EPA Webinar Series

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Optimize Your Wastewater Plant Operations; Save Energy – Save Money; Reduce Nutrient Discharge

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OUTLINE

- Glossary of Terms
- What We Will Learn Today
- Activated Sludge Process Goals
    - CBOD Removal
    - Nitrification
    - TSS Removal
- Activated Sludge Data Requirements
    - Regulatory Data vs. Process Control Data
- Common Operator Errors
- Reduce Aeration & Save Energy
- Reduce Aeration & Reduce Nutrient Discharge

Glossary of Terms

1. **Biochemical Oxygen Demand (BOD)** – measure of quantity of oxygen required by microbes in the oxidation of organic matter (and ammonia nitrogen) under aerobic conditions; **CBOD** – oxidation of organic matter; **NBOD** – oxidation of ammonia-N.

2. **Suspended Solids (TSS)** – solids in suspension larger than about 1.2 microns in size that can be removed by laboratory filtration techniques.

Glossary of Terms

3. **Biomass** – living biological matter.

4. **Activated Sludge Process** – a biological wastewater treatment process in which a mixture of the wastewater and activated sludge (biomass) is aerated in a reactor basin or aeration tank. Biomass is settled in final clarifier with most biomass returned to the aeration tanks, while some biomass is wasted from the process.

Glossary of Terms

5. **Return Activated Sludge (RAS)** – settled activated sludge that is returned to mix with the raw or primary settled wastewater.

6. **Waste Activated Sludge (WAS)** – the quantity of microbial solids that has to be wasted from the system at the rate it is produced; same as *excess biomass*.

Glossary of Terms

7. **Sludge Age** – the average time in days a microbial cell remains in an activated sludge system; same as *mean cell residence time* (**MCRT**) and *solids retention time* (**SRT**).

8. **Mixed Liquor** – a mixture of wastewater and activated sludge undergoing aeration in a reactor basin or aeration tank in the activated sludge process.

Glossary of Terms

9. **MLSS (mixed liquor suspended solids)** – the suspended solids concentration in the mixed liquor

10. **Settleability** – how well the biomass settles, compacts, and clears in the final clarifier.

11. **Nitrification** – biological conversion of ammonia-N to nitrite-N to nitrate-N by nitrifying bacteria.

Glossary of Terms

12. **Denitrification** – biological conversion of nitrate-N to nitrogen gas under *anoxic conditions*.

13. **Anoxic Condition** – condition when the mixed liquor has no *oxygen* but has *nitrate-N* available to the biomass.

14. **Anaerobic Condition** - condition when the mixed liquor has no *oxygen* and no *nitrate-N* available to the biomass.

Glossary of Terms

15. **Facultative Heterotrophs** – bacteria that use organic matter as their carbon source and can thrive in the aerobic, anoxic, or anaerobic mode.

16. **Endogenous Respiration** – the continuous process whereby bacteria oxidize their cell mass to produce energy.

What will we learn today?

1. To identify and understand the primary activated sludge process goals

2. To identify and understand the primary data requirements needed to operate the activated sludge process efficiently

What will we learn today?

3. To recognize common operator errors and how to eliminate them

4. To reduce aeration to achieve energy and money savings

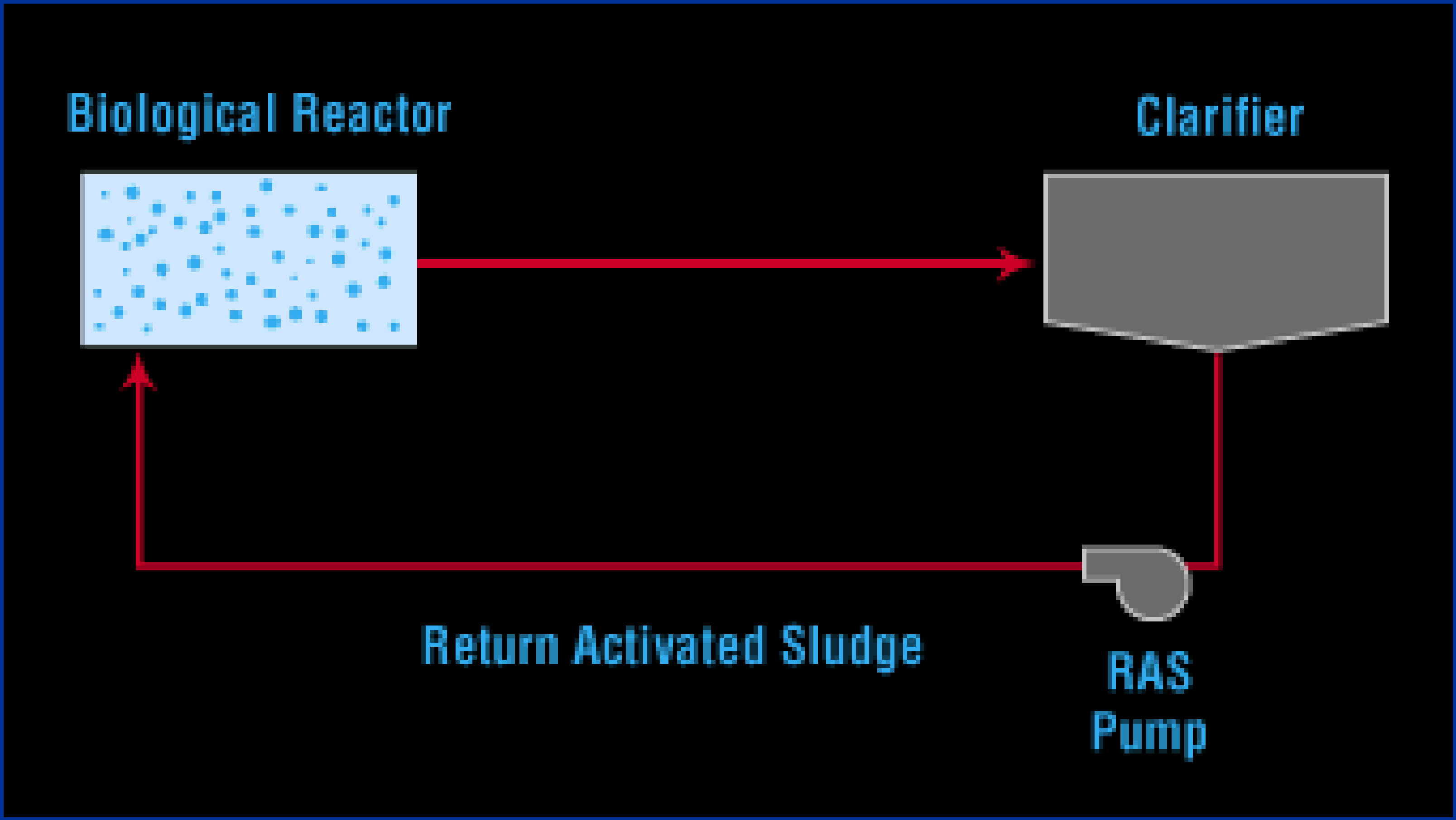
What will we learn today?

5. To reduce aeration to decrease nutrient loadings discharged to receiving waters

6. To understand the activated sludge process better

Polling Question #1

Learning Point #1: Activated Sludge Process Goals



Return activated sludge (RAS) is recycled back to the biological reactor.

Activated Sludge Process Goals

- CBOD removal
- Nitrification (where required)
- TSS removal
- Maintaining neutral pH

Additional Process Goals:

- Minimizing the quantity of solids produced
- Optimizing the energy used
- Denitrification
- Phosphorus removal

Successful activated sludge process performance is judged by effluent quality.

We want to achieve excellent effluent quality while achieving our process goals, minimizing energy use, and using plant equipment efficiently.

Typical $CBOD_5$ Test Setup

Conventional activated sludge processes are primarily designed to remove CBOD and TSS from wastewater.

Organic Load entering activated sludge is channeled into two directions

Growth Reaction

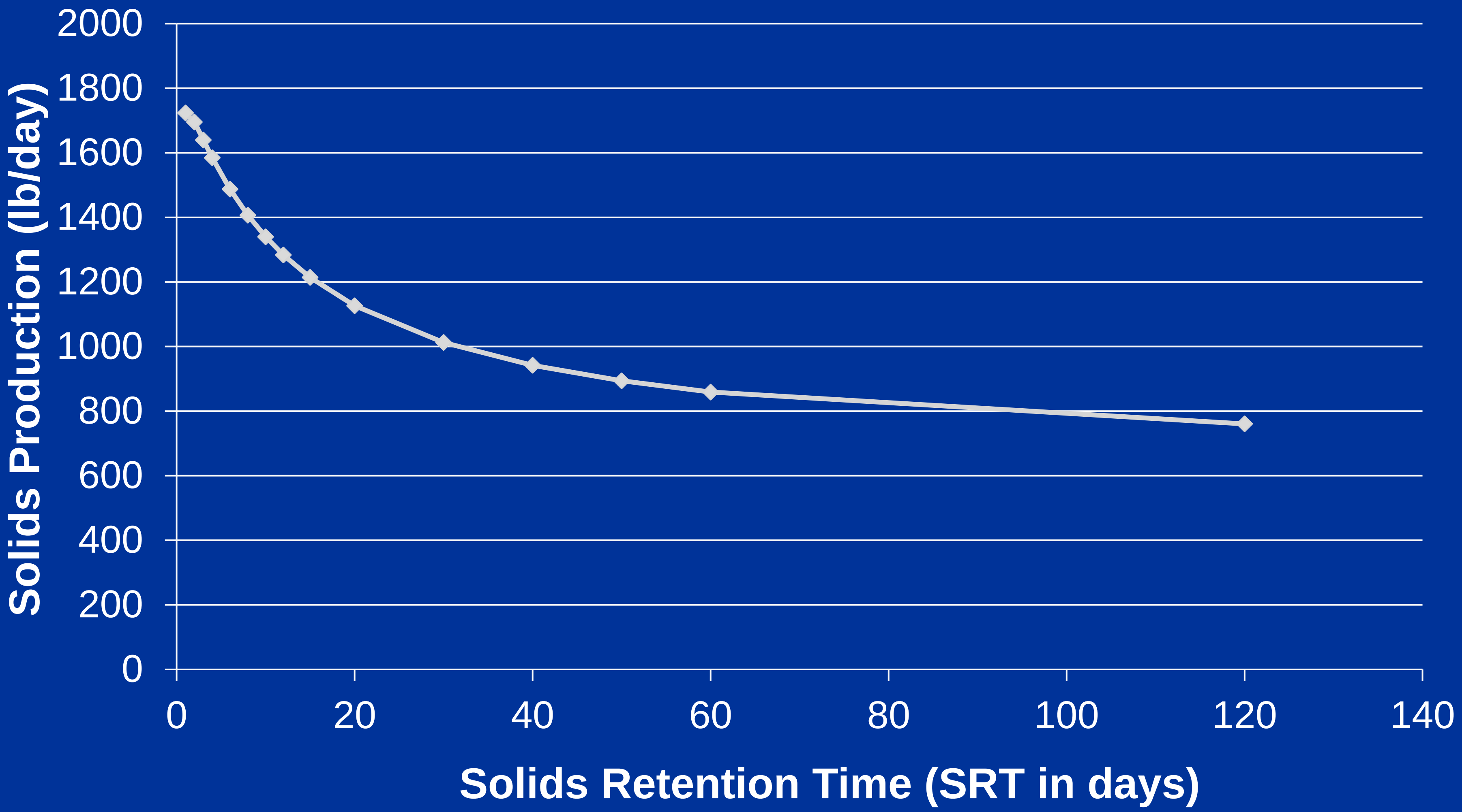
Energy Reaction

Growth Reaction

Organics + Nutrients $\longrightarrow$ Biomass

New cells are produced by the growth reaction (biomass is produced as a result of consumption of organic matter).

Sludge Production vs SRT for Activated Sludge

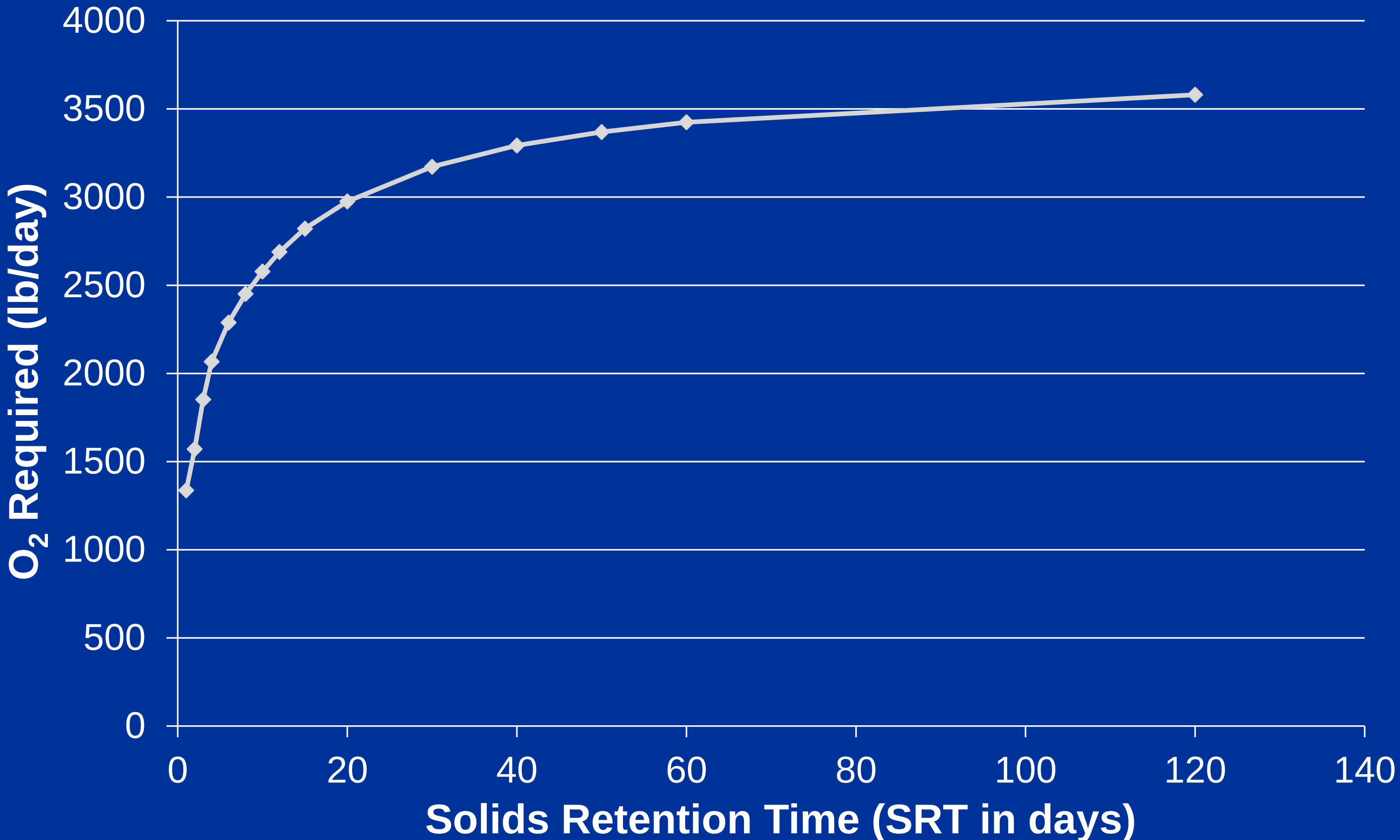


Energy Reaction

$$\text{Organics} + O_2 \longrightarrow CO_2 + H_2O + \text{energy}$$

Oxidation of organic matter in wastewater is accomplished biologically using a variety of microorganisms, primarily bacteria; the oxidation reaction produces energy for the bacteria.

Oxygen Required (CBOD + NBOD) vs SRT for Activated Sludge



Nitrification Reactions

$$NH_4^+ + 1.5\ O_2 \longrightarrow NO_2^- + 2H^+ + H_2O + \text{Energy}$$

Ammonia | *Oxygen* | *Nitrosomonas* | *Nitrite* | *Acid* | *Water*

$$NO_2^- + 0.5\ O_2 \longrightarrow NO_3^- + \text{Energy}$$

Nitrite | *Oxygen* | *Nitrobacter* | *Nitrate*

During nitrification, alkalinity is needed to buffer pH.

Polling Question #2

Learning Point #2: Data Requirements for Activated Sludge

Regulatory Data

- BOD
- TSS
- pH
- Chlorine Residual
- NH_3
- Oil and Grease
- Fecal Coliform or *E. coli*

Typical Activated Sludge Process Measurements

	Influent	*Effluent*
BOD_5	100 - 300 mg/L	5 - 20 mg/L
TSS	100 - 300 mg/L	5 - 30 mg/L
Ammonia	10 - 30 mg/L	< 2 mg/L
pH	6.5 - 8.5	≈ 7.0

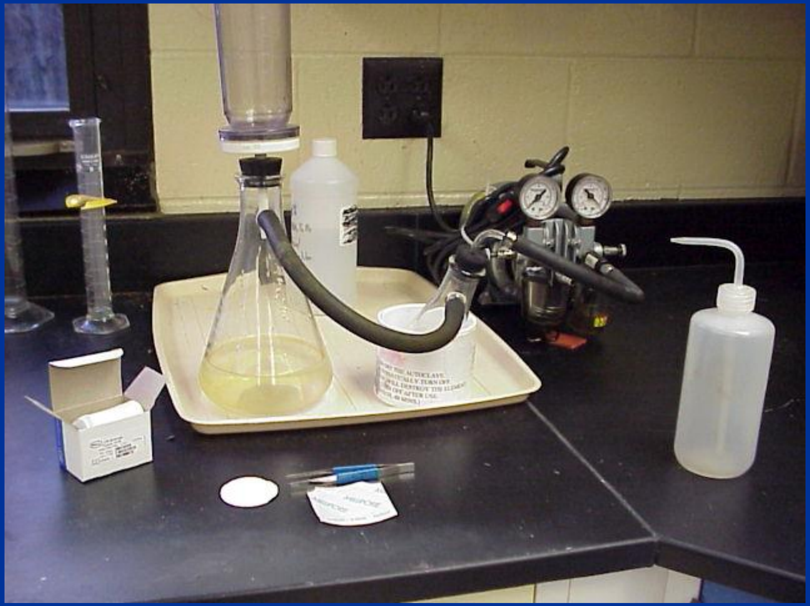
Process Control Data

- Settleability
- Dissolved Oxygen (DO)
- Temperature
- Depth of Blanket (DOB)
- Blanket Thickness

More Process Control Data

- Flow rates
- pH
- Microscopic analysis
- Solids concentrations

Solids Concentration



- MLSS
- MLVSS
- Return (RAS)
- Waste (WAS)
- Recycle
- Effluent TSS

Flow Rates

Influent Flow (Q)

Return Sludge Flow (RSF)

Waste Sludge Flow (WSF)

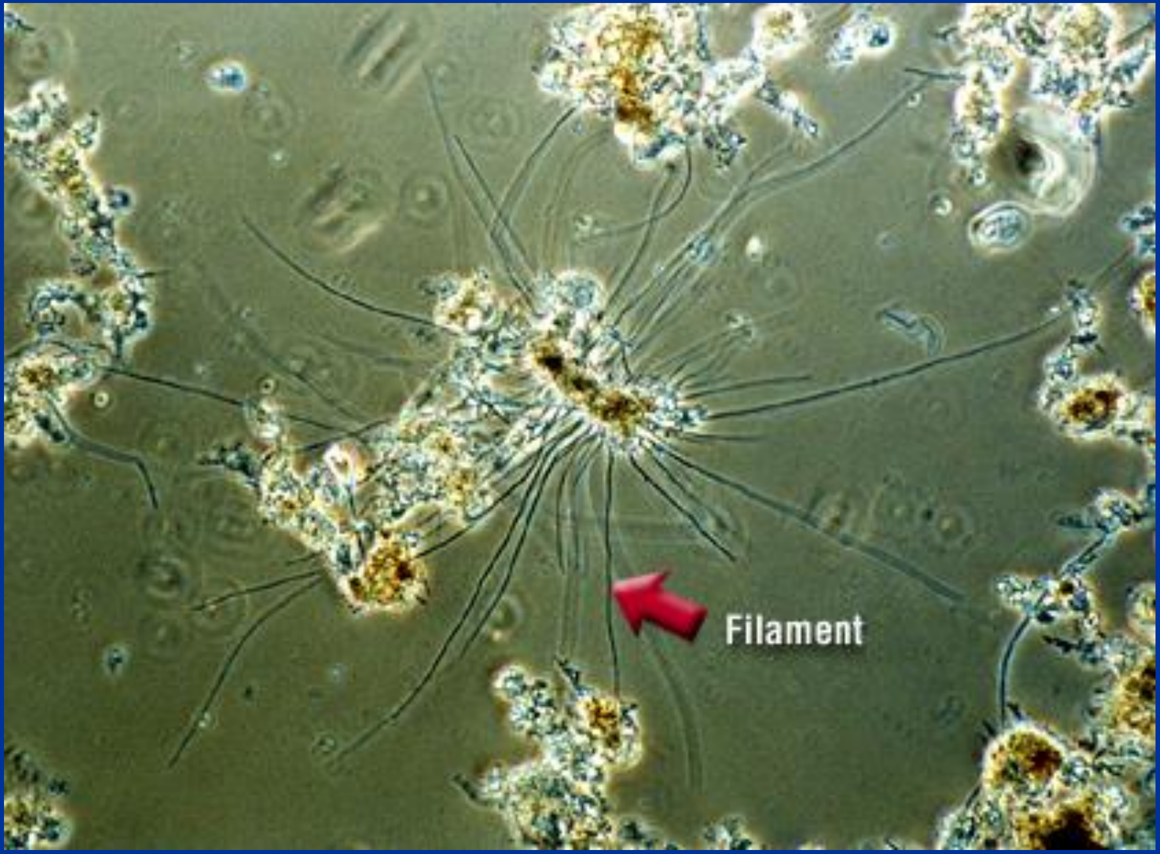
Recycle Flows

Dissolved Oxygen

- Aeration Tank Effluent
- Profiles
  - Longitudinal
  - Transverse
  - Vertical

Temperature

- Use DO meter
- Affects metabolism rate of microorganisms



Settleometer Test

- Use settleometer
- Do not use graduated cylinder
- Fresh sample
- Take sample near effluent weir of aeration basin

Sludge Judge

- How is the clarifier working?
  - Flocculating/Clearing
  - Settling
  - Compacting
- "Allow biomass to settle to a reasonable thickness and get it out!"

Clarifier Problems & Typical Causes

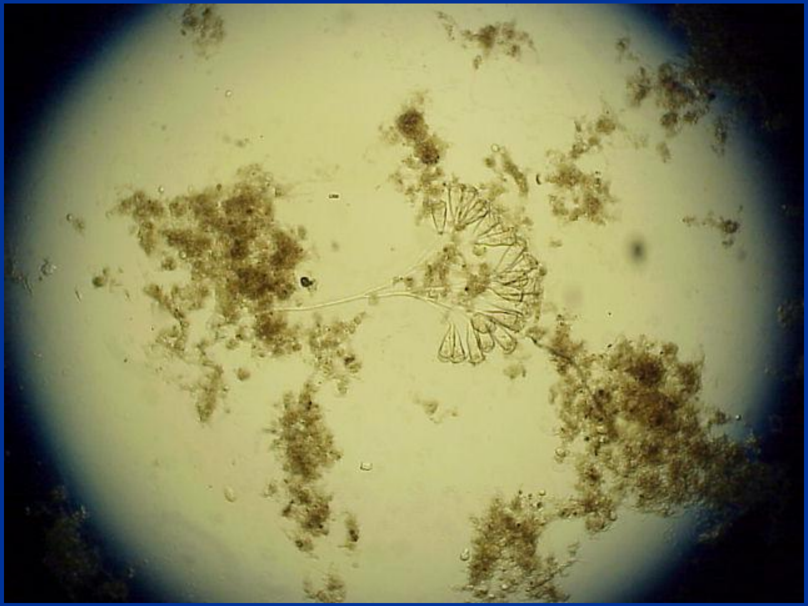
- Bulking: sludge quality
- Billowing: hydraulic overload
- Clumping: denitrification
- Ashing/Pin Floc: old sludge
- Straggler Floc: young sludge

Desired Data Ranges for Most Activated Sludge Processes

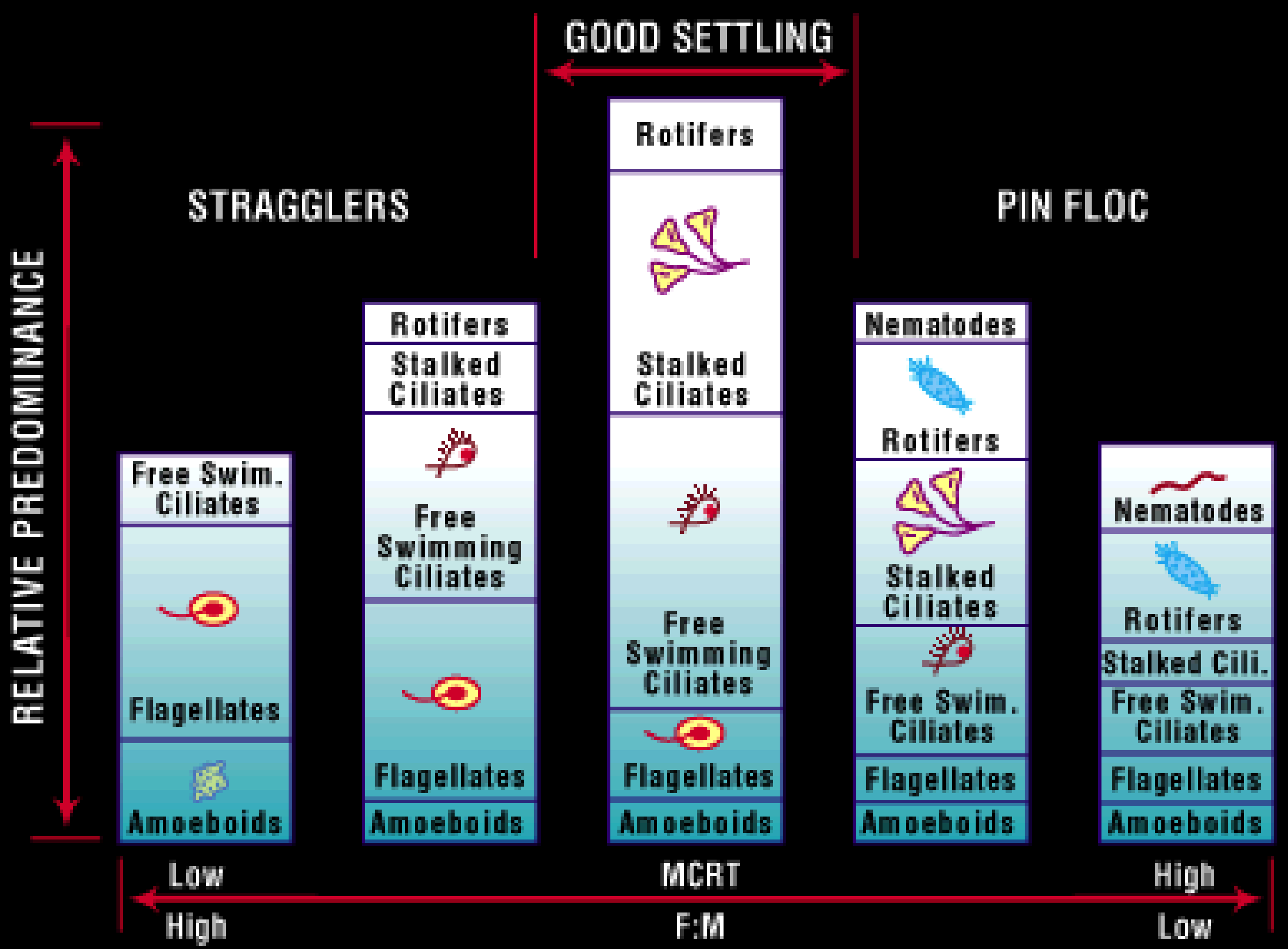
Reactor average DO:	1.0 to 2.0 mg/L
30-min settleability:	200 to 400 mL/L
Sludge Volume Index:	50 to 150 mL/gram
MLSS concentration:	1,500 to 3,500 mg/L
Clarifier blanket thickness:	10% to 25% of depth
RAS rate:	25% to 60%
pH of mixed liquor:	6.5 to 8.0
SRT for conv. act. sludge:	5 to 15 days
SRT for ext. aer. act. sldg:	15 to 35 days

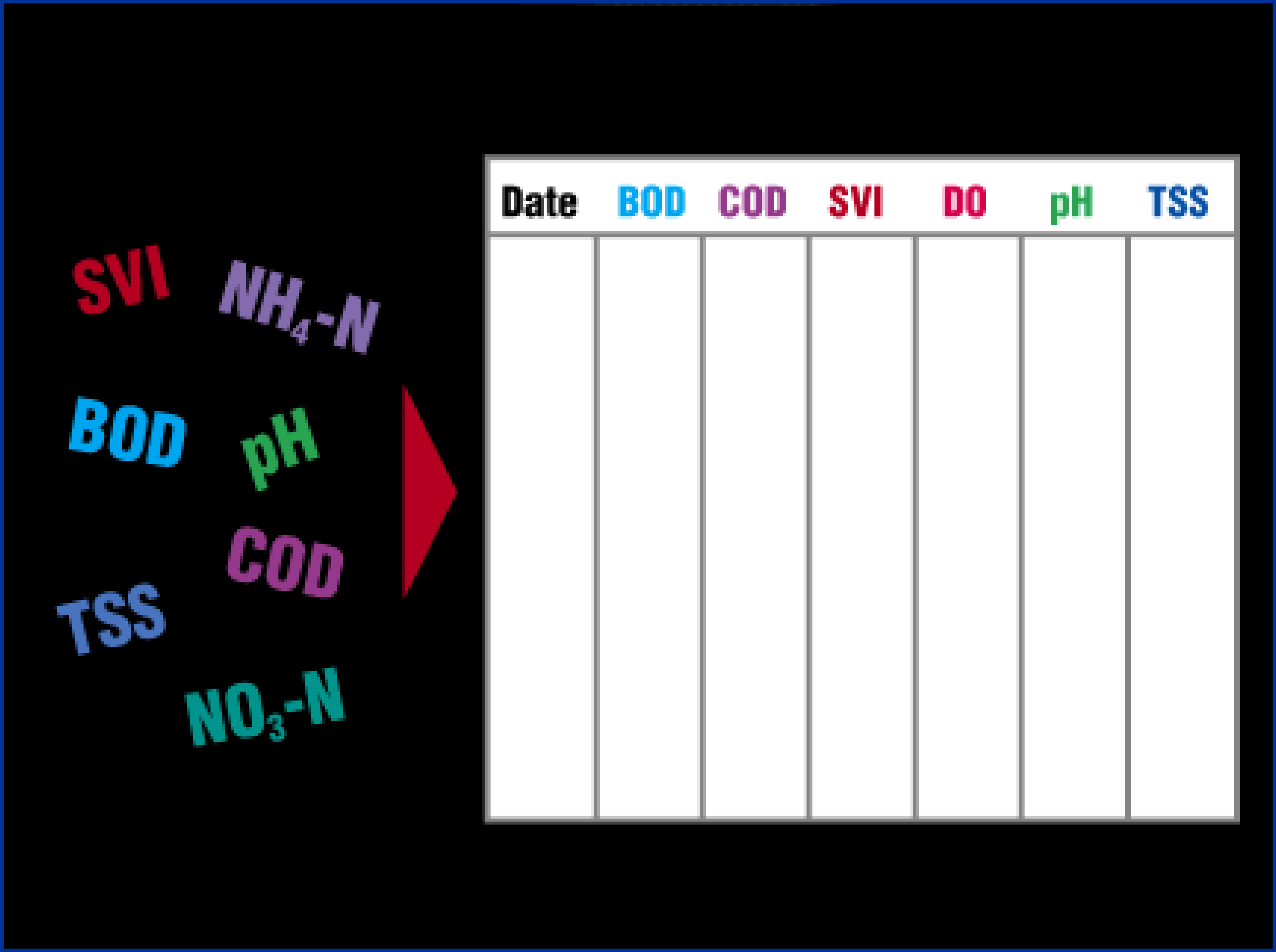
Microscopic Exam

- General
- Floc analysis
- Protozoa counts
- Metazoan counts
- Filament abundance and location
- Identification of filamentous organisms

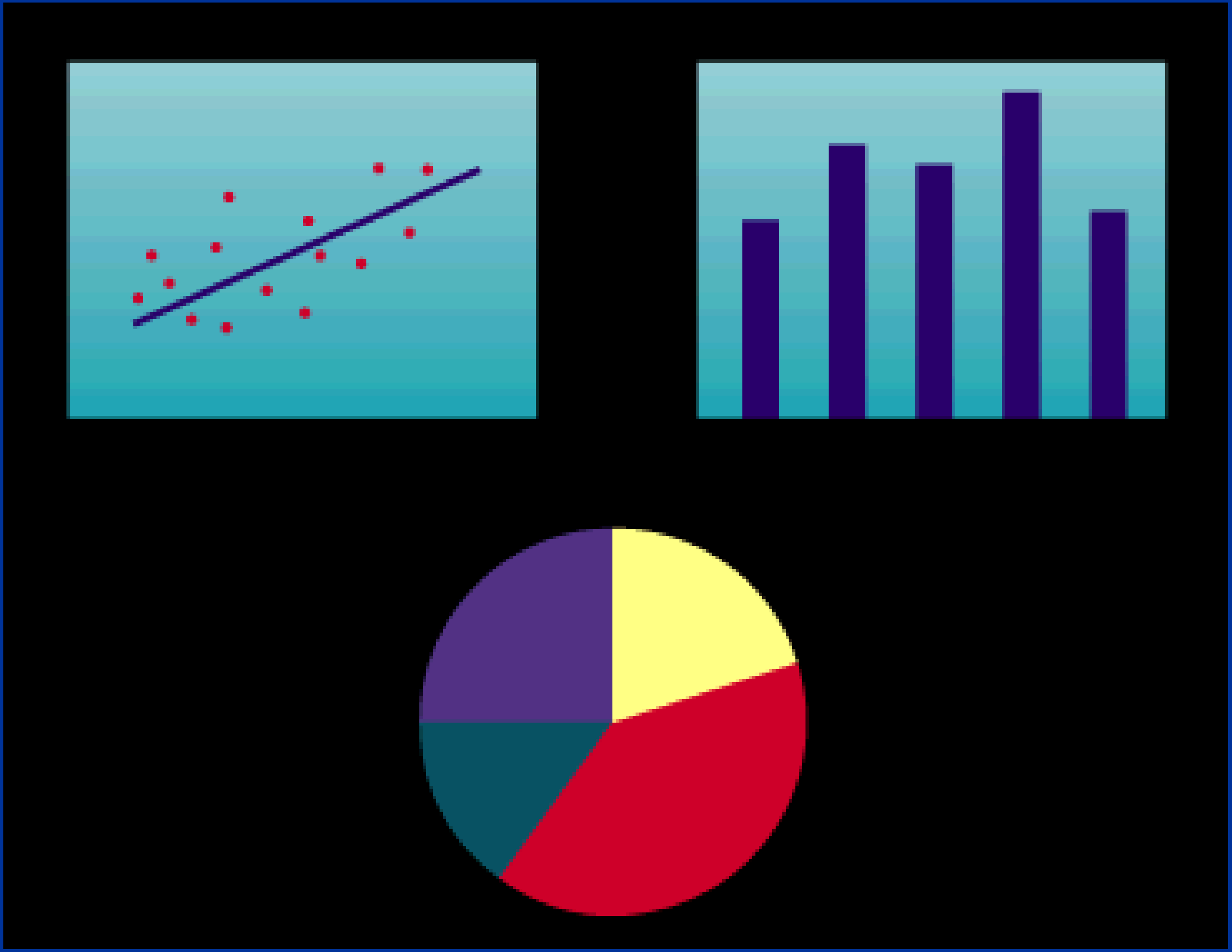


Relative predominance of microorganisms versus F:M and MCRT





Data must be organized for effective use.
Put operating data in an Excel spreadsheet!



Standard software can produce useful analysis and representations of data.

Observation of the appearance and characteristics of the reactor contents should be recorded with the analytical data in your database.

Observations and data are important to process control.

Polling Question #3

Learning Point #3: Common Operator Errors

- Keeping MLSS too high (SRT too high)
- Keeping DO too high
- Keeping RAS flow rate too high
- Not paying close attention to variations in influent BOD and TSS loadings
- Not analyzing operating data correctly
- Keeping too many reactors in service

Problems with High MLSS

- Poor settleability
- Old, glutted sludge
- Filamentous bulking (due to old sludge)
- Possibly poor effluent quality (BOD & TSS)
- Potentially high sludge blanket thickness that may lead to solids washout during and after major storm events

Problems with High DO

- Over-oxidation of the biomass
- Wasting energy
- Causing high electric bills for the plant
- Creating too much turbulence in the reactor (shearing the floc)

Automated DO Control

- Tight DO control can save a WWTP between **10% and 30% of total energy costs.**
- Energy savings will be site specific and are highly dependent on the control system in place prior to the upgrade to automated process control.
- If the plant cannot afford an automated DO control system, install timers on aerators.

Problems with High RAS Flow Rate

- Sludge blanket thickness in final clarifiers is too low.
- Sludge in final clarifiers does not have enough time to compact adequately.
- RAS TSS concentration is low.
- Low RAS TSS concentration may make sludge processing operations more difficult.
- Additional power costs for high RAS pumping rate

Problems with Overlooking Influent Load Variations

- Inefficient use of aeration equipment
  - Daytime organic load is 130% of average
  - Nighttime organic load is 72% of average

- Washout of reactor biomass to clarifiers during periods of high infiltration/inflow (I/I)

- Washout of biomass to effluent due to high flow rates to final clarifiers and high sludge blankets

Use Aeration System Efficiently in Response to Influent BOD/TKN Load Variations

- A WWTP may save considerable energy by quickly adjusting to variable conditions within the basin.
- Oxygen required for biotreatment is proportional to organic and TKN loading in the influent wastewater.
- Oxygen demand for aeration drops in the middle of the night and peaks in the morning and evening.

Problems with Not Analyzing Process Data Correctly

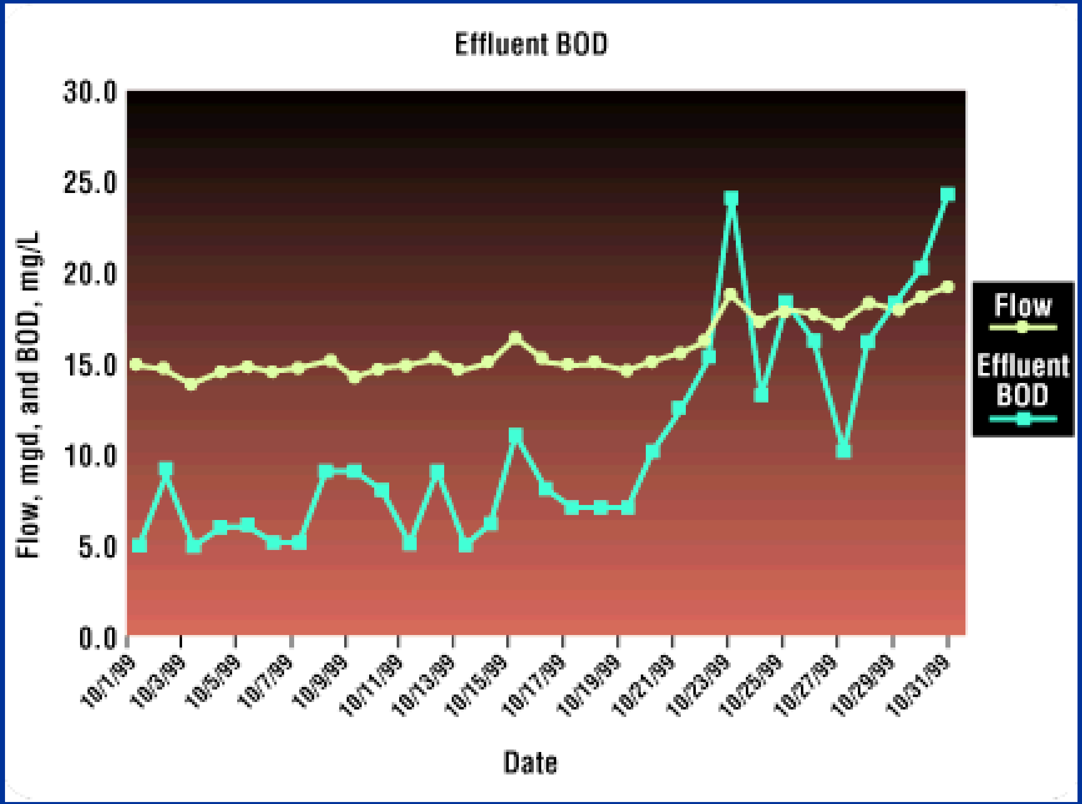
- Failure to carefully review process data may lead to bad process decisions
- Sludge settleability problems may occur
- Effluent quality may deteriorate
- Operating costs may increase
- NPDES permit violations may occur

Know Your Plant Operations

- Know your influent BOD, TSS, and TKN loadings
- Determine the MLSS concentration that optimizes process performance
- Know your basin capacities
- Know your plant flow patterns

Know Your Plant Operations

- Know your process control tools
- Know which process control tests to perform and how to interpret test results



Learning Point #4: Reduce Aeration & Save Energy

- If your reactor DO concentration > 2.0 mg/L, you are likely wasting energy.
- For example, operating at DO = 4 mg/L instead of at DO = 2 mg/L reduces the oxygen transfer rate of the aerators ~ 35%.

Learning Point #4: Reduce Aeration & Save Energy
(continued)

- Typical energy use for conventional activated sludge is 1,800 kWh per mil gal.
- Typical energy use for conventional activated sludge is 1.0 kWh per lb BOD_5 removed.

Reduce Aeration & Save Energy

- Typical energy use for oxidation ditch activated sludge is 2,700 kWh per mil gal.
- Typical energy use for oxidation ditch activated sludge is 1.6 kWh per lb BOD_5 removed.

Reduce Aeration & Save Energy

(continued)

- In an oxidation ditch, turn aerators off 4 to 6 hours per day … will achieve energy savings of ~ 12% for your plant.

Learning Point #5: Reduce Aeration & Reduce Nutrient Discharge

- In an oxidation ditch that is operating in the aerobic mode 24 hours/day, expected effluent nitrate-N is 12 to 25 mg/L.
- In this oxidation ditch, turn aerators off 4 to 6 hours per day … will achieve nitrogen reduction of ~ 60% for your plant!!!
- For a 2.0 mgd flow rate, this will reduce N loading to the receiving stream about 36 tons/year!!!

Before and After Effluent Quality

	Before	After
BOD_5	5 - 25 mg/L	5 - 15 mg/L
TSS	10 - 25 mg/L	10 - 20 mg/L
Ammonia-N	1 - 5 mg/L	1 - 2 mg/L
NO_x-N	13 - 20 mg/L	5 - 8 mg/L
Total N	15 - 22 mg/L	6 - 10 mg/L
*SVI	125 - 225	50 – 125

* impacts on mixed liquor at one facility

Other Benefits of Turning Aerators Off in Oxidation Ditch

- Sludge settleability may improve by eliminating filaments.
- Alkalinity will be generated … possibly eliminating the need for addition of lime or soda ash for nitrification.

That's all folks!!!