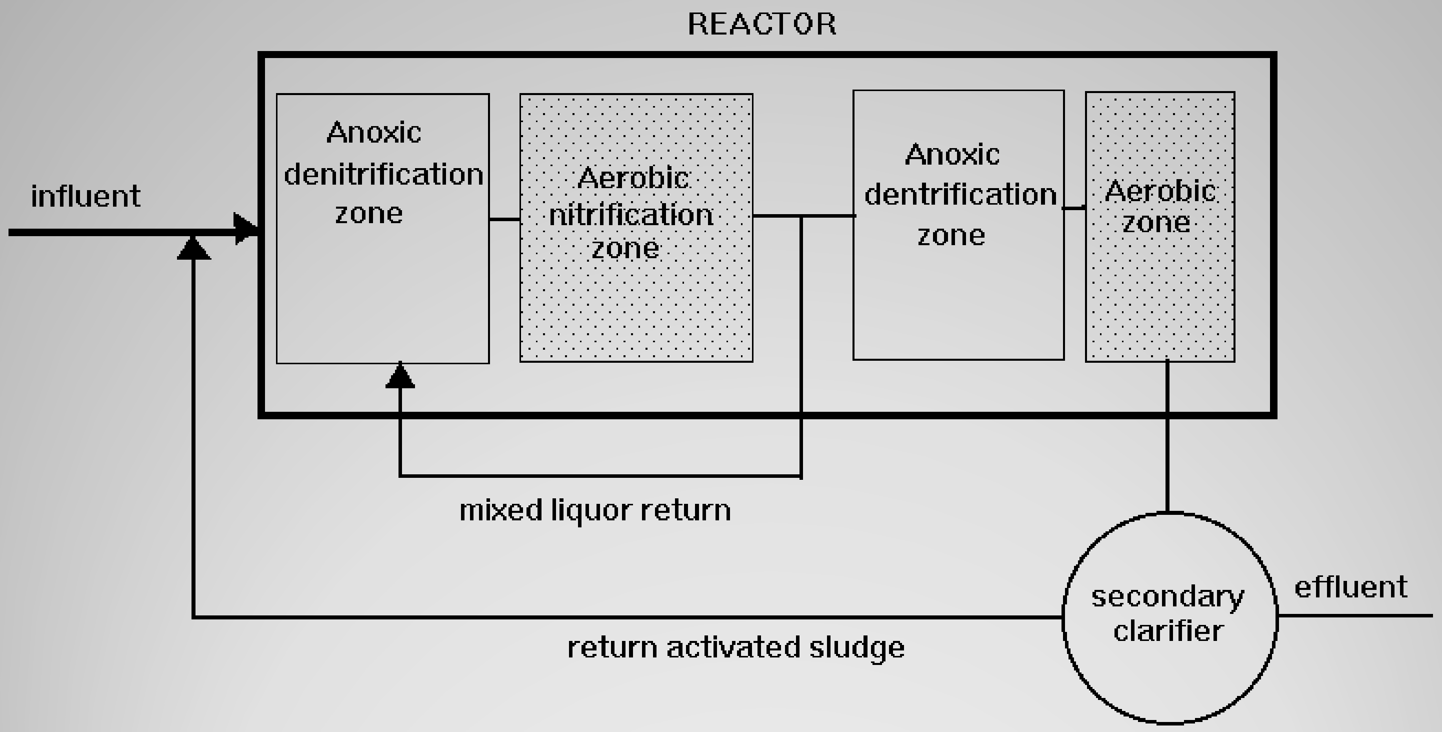



# Types of Activated Sludge Plants

Schreiber

# Types of Activated Sludge Plants

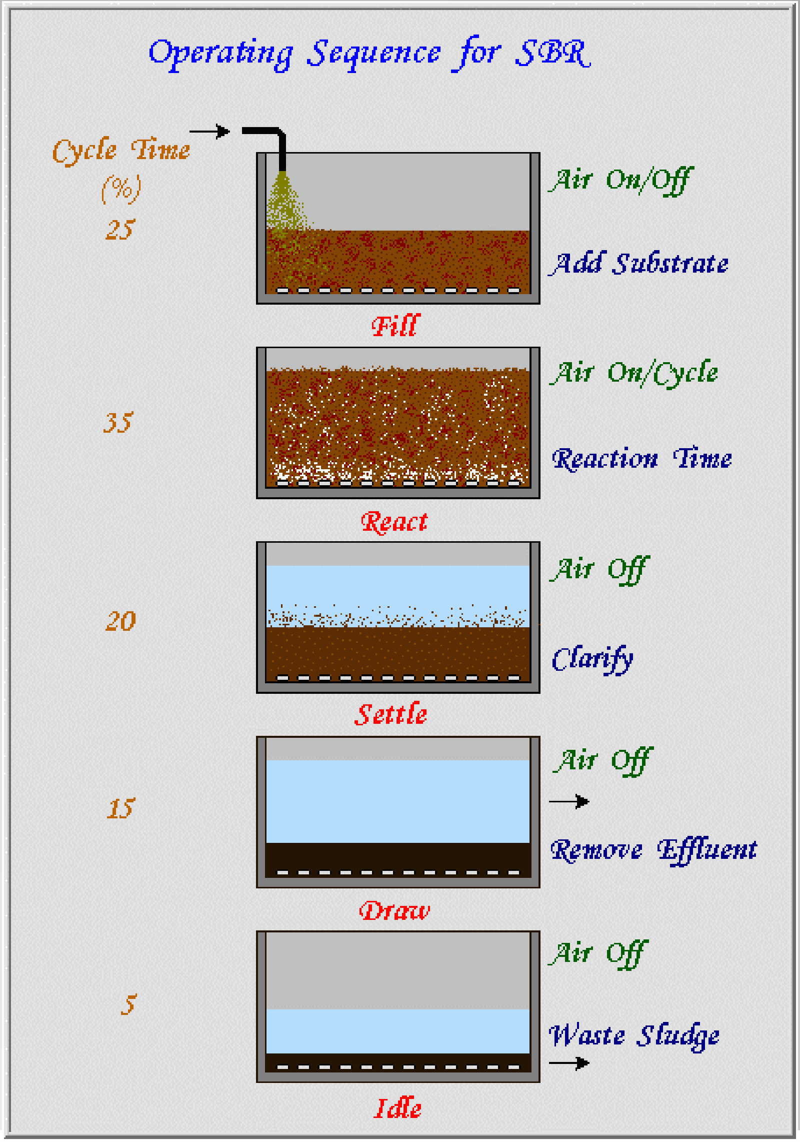
# Bardonpho – 4 Stage




# Types of Activated Sludge Plants

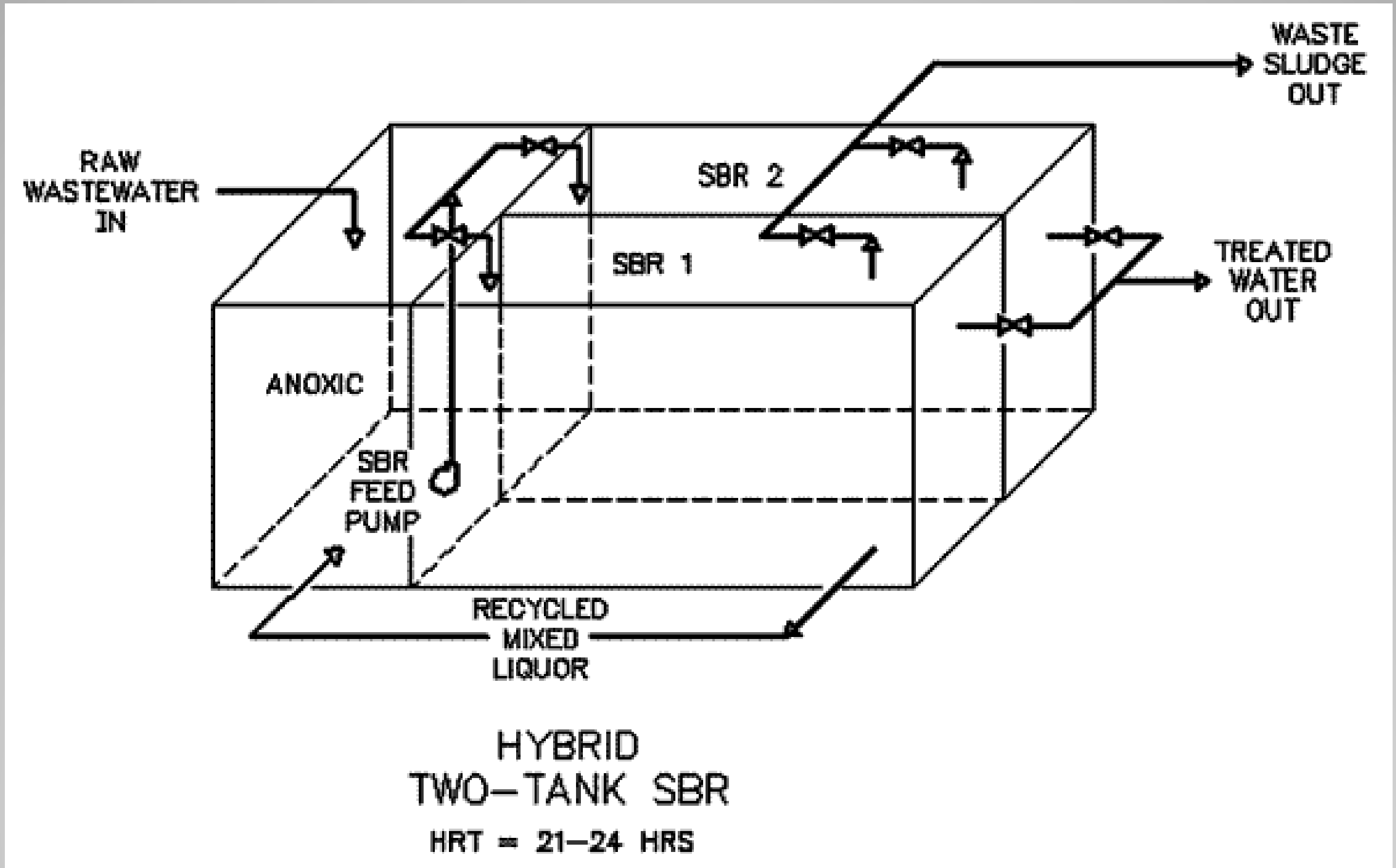
# SBR

No clarifier, therefore, no return rate.



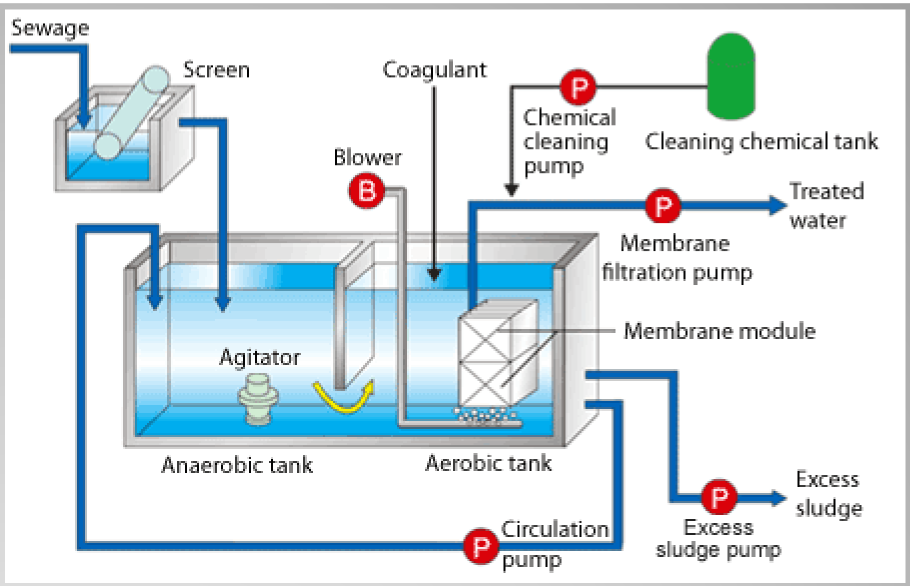

# Types of Activated Sludge Plants

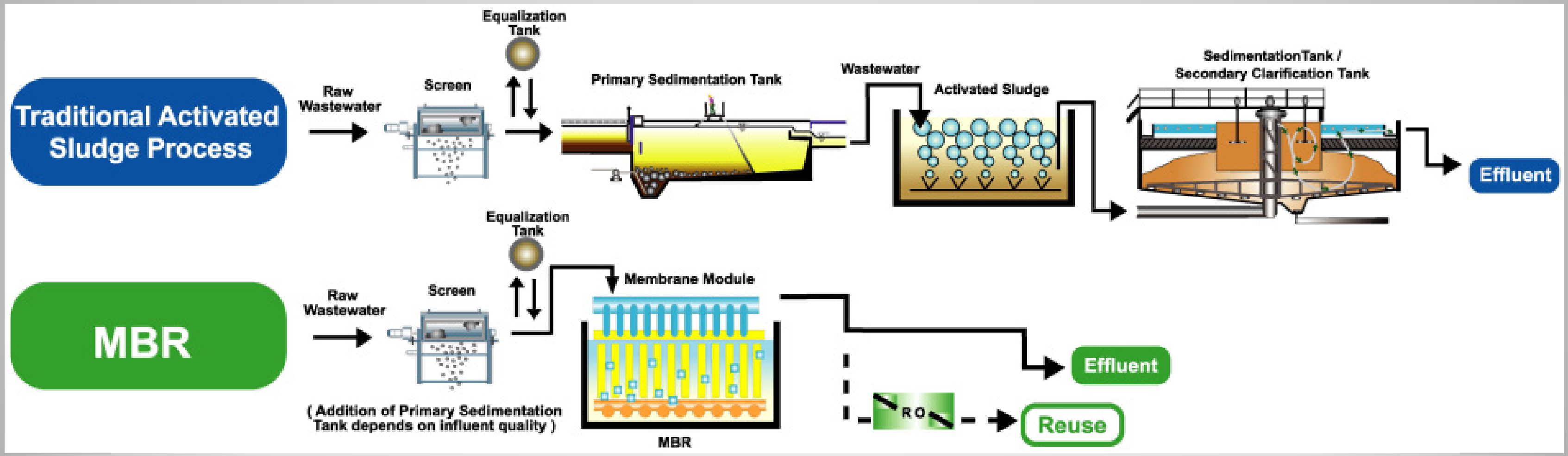
Pace / Perc




# Types of Activated Sludge Plants

# Membrane




# Types of Activated Sludge Plants

# Process Design and Engineering Standards

# Process Design

- To achieve the desired results we have to understand what the system is and what each unit does, as well as, the impact of each process on the other.

- Activated sludge refers to a mass of microorganisms cultivated in the treatment process to break down organic matter into carbon dioxide, water, and other inorganic compounds. The activated sludge process has three basic components: 1) a reactor in which the microorganisms are kept in suspension, aerated, and in contact with the waste they are treating; 2) liquid-solid separation; and 3) a sludge recycling system for returning activated sludge back to the beginning of the process. There are many variants of activated sludge processes, including variations in the aeration method and the way the sludge is returned to the process.

    - http://water.worldbank.org/shw-resource-guide/infrastructure/menu-technical-options/activated-sludge

# Activated Sludge Defined

## Where do we get the Design Parameters

- Plants are designed by applying known engineering standards and process algorithms to historical and current data as well as projected loadings. When these are wrong or the service area demographics change the plant may issues and/or need an upgrade.
- Use this design data as starting point for process settings.
- Also look at data from other similar plants.
- Check literature or Internet for common operational standards

# Engineering Standards

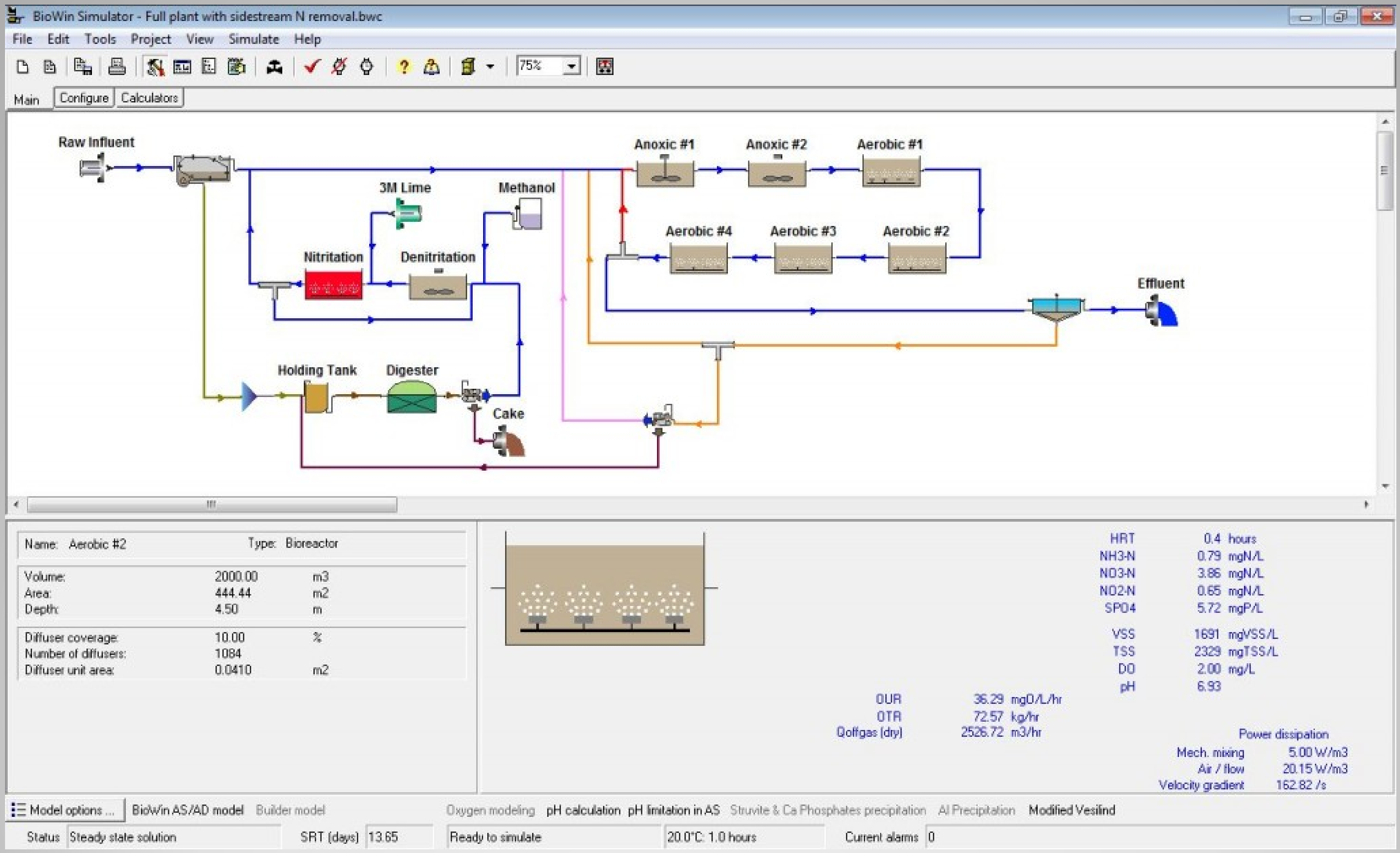
## Design Parameters

Activated Sludge Operational Parameters - Typical Ranges

| Activated Sludge Process | SRT days | MLSS mg/L | F:M $\frac{\text{lb BOD/day}}{\text{lb MLVSS}}$ | $Q_r / Q_o$ % |
|---|---|---|---|---|
| Conventional Plug Flow | 3 - 15 | 1000 - 3000 | 0.2 - 0.4 | 25 - 75 |
| Complete Mix | 3 - 15 | 1500 - 4000 | 0.2 - 0.6 | 25 - 100 |
| Extended Aeration | 20 - 40 | 2000 - 5000 | 0.04 - 0.1 | 50 - 150 |

# Engineering Standards

## Design Software




# Engineering Standards

# Typical Wastewater Characteristics

When no data is available or future loadings need to be projected it may be necessary to use standard values from literature

| Table 1. Composition of Typical Residential Untreated Wastewater | | | |
|---|---|---|---|
| Constituent | Unit | Range | Typical |
| Total Solids | mg/L | 300-1200 | 700 |
| Dissolved | mg/L | 250-1200 | 500 |
| Fixed | mg/L | 150-550 | 150 |
| Volatile | mg/L | 100-300 | 150 |
| Suspended | mg/L | 100-400 | 220 |
| Fixed | mg/L | 30-100 | 70 |
| Volatile | mg/L | 70-300 | 150 |
| Setteable | mg/L | 50-200 | 100 |
| BOD5 | mg/L | 100-400 | 250 |
| TOC | mg/L | 100-400 | 250 |
| COD | mg/L | 200-1,000 | 500 |
| Total Nitrogen | mg/L | 15-90 | 40 |
| Organic | mg/L | 5-40 | 25 |
| Ammonia | mg/L | 10-50 | 25 |
| Nitrite | mg/L | 0 | 0 |
| Nitrate | mg/L | 0 | 0 |
| Total Phosphorous | mg/L | 5-20 | 12 |
| Organic | mg/L | 1-5 | 2 |
| Inorganic | mg/L | 5-15 | 10 |
| Chloride | mg/L | 30-85 | 50 |
| Sulfate | mg/L | 20-60 | 15 |
| Alkalinity | mg/L | 50-200 | 100 |
| Grease | mg/L | 50-150 | 100 |
| Total Coliform | Colonies/100mL | $10^6$-$10^8$ | $10^7$ |
| VOCs | µg/L | 100-400 | 250 |

# Engineering Standards

# Process Controls

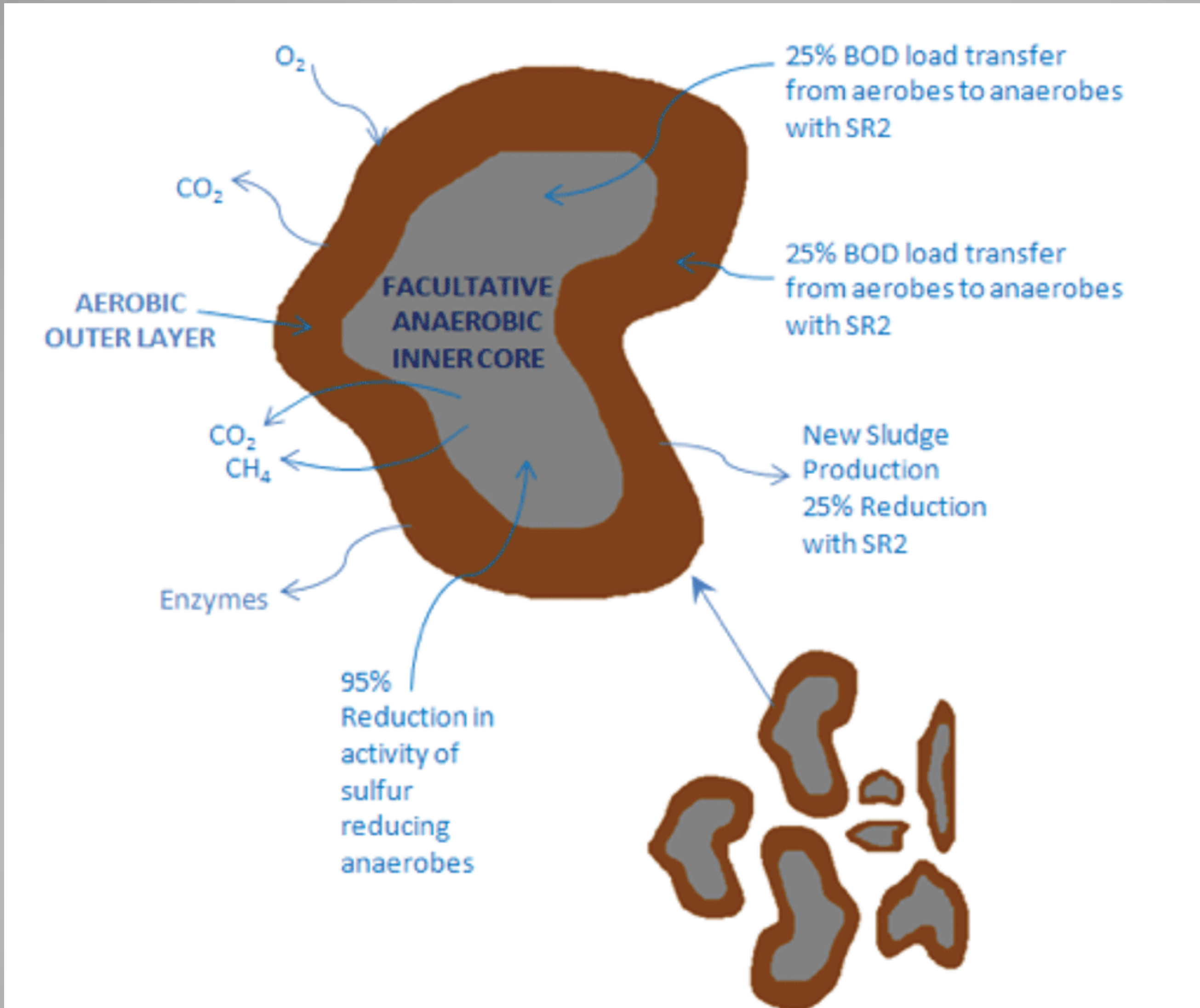
# Control Measures

- Dissolved Oxygen
- Wasting
- Return Rates IR and RAS
- Number and Condition of Units on Line
- Additives
- Controls during Process Recovery
- Daily Monitoring and Calibration

# Dissolved Oxygen

- The number one control is the dissolved oxygen(DO) level in the mixed liquor.
- The DO level is different in the various process units dependent upon the required ORP in the process.
- Loadings can require higher DO
- Improve efficiency through type of method used.
- Delivery system in good shape
- Compare hand held reading to in-line probe.

## Process Control




The loading on the plant affects the oxygen uptake and may require a higher DO to drive the oxygen into the inner layers of the floc to avoid complete anaerobic conditions which can cause disintegration of the floc.

# Process Control

# Wasting

- To keep effluent quality the operator must maintain a sludge mass that can achieve desired pollutant removal while having good settling properties.
- Seasonal changes due to loadings and temperatures can change the sludge age required.
- Membrane systems can hold more solids since settling characteristics are not important.

# Return Rates

- Excessive return rates from clarifiers can hydraulically overload the clarifiers.
- Excessive internal return rates can raise DO in denitrification.
- Low clarifier return rates can cause high blankets and solids carry over as well as promoting anoxic or anaerobic conditions.
- Low internal recirculation rates can reduce denitrification by not exposing enough nitrates to anoxic conditions and not diluting the ammonia entering the plant.
- In a SBR similar control is done through cycle times

# Number and Condition of Units on Line

- Number of other units (clarifiers, screens, digesters, etc.) on line
- Aeration of channels for low flow.
- Return equipment proportional control
- Based on peaking factor, seasonal flow.
- Mechanical condition of equipment is one of most important controls. Stuck vales and gates, failed motors, pumps and blowers, poor clarifier collection can cause process failure. A preventative maintenance program is essential
- An inventory of spare parts keeps down time to a minimum
- Poor screening leads to ragging of equipment.
- Are other units adding excessive loadings due to poor dewatering, digester supernatant, or odor control chemicals

# Additives

- Coagulations and flocculants to improve settling
- Enzymes
- Chlorine
- Defoaming Agents
- Nutrients and Biostimulants
- pH Control for Alkalinity

## Process Recovery Controls

- At times the plant may suffer a complete or near complete die-off. Dependent upon upset you may have to:
- Look at return streams from other processes
- Determine if it was due to a mechanical failure or operator error.
- Waste more if a toxic load was the cause.
- Don't worry about denitrification because you can't denitrify until you nitrify.
- Put more units on line
- Import seed sludge.
- Do nothing or very little other than using additives for a short term.
- Record as much as you can to find cause and how recovery was achieved.

# Recovery Control

# Daily Monitoring

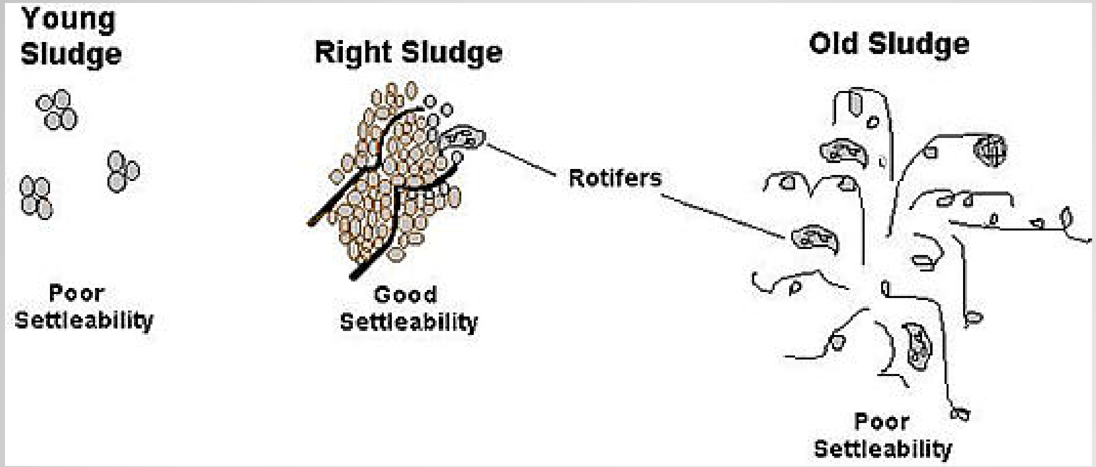
- The operator can not control the process unless he knows what is going on in the process
- The process should be monitored through readings and sampling. Daily is the best frequencies but do what you can with the resources available to you.
- Follow the recommendations in the operations manual for the plant. Change the frequency as required by actual operational conditions.
- True readings can only be taken if the instrumentation is in good shape and proper lab and sampling procedures are followed.
- Ensure probes are calibrated and replaced before the end of their service life.

# Daily Monitoring

- The following are some tests that monitor the condition of the activated sludge. They may not be included in the Operation manual which has the suggested sampling and testing schedule.

## Settleability






# Sludge Condition

## Sludge Volume Index - SVI

$$\text{SVI (mL/g)} = \frac{\text{Settled Sludge Volume (mL/L)}}{\text{Mixed Liquor Suspended Solids (g/L)}} \times 1{,}000$$

### Design of Secondary clarifier on the basis of SVI and ZSV

Settling and thickening characteristics of the mixed liquor measured by either SVI or ZSV can be used as basis

SVI below 100 is desired and above 150 typically indicates filamentous growth

Surface over flow rate for a secondary clarifier is related to zone settling velocity as shown below

$$Surface\ overflow\ rate = \frac{V_i}{SF}$$

ZSV ($V_i$) can be estimated by

$$V_i = V_{max} \exp(-K)x$$

Here $V_i$ is zone settling velocity (SVI)

SF is safety factor and taken as 1.75 to 2.5

$V_{max}$ is maximum zone settling velocity taken as 7 m/h

K is a constant with value 600 l/mg for ML with SVI 150

X if MLSS concentration

# Sludge Condition

## Oxygen Update Rate - OUR

Dissolved Oxygen Uptake (DOUR) Test

- Our can be used to see how much of an oxygen demand, due to loadings, is being placed on the system and can tell you when the endogenous state has been reached.
- The real time graph of the DO in a SBR mixing cycle can be used for the OUR and help determine if full nitrification has been reached.

# Sludge Condition

## On Line Oxidation Reduction Potential - ORP

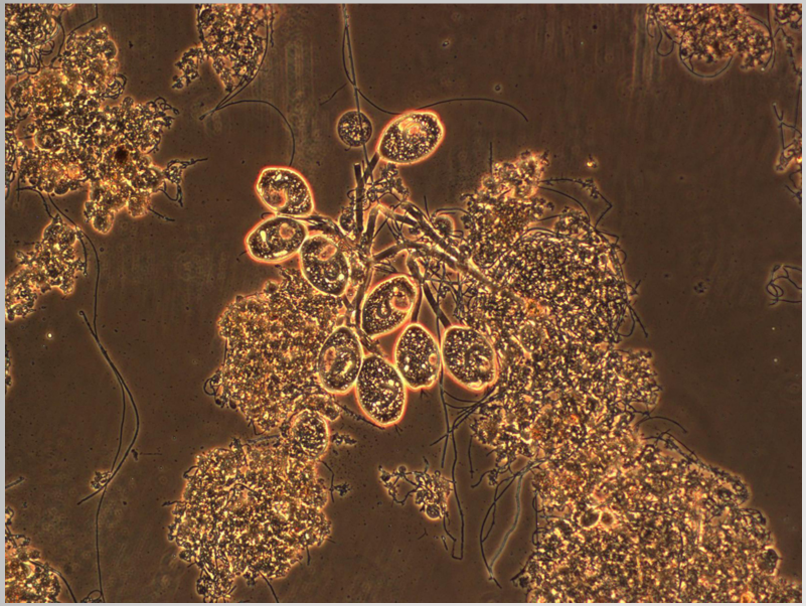
**Biochemical Reactions and Corresponding ORP Values**

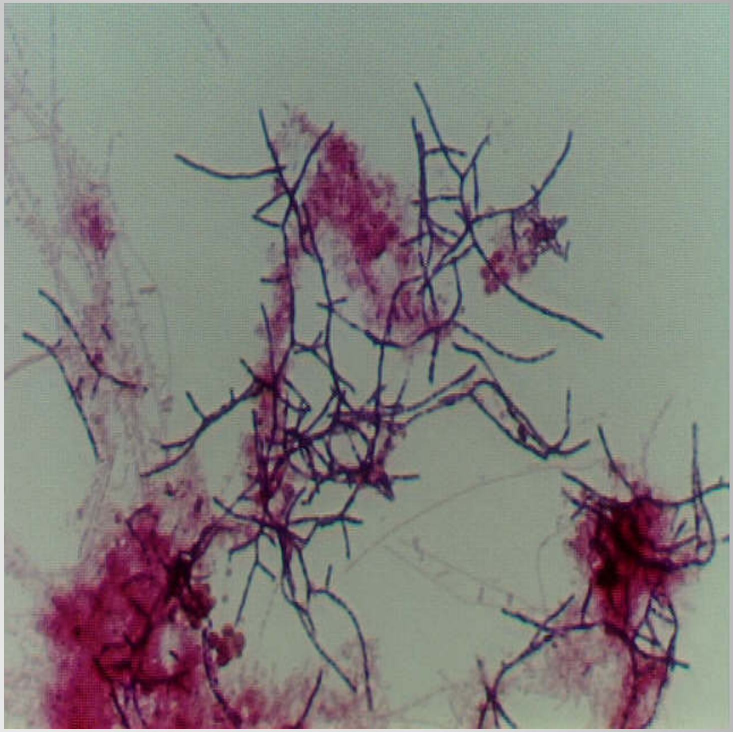
| Biochemical Reaction | ORP, mV |
|---|---|
| Nitrification | +100 to +350 |
| cBOD degradation with free molecular oxygen | +50 to +250 |
| Biological phosphorus removal | +25 to +250 |
| Denitrification | +50 to -50 |
| Sulfide ($H_2S$) formation | -50 to -250 |
| Biological phosphorus release | -100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

# Sludge Condition

## Microscopic Examination

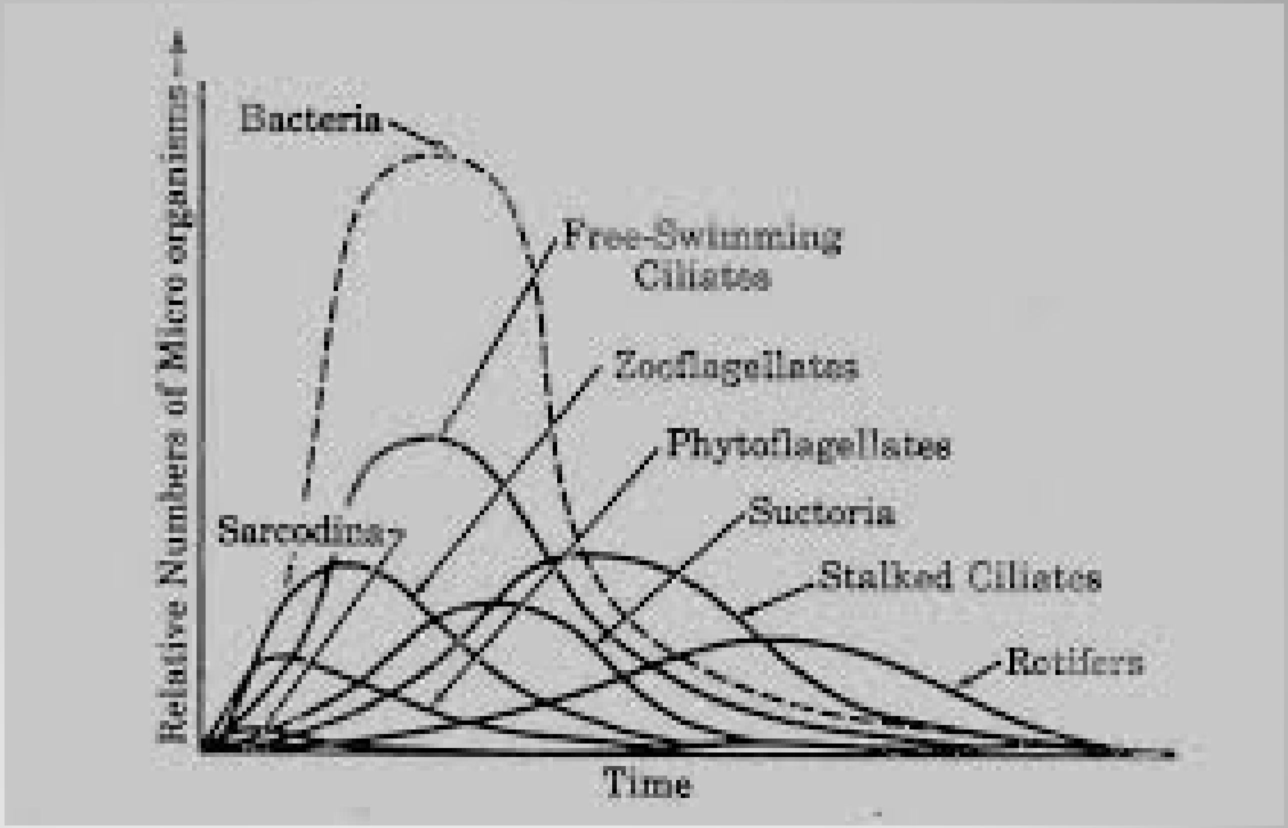
- In house or professional service.
- Staining helps identify bacteria.





# Sludge Condition

Microscopic Examination




# Sludge Condition

# Data Collection and Record Keeping

## Data Collection

- Do not pencil whip data
- Establish a through schedule with checklist.
- Some data is best collected at same time daily other is better at different times
- Use flow proportional data as opposed to time based.
- Is the data collected useful or just always been done that way.
- Have a procedure that alert to bad numbers
- Ensure chain of custody filled out for compliance samples
- Make extra observations when units are down for repairs. E.g. position of probes, aerator position, dead zones, condition of pipes and valves.
- Calibration record of meters and probes.
- Decide if a spreadsheet or data base to be used
- If practical, purchase a program.

# Data and Records

## Records

- Helps in financial decisions
- Compare data to model
- Can identify a reoccurring problem.
- Provides data for other projects
- Gives state agencies proof as what is being done to control the process. This is helpful in case a violation has occurred.
- Keep records at least ten years
- Know when major changes made to plant

# Data and Records