ACTIVATED SLUDGE PROCESS

Prepared by
Michigan Department of Environmental Quality
Operator Training and Certification Unit

ACTIVATED SLUDGE PROCESS

To "Treat" Wastewater

Remove (reduce) Or "Stabilize" The Material in Wastewater

SECONDARY TREATMENT

Biological Wastewater Treatment

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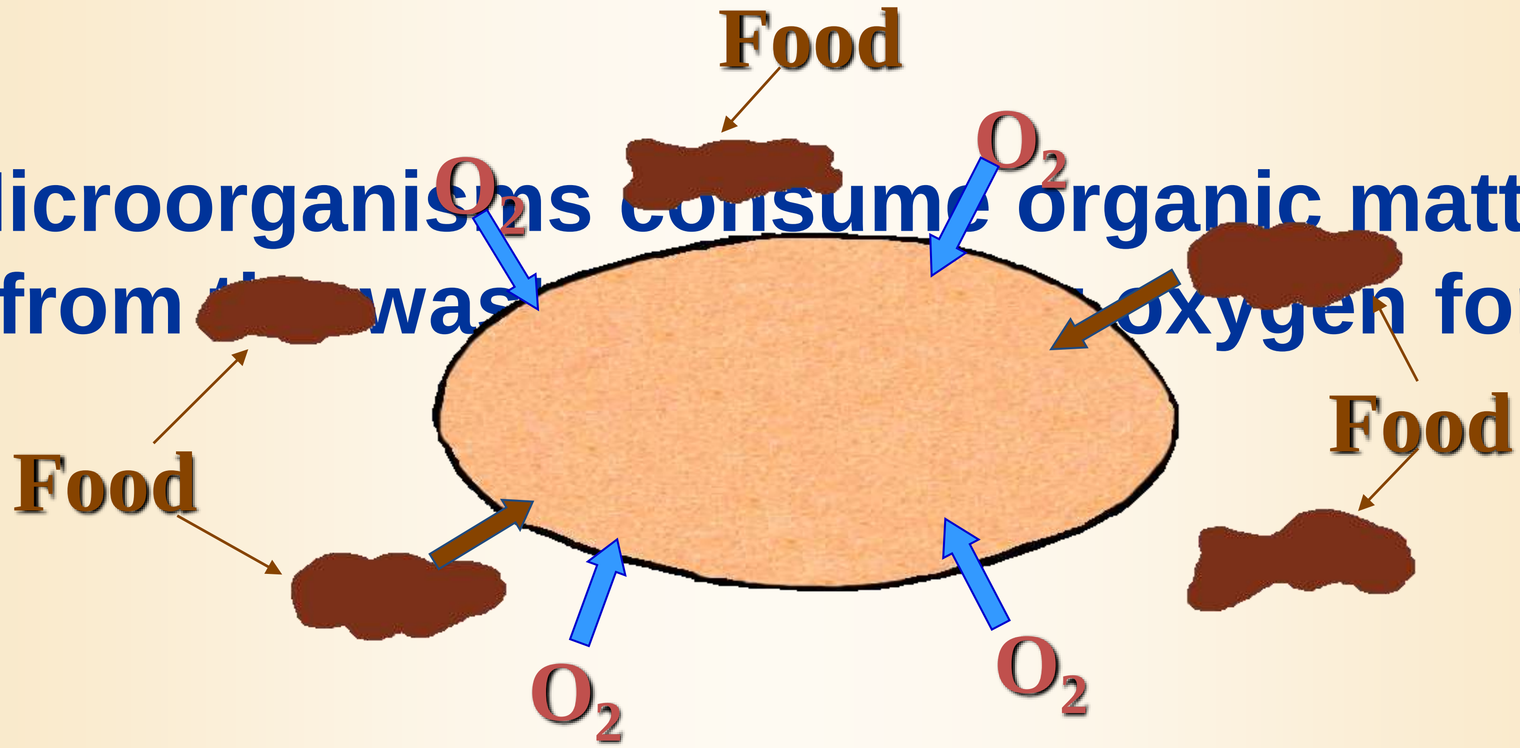
Biological Wastewater Treatment

Microorganisms consume organic matter
from [illegible] was[illegible] oxygen for



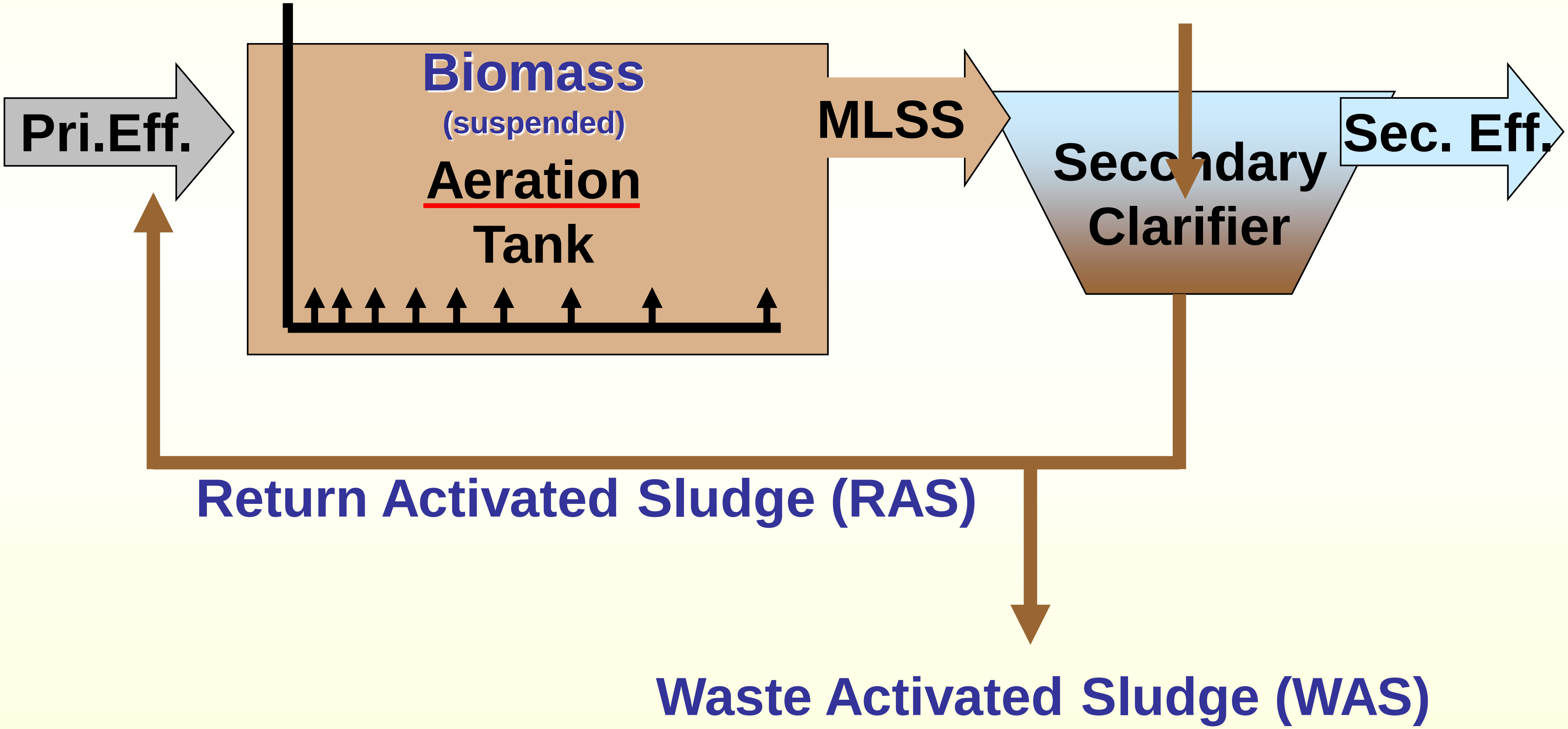
Millions of aerobic and facultative micro-organisms remove pollutants thru living and growing process

Activated Sludge

Suspended Growth,
Biological Treatment

Activated Sludge System

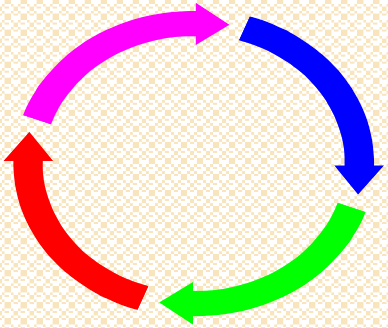
Air →Provides Oxygen and Mixing



Activated Sludge

Suspended Growth,
Biological Treatment

Need favorable conditions for growth and for separation from the water



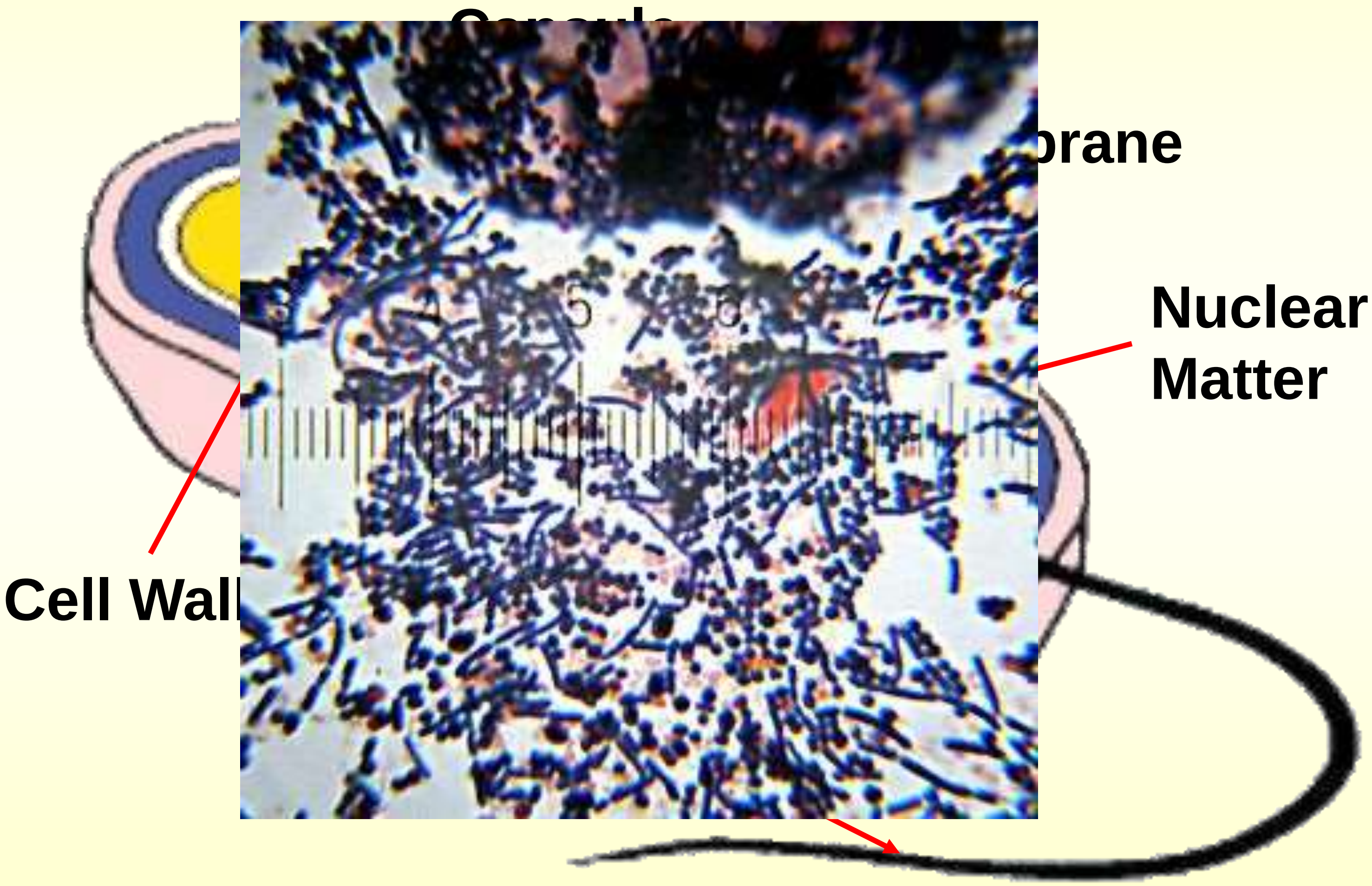
Biological solids are used over and over

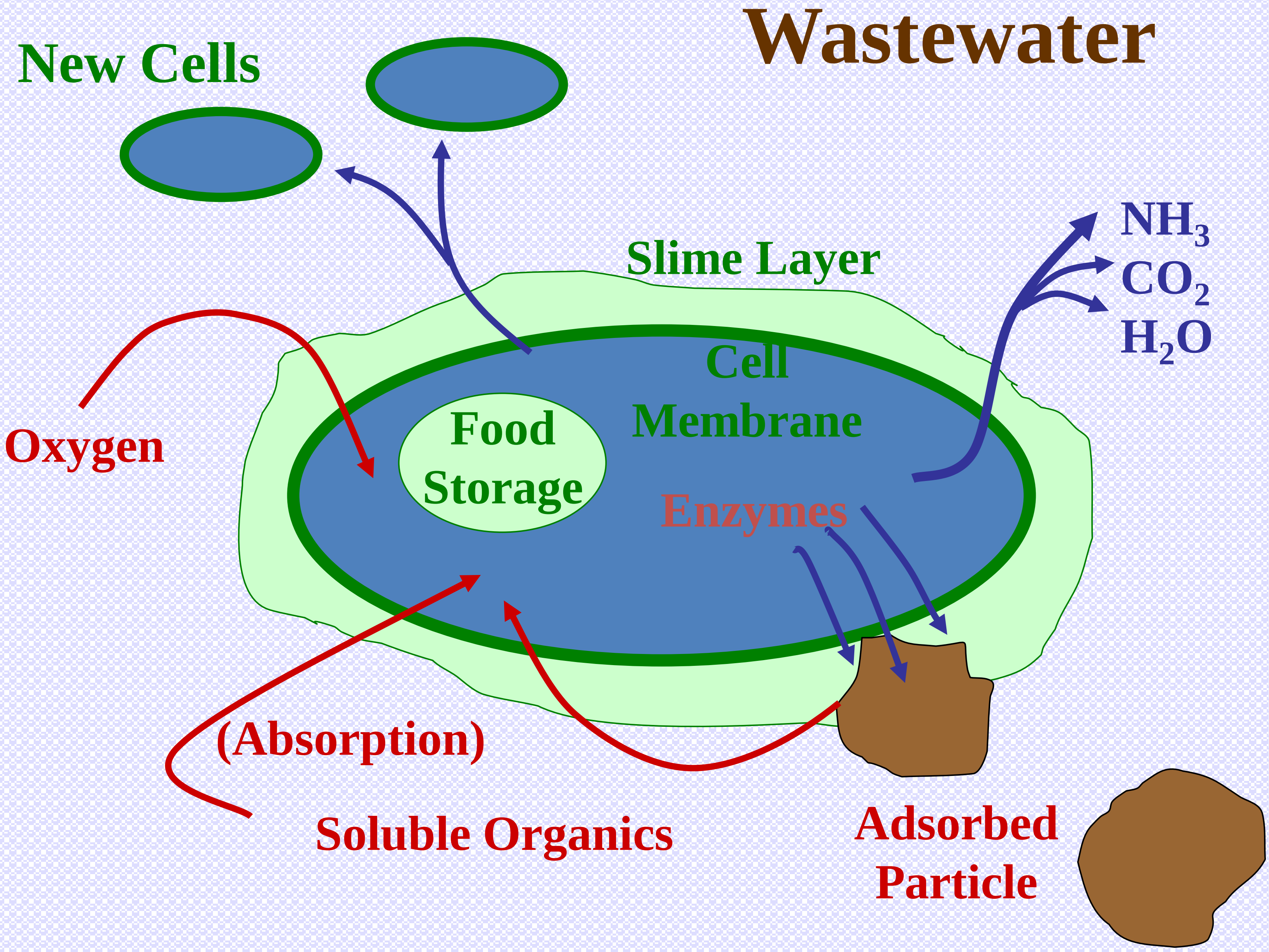
Growth rate produces about 0.7 lbs of biological solids per lb BOD removed


Primary Effluent
Return Sludge
Aeration Tank
Mixed Liquor
(MLSS)

Secondary Clarifier

PARTS OF A GENERALIZED BACTERIAL CELL OF THE BACILLUS TYPE

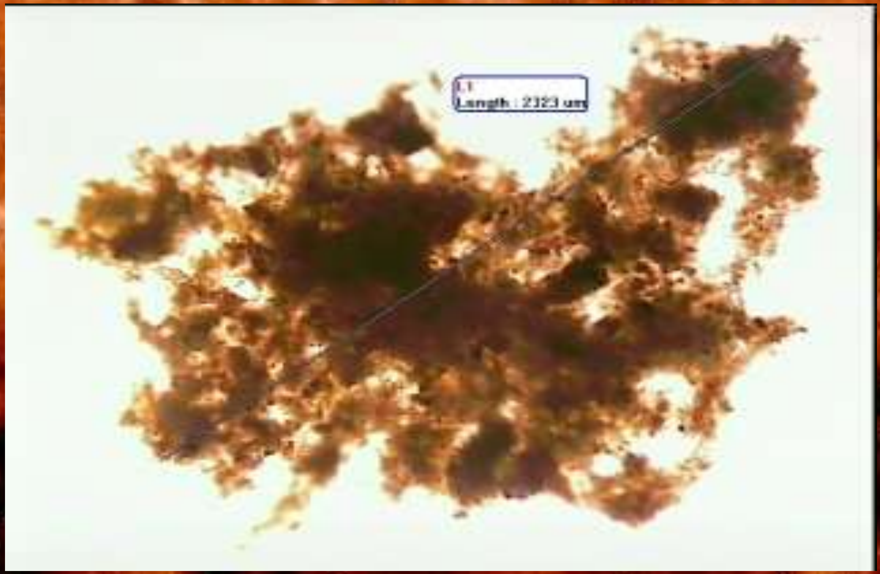



Wastewater
New Cells
Slime Layer
NH_3
CO_2
H_2O
Cell Membrane
Food Storage
Oxygen
Enzymes
(Absorption)
Soluble Organics
Adsorbed Particle

Mixed Liquor

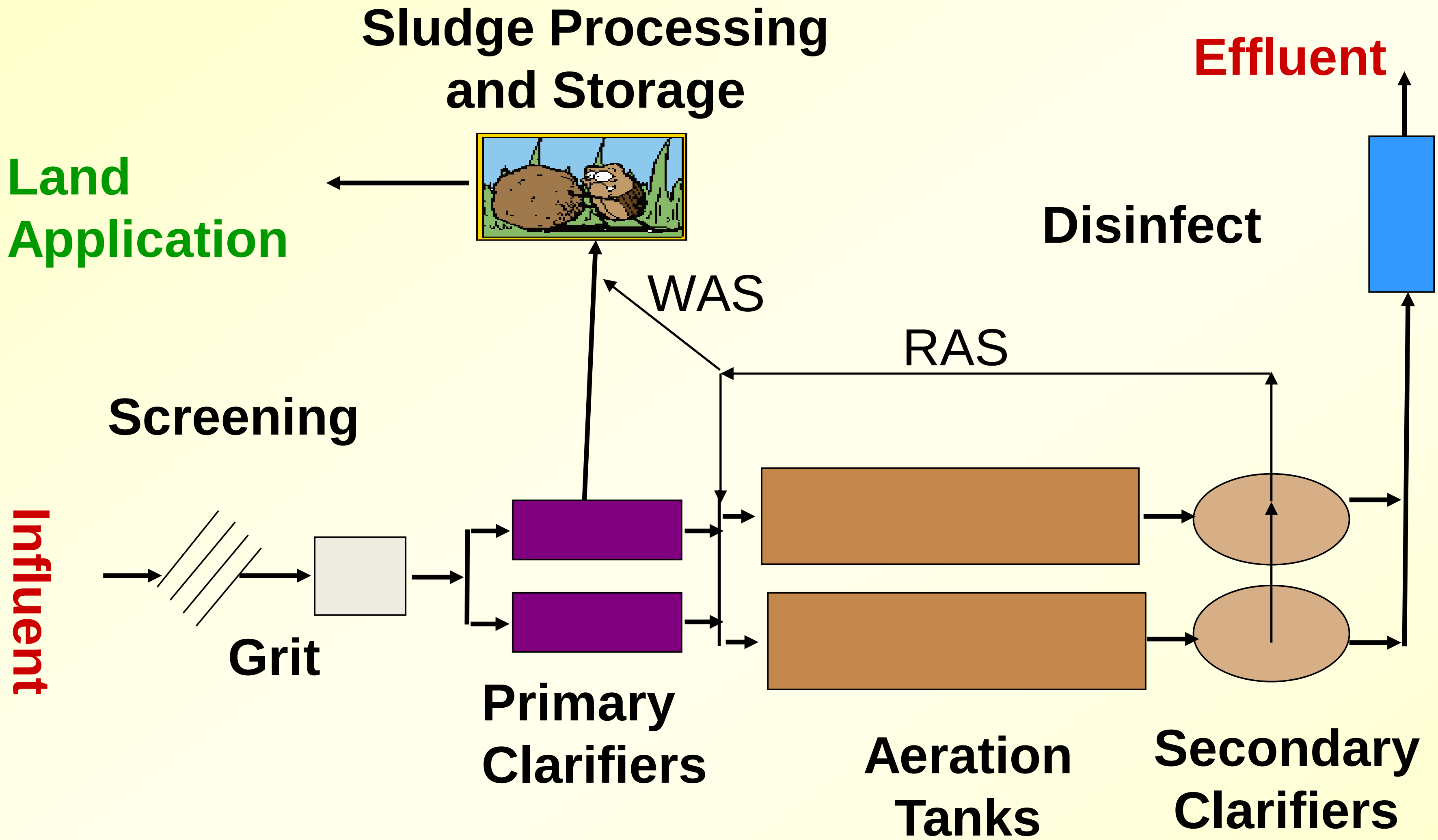
Flocculation

A process of contact and adhesion whereby the particles of a dispersion form larger-size clusters.



Aeration Tank

Secondary Clarifier



Typical Flow-Through Activated Sludge Plant

Biological Wastewater Treatment

Three Steps

1. Transfer of Food from Wastewater to Cell.

Adequate Mixing

Enough Detention Time

Biological Wastewater Treatment

2. Conversion of Food to New Cells and Byproducts.

Acclimated Biomass

Useable Food Supply

Adequate D.O.

Proper Nutrient Balance

100 : 5 : 1

C : N : P

Biological Wastewater Treatment

3. Flocculation and Solids Removal

Proper Mixing
Proper Growth Environment
Secondary Clarification

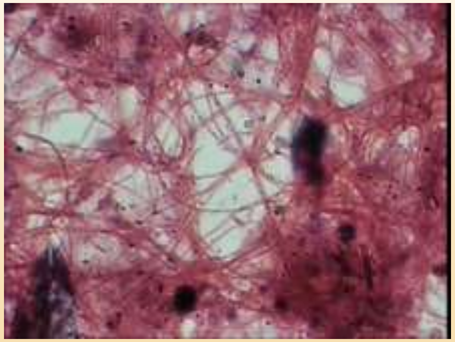
Biological Wastewater Treatment

3. Flocculation and Solids Removal

Must Have Controls

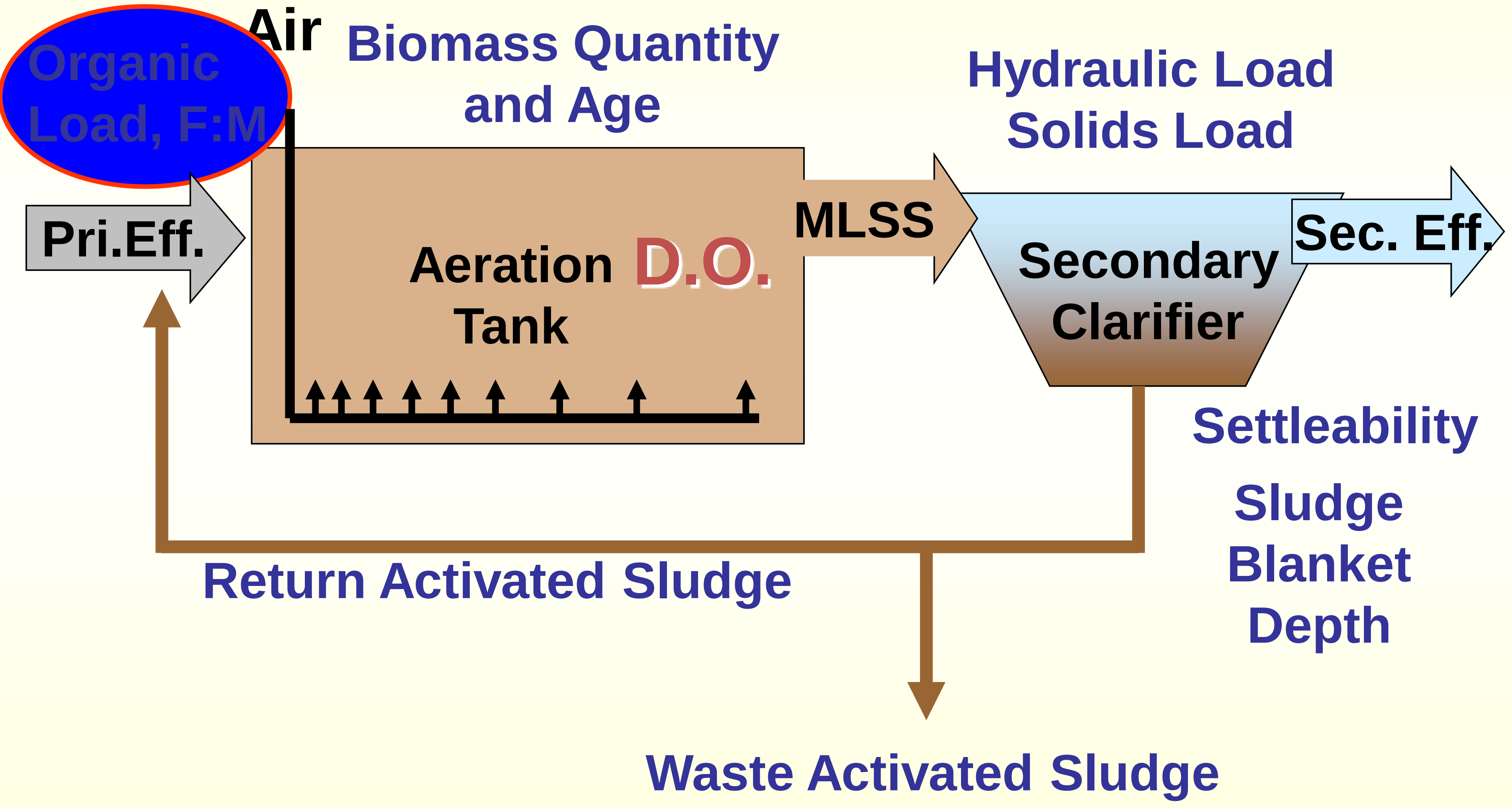
Proper Growth Environment

Filamentous Bacteria – Form Strings



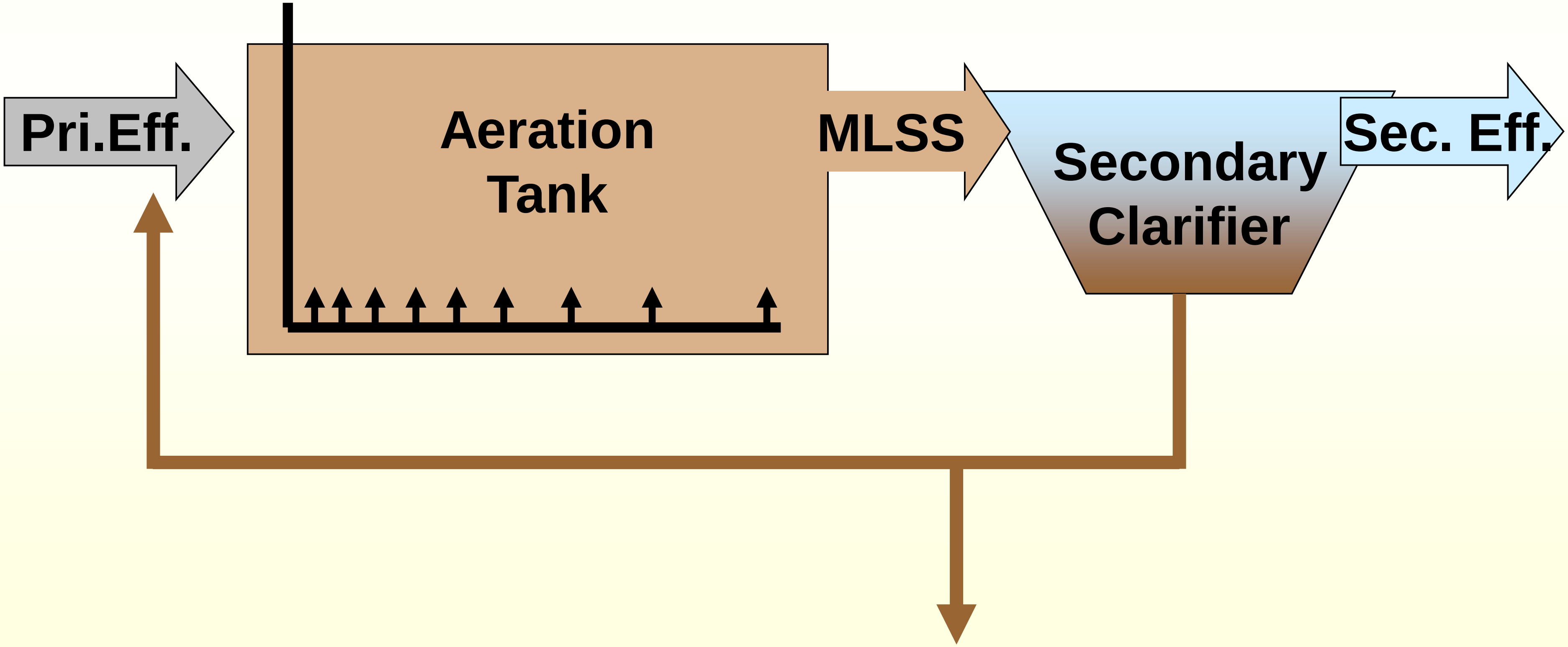
Mixed Liquor Does Not Compact - Bulking

Control Factors



Activated Sludge System

Organic Load = <u>Pounds</u> of Organics (<u>BOD</u>)
Coming into Aeration Tank



CALCULATION OF POUNDS

Pounds =

Conc. x Flow (or Volume) x 8.34 Lbs/gallon

Concentration Of STUFF In the Water	X	Quantity Of Water The STUFF Is In	X	Weight Of The Water

CALCULATION OF POUNDS

Pounds =

Conc. x Flow (or Volume) x 8.34 Lbs/gallon

Flow (Volume) and Concentration must be expressed in specific units.

Concentration must be expressed as parts per million parts.

Concentration is usually reported as milligrams per liter.

This unit is equivalent to ppm.

$$\frac{1\text{ mg}}{\text{liter}} = \frac{1\text{ mg}}{1000\text{ grams}} = \frac{1\text{ mg}}{1{,}000{,}000\text{ mg}} = \text{ppm}$$

$$\text{ppm} = \frac{\text{Parts}}{\text{Mil Parts}} = \frac{\text{Lbs.}}{\text{Mil Lbs.}}$$

Flow or Volume must be expressed as millions of gallons:

$$\frac{\text{gallons}}{1{,}000{,}000 \text{ gal/MG}} = \text{MG}$$

i.e.) A tank contains 1,125,000 gallons of water. How many million gallons are there?

$$\frac{1{,}125{,}000 \text{ gal}}{1{,}000{,}000 \text{ gal/MG}} = 1.125 \text{ MG}$$

When **Volume** is expressed as **MG** and **concentration** is in **ppm**, the units cancel to leave only ***Pounds***.

Lbs. =

Concentration x Volume x 8.34 Lbs/gallon

$$\frac{\cancel{\text{Lbs.}}}{\cancel{\text{M}}\ \cancel{\text{Lbs.}}} \times \cancel{\text{M}}\ \cancel{\text{gal}} \times \frac{\text{Lbs.}}{\cancel{\text{gal}}}$$

= Lbs

When Flow is expressed as MGD and concentration is in ppm, the units cancel to leave ***Pounds/Day***.

Lbs./Day =

Concentration x Flow x 8.34 Lbs/gallon

$$\frac{\cancel{\text{Lbs.}}}{\cancel{\text{M}}\ \cancel{\text{Lbs.}}} \times \frac{\cancel{\text{M}}\ \cancel{\text{gal}}}{\text{Day}} \times \frac{\text{Lbs.}}{\cancel{\text{gal}}}$$

= Lbs/Day

EXAMPLE:

How many **pounds** of suspended solids leave a facility each day if the flow rate is **150,000 gal/day** and the concentration of suspended solids is **25 mg/L**?

$$\text{Lbs/day} = \text{Conc. (mg/L)} \times \text{Flow (MGD)} \times \frac{8.34 \text{ Lbs}}{\text{gal}}$$

$$\text{Lbs/day} = 25 \text{ mg/L} \times \frac{150{,}000 \text{ gal/day}}{1{,}000{,}000 \text{ gal/MG}} \times \frac{8.34 \text{ Lbs}}{\text{gal}}$$

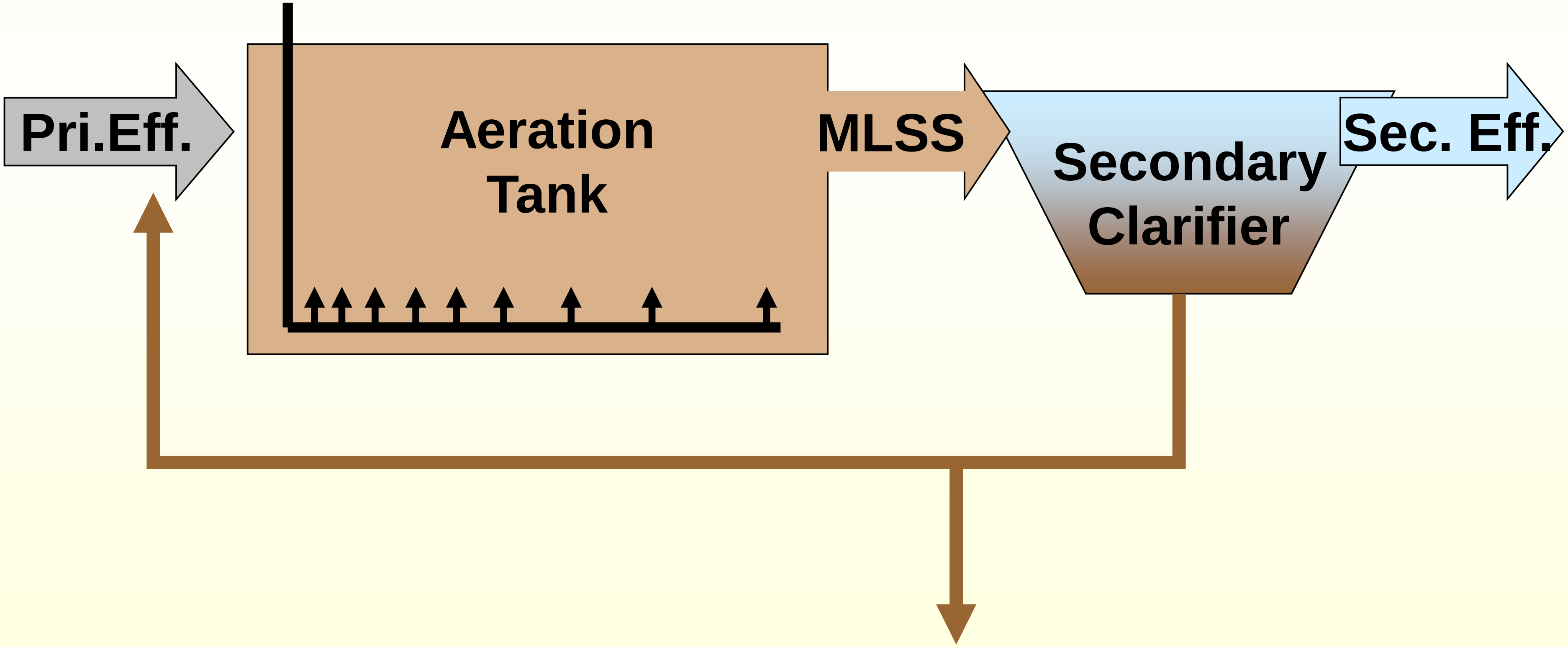
$$= 25 \times 0.15 \times 8.34$$

$$= 31 \text{ Lbs/day}$$

Activated Sludge System

Organic Load = $\frac{\text{Pounds of Organics (BOD) Coming into Aeration Tank}}{}$

Organic Load = <u>Pounds</u> of Organics (<u>BOD</u>)
Coming into Aeration Tank

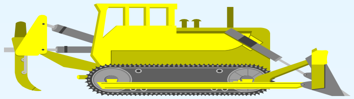


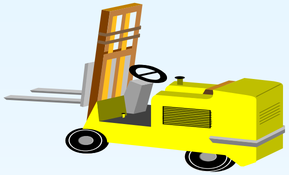
Example Problem
BOD Loading

An activated sludge plant receives 2.0 MGD from the primary clarifiers at 120 mg/L BOD. Calculate the organic loading (Lbs/D BOD) on the activated sludge process.

Work Calculation on Separate Paper
Answer Given on Next Slide

Example Problem BOD Loading





An activated sludge plant receives 2.0 MGD from the primary clarifiers at 120 mg/L BOD. Calculate the organic loading (Lbs/D BOD) on the activated sludge process.

$$\text{Lbs/day} = \text{Conc. (mg/L)} \times \text{Flow (MGD)} \times 8.34 \frac{\text{Lbs}}{\text{gal}}$$

$$\frac{\text{Lbs}}{\text{Day}} = 120 \text{ mg/L} \times 2.0 \text{ MGD} \times 8.34 \frac{\text{Lbs}}{\text{Gal}}$$

$$= 2001.6 \frac{\text{Lbs BOD}}{\text{Day}}$$

OXYGEN DEMAND

Biochemical Oxygen Demand
B.O.D.

The Quantity of Oxygen Used in the Biochemical Oxidation of Organic Material.

5 Day Test

OXYGEN DEMAND

Biochemical Oxygen Demand
B.O.D.

Best to Use a "Moving Average" to Determine the Average Impact on a Treatment System.

5 Day Test

BOD Moving Average

Calculate the 7 day moving average of pounds of BOD for 10/5 and 10/6.

Date	Pounds of BOD
9/29	2281
9/30	2777
10/1	1374
10/2	2459
10/3	960
10/4	1598
10/5	2076
10/6	1577
10/7	2351

10/5

2281
2777
1374
2459
960
1598
2076
13,525

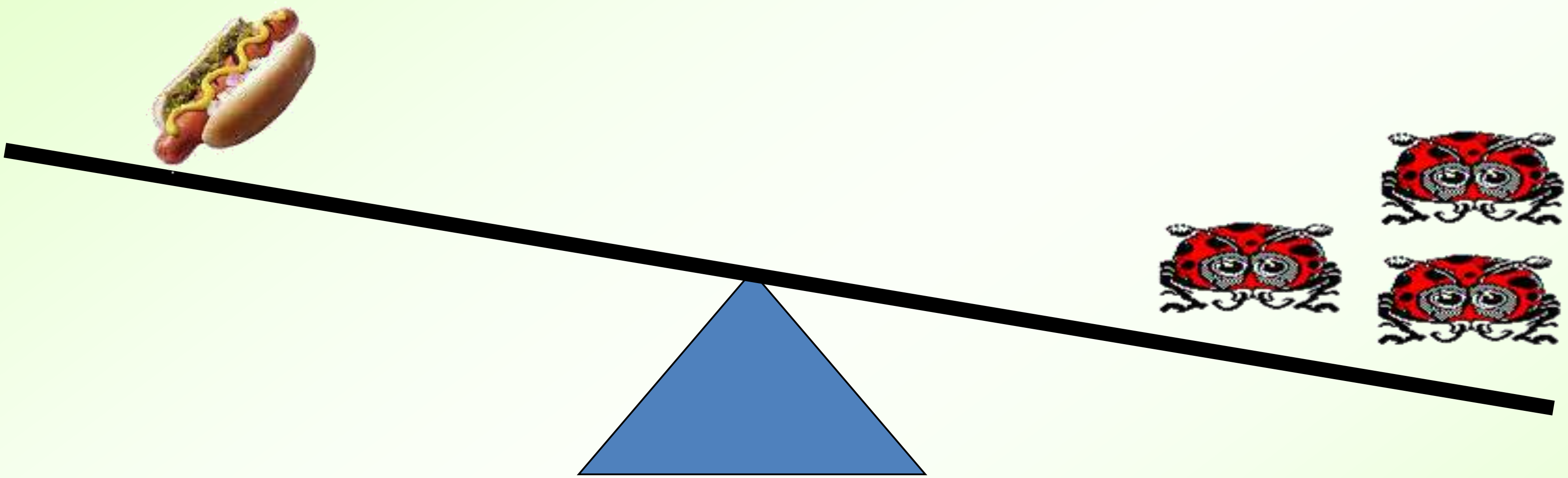
$$\frac{13,525}{7} = 1932$$

10/6

13,525
\- 2281
\+ 1577
12,821

$$\frac{12,821}{7} = 1832$$

Need to Balance Organic Load (lbs BOD) With Number of Active Organisms in Treatment System



Food to Microorganism Ratio

F:M or $\frac{F}{M}$

How Much Food ?

Primary Effluent BOD

Lbs/D BOD = FLOW (MGD) X 8.34 Lbs/Gal X P.E. BOD (mg/L)

F = Pounds BOD
(Coming into Aeration Tank)

How is **M** (Microorganisms) measured?

Mixed Liquor Volatile Suspended Solids (MLVSS)

M = Pounds MLVSS
(In Aeration Tank)

Mixed Liquor Suspended Solids (MLSS)
and
Mixed Liquor Volatile Suspended Solids (MLVSS)

Mixed Liquor Suspended Solids (MLSS)
and
Mixed Liquor Volatile Suspended Solids (MLVSS)

Determining MLSS

Solids

$$\text{Wt. of Solids + Paper, mg} - \text{Wt. of Paper, mg}$$

$$\text{Wt. of Solids, mg}$$

$$\frac{\text{Wt. of Solids, mg}}{\text{Volume of Sample, L}} \longrightarrow \text{MLSS, mg/L}$$

Determining MLVSS

Volatile Solids

550 °C

Solids

Wt. of Dish + Solids, mg

— Wt. of Dish + Ash, mg

Wt. of Volatile Solids, mg

$$\frac{\text{Wt. of Volatile Solids, mg}}{\text{Volume of Sample, L}} \longrightarrow \text{MLVSS, mg/L}$$

How Much Food ?
Primary Effluent BOD

Lbs/D BOD = FLOW (MGD) X 8.34 Lbs/Gal X P.E. BOD (mg/L)

F = Pounds BOD
(Coming into Aeration Tank)

How is M (Microorganisms) measured?

Mixed Liquor Volatile Suspended Solids (MLVSS)

M = Pounds MLVSS
(In Aeration Tank)

Analysis Gave Us M (MLVSS) In mg/L

How Do We Get To Pounds?

Lbs/D BOD =

Volume (MG) X 8.34 Lbs/Gal X MLVSS (mg/L)

Volume Of What ?

Where Microorganisms Are

Aeration Tank

How Do We Get Volume ?

Aeration Tank Volume (MG)

$L\ (ft) \times W\ (ft) \times SWD\ (ft) = Volume\ (ft^3)$

$ft^3 \times 7.48\ gal/ft^3 = gallons$

$gallons / 1{,}000{,}000 = million\ gallons\ (MG)$

Aeration Tank Volume (MG)

Example Calculation:

A. **Calculate the volume in million gallons of an aeration tank that is 120 ft long, 35 ft wide, with a SWD of 15 ft.**

$$V = L \times W \times D$$

$$V = 120\text{ ft} \times 35\text{ ft} \times 15\text{ ft} = 63{,}000\text{ ft}^3$$

$$63{,}000\text{ ft}^3 \times 7.48\ \frac{\text{gal}}{\text{ft}^3} = 471{,}240\text{ gallons}$$

$$471{,}240\text{ gallons} / 1{,}000{,}000 = 0.471\text{ MG}$$

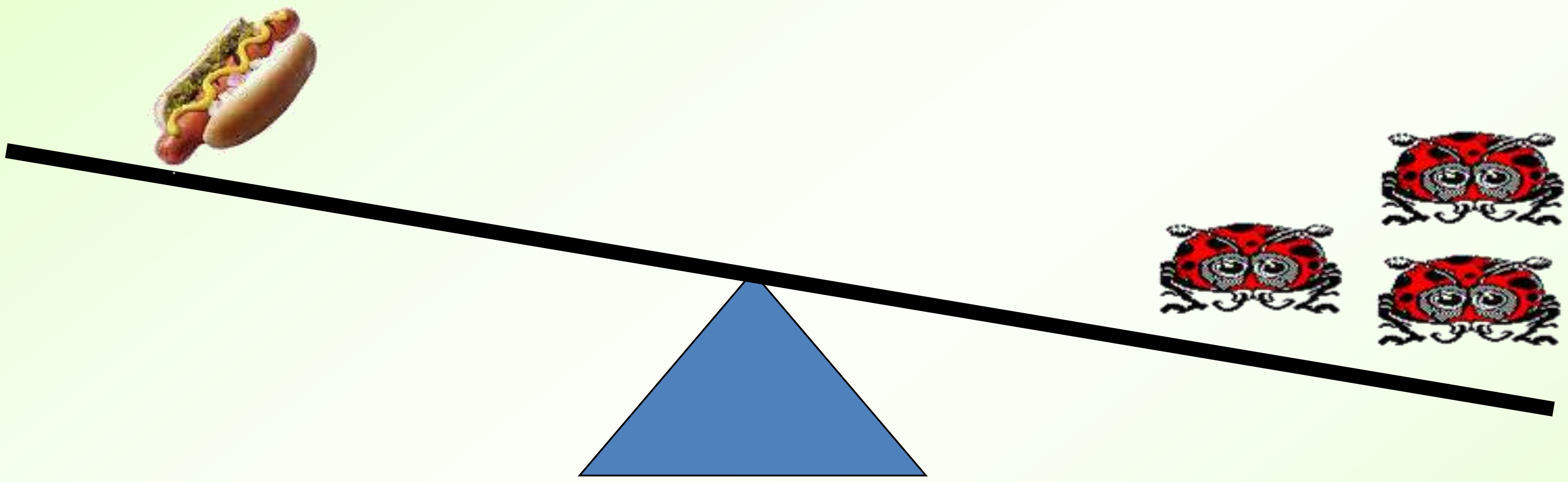
Aeration Tank Volume (MG)

Example Calculation:

B. The average BOD load on this aeration tank is 1954 lbs/day. Calculate the organic loading in lbs/day/1000ft^3.

$$\frac{1954\text{ lbs/day}}{63{,}000\text{ ft}^3} \times 1{,}000 = 31.0\text{ lbs/day/1000ft}^3$$

Need to Balance Organic Load (lbs BOD) With Number of Active Organisms in Treatment System



Food to Microorganism Ratio

F:M or $\frac{F}{M}$

How Much Food (F) ?
Pounds BOD

Lbs/D BOD =

FLOW (MGD) X 8.34 Lbs/Gal X Pri. Eff. BOD (mg/L)

How is M (Microorganisms) measured?

Mixed Liquor Volatile Suspended Solids (MLVSS)

M = Pounds MLVSS

CALCULATION OF POUNDS

Pounds =

Conc. x Flow (or Volume) x 8.34 Lbs/gallon

Concentration Of STUFF In the Water	X	Quantity Of Water The STUFF Is In	X	Weight Of The Water

Pounds of Volatile Solids in the Aeration Tank

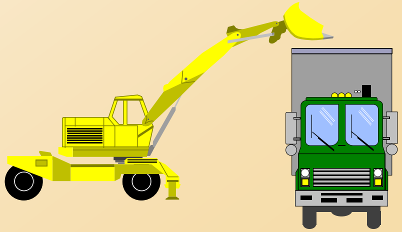
Lbs MLVSS =

Volume Aeration Tank, MG X MLVSS, mg/L X 8.34 Lbs/gal

Example Problem:
Calculate the pounds of volatile solids in an aeration tank that has a volume of 0.471 MG and the concentration of volatile suspended solids is 1700 mg/L.

Lbs = 0.471 MG X 1700 mg/L X 8.34 lbs/gal

= 6678 lbs MLVSS



Food to Microorganism Ratio

$$= \frac{\text{Lbs of BOD}}{\text{Lbs of MLVSS}}$$

Example Problem:
The 7-day moving average BOD is 2002 lbs and the mixed liquor volatile suspended solids is 6681 pounds. Calculate the F/M ratio of the process.

$$\frac{F}{M} = \frac{\text{2002 lbs BOD}}{\text{6681 lbs MLVSS}} = 0.30$$

Food to Microorganism Ratio

The F/M Ratio for Best Treatment Will Vary for Different Facilities

Determined by Regular Monitoring and Comparing to Effluent Quality

Often Will Vary Seasonally

Typical Range:

Conventional Activated Sludge

F:M 0.25 - 0.45

Extended Aeration Activated Sludge

F:M 0.05 - 0.15

Food to Microorganism Ratio

$$\frac{F}{M} =$$

$$= \frac{\text{Lbs of BOD}}{\text{Lbs of MLVSS}}$$

Calculate Often to Monitor/Control

Monthly (Minimum)
Weekly (Better)
Use Moving Average

Food to Microorganism Ratio Calculations

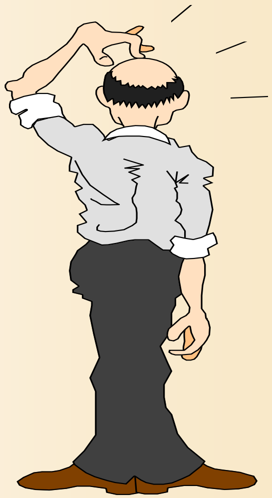
F/M Ratio is Used to Determine the Lbs of MLVSS Needed at a Particular Loading Rate

FOR DAILY USE

$$F/M = \frac{\text{Lbs BOD}}{\text{lbs MLVSS}}$$

$$\frac{F}{F/M} = M \text{ (Lbs MLVSS)}$$

suppose F/M of 0.30 is desired
and BOD loading is 1200 lbs/day



$$\frac{F}{M} = 0.30$$

$$\frac{F}{0.30} = M$$

$$\frac{1200 \text{ lbs}}{0.30} = 4000 \text{ lbs MLVSS}$$

Food to Microorganism Ratio Calculations

If we Know the Pounds of MLVSS Needed and the Volume of the Aeration Tank We Can Calculate MLVSS, mg/L.

Calculate the MLVSS, mg/L given an Aeration Tank Volume of 0.20 MG.

$$4000 \text{ lbs} = 0.20 \text{ MG} \times 8.34 \frac{\text{lbs}}{\text{gal}} \times \text{? mg/L}$$

$$\frac{4000 \text{ lbs}}{0.20 \text{ MG} \times 8.34 \text{ lbs/gal}} = 2398 \text{ mg/L}$$

F:M Calculations

Problem A:
How many pounds of MLVSS should be maintained in an aeration tank with a volume of 0.105 MG receiving primary effluent BOD of 630 lbs/d ? The desired F:M is 0.3.

$$\frac{F}{F/M} = M \qquad = \frac{630 \text{ lbs/d}}{0.3} \qquad = 2100 \text{ lbs MLVSS}$$

F:M Calculations

Problem B:
What will be the MLVSS concentration in mg/L ?

$$2100 \text{ lbs} = \text{Conc} \times 0.105 \text{ MG} \times 8.34 \text{ lbs/gal}$$

$$\frac{2100 \text{ lbs}}{0.105 \text{ MG} \times 8.34 \text{ lbs/gal}} = 2398 \text{ mg/L}$$

Food to Microorganism Ratio Calculations

F/M Ratio is Used to Determine the Lbs of MLVSS Needed at a Particular Loading Rate

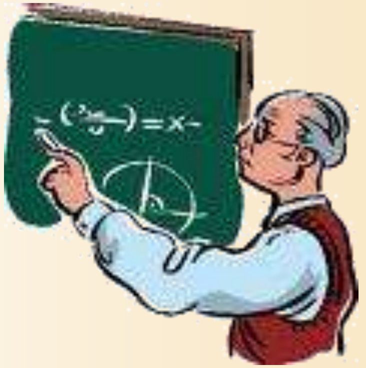
$$F/M = \frac{\text{Lbs BOD}}{\text{lbs MLVSS}} \qquad \frac{F}{F/M} = M\ (\text{Lbs MLVSS})$$

Can you Calculate the **Pounds of MLVSS** Needed for a Specific **F/M**

and

What **Concentration** That Would Be in an Aeration Tank?

Prove It !



F:M Calculations II

Problem C:
How many pounds of MLVSS should be maintained in an aeration tank with a volume of 0.471 MG receiving primary effluent BOD of 2502 lbs/d ? The desired F:M is 0.3.

Problem D:
What will be the MLVSS concentration in mg/L ?

Work Calculations on Separate Paper
Answers Given on Next Slides

F:M Calculations II

Problem C:
How many pounds of MLVSS should be maintained in an aeration tank with a volume of 0.471 MG receiving primary effluent BOD of 2502 lbs/d ? The desired F:M is 0.3.

$$\frac{F}{F/M} = M = \frac{2502 \text{ lbs/d}}{0.3} = 8340 \text{ lbs MLVSS}$$

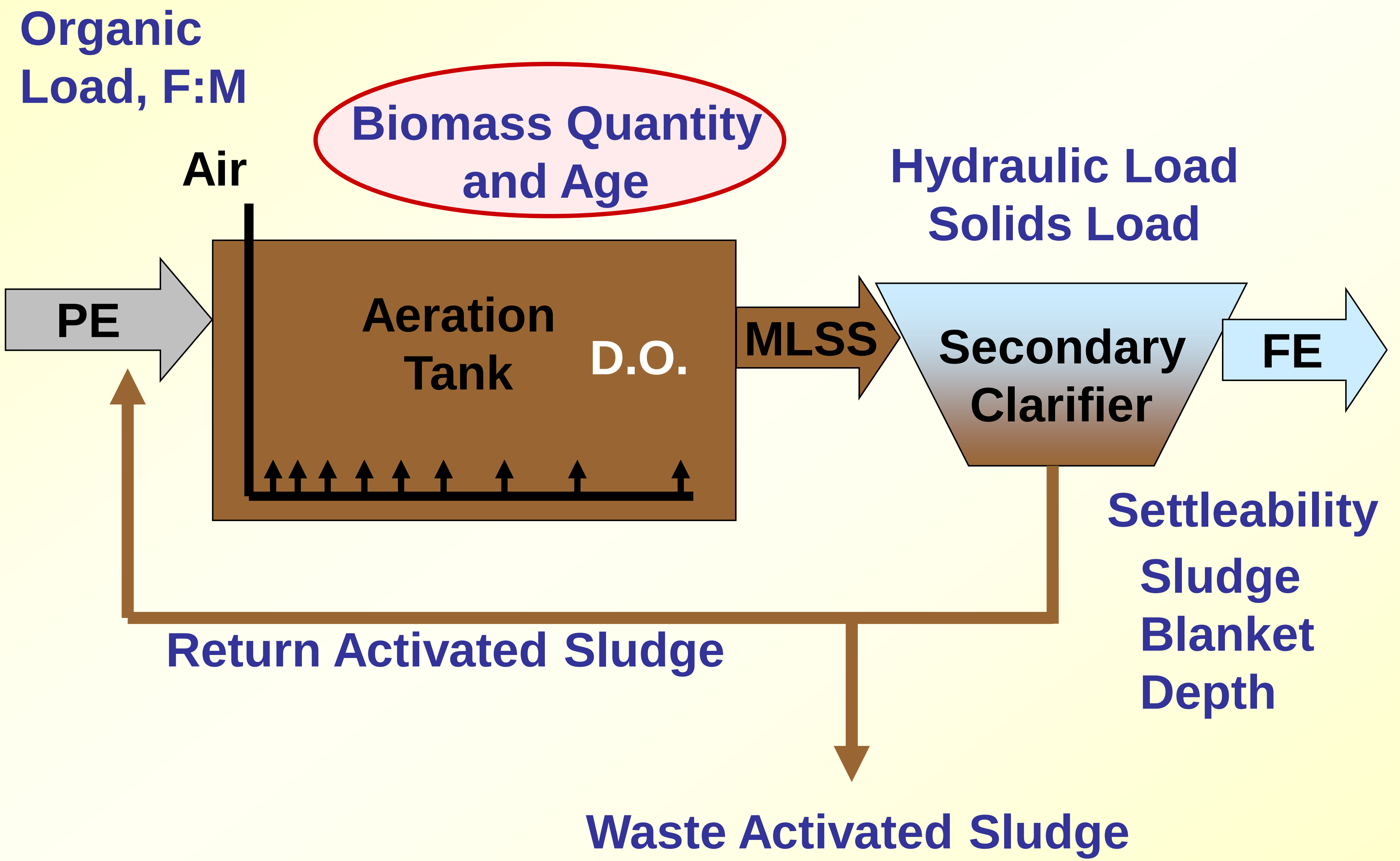
F:M Calculations II

Problem D:
What will be the MLVSS concentration in mg/L ?

8340 lbs = Conc X 0.471 MG X 8.34 lbs/gal

$$\frac{8340 \text{ lbs}}{0.471 \text{ MG} \times 8.34 \text{ lbs/gal}} = 2123 \text{ mg/L}$$

Control Factors



Graph Showing Growth Phases in a Biological System

Growth Rate of Organisms

X

Abundance of Food

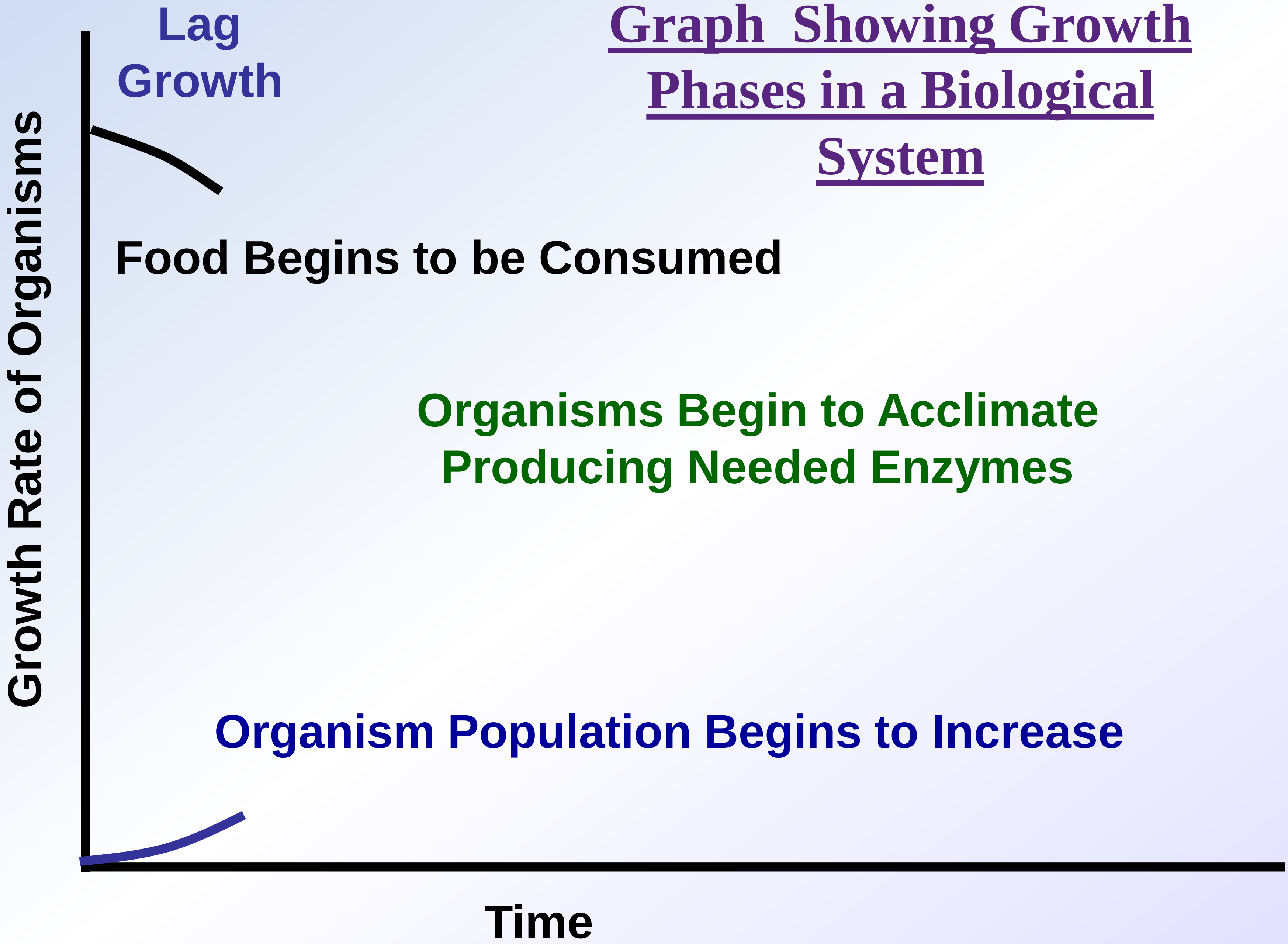
When Food Supply is Introduced into a Biological Treatment System that is in Start-up

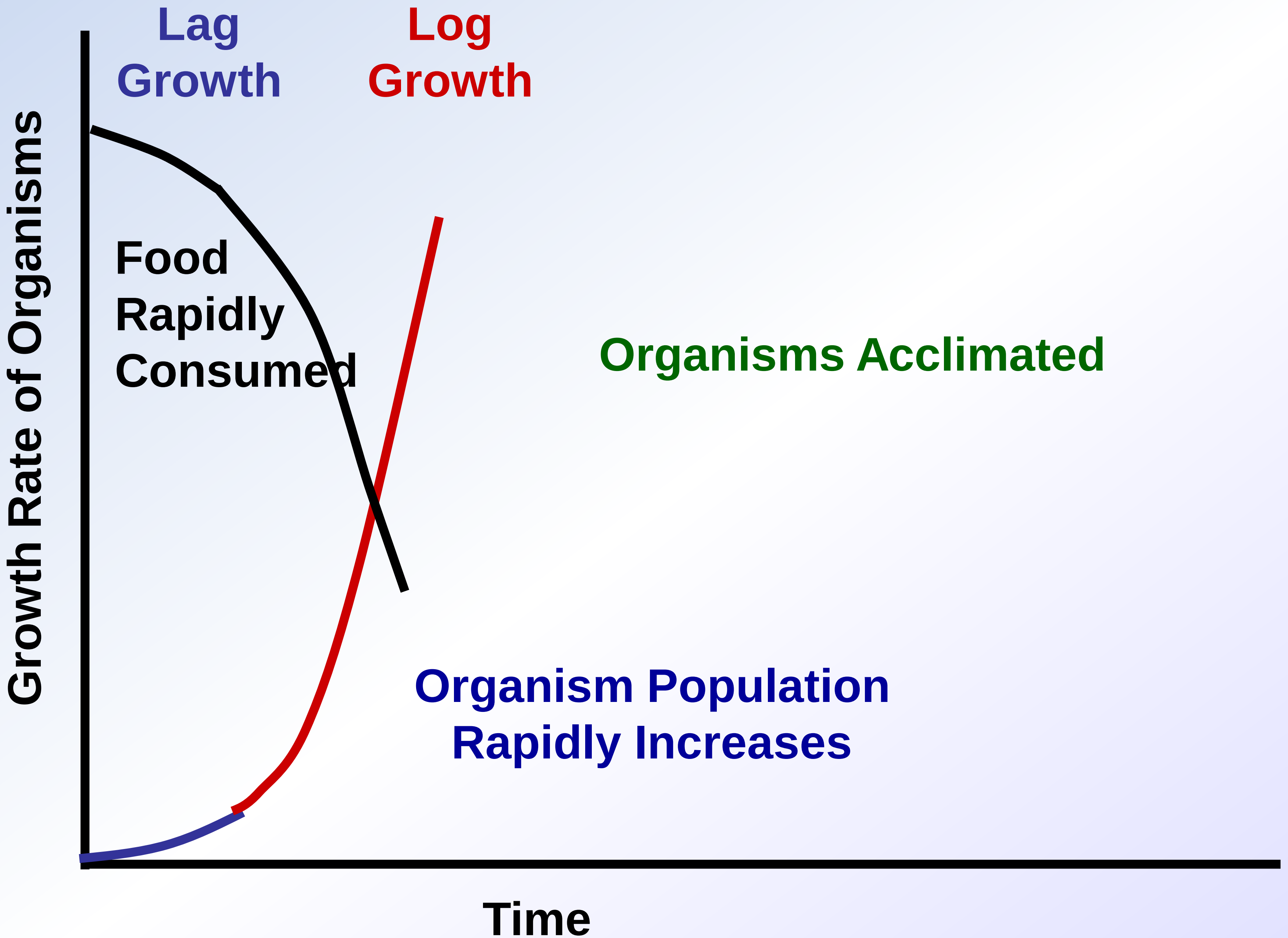
Few Organisms

X

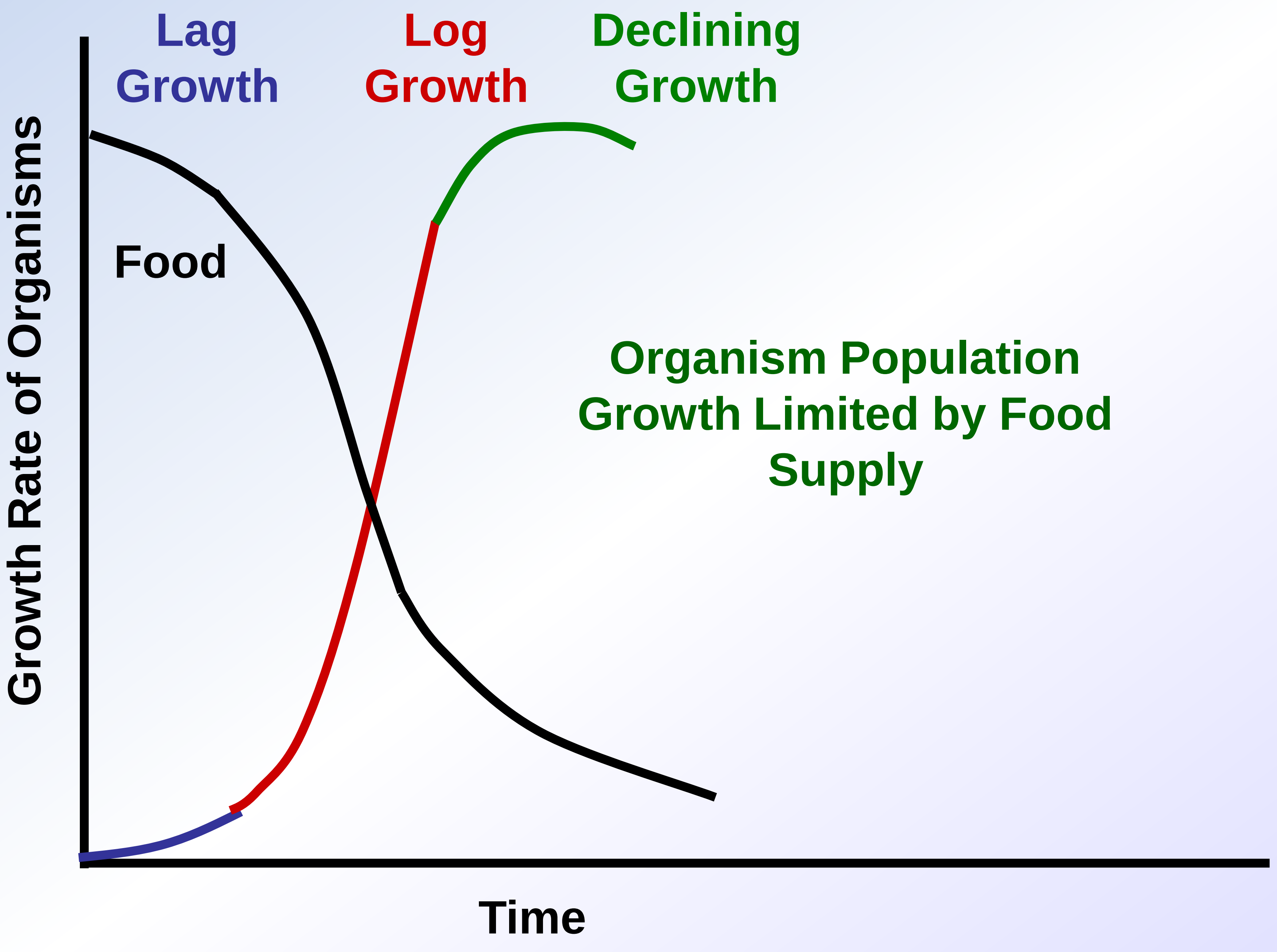
Time

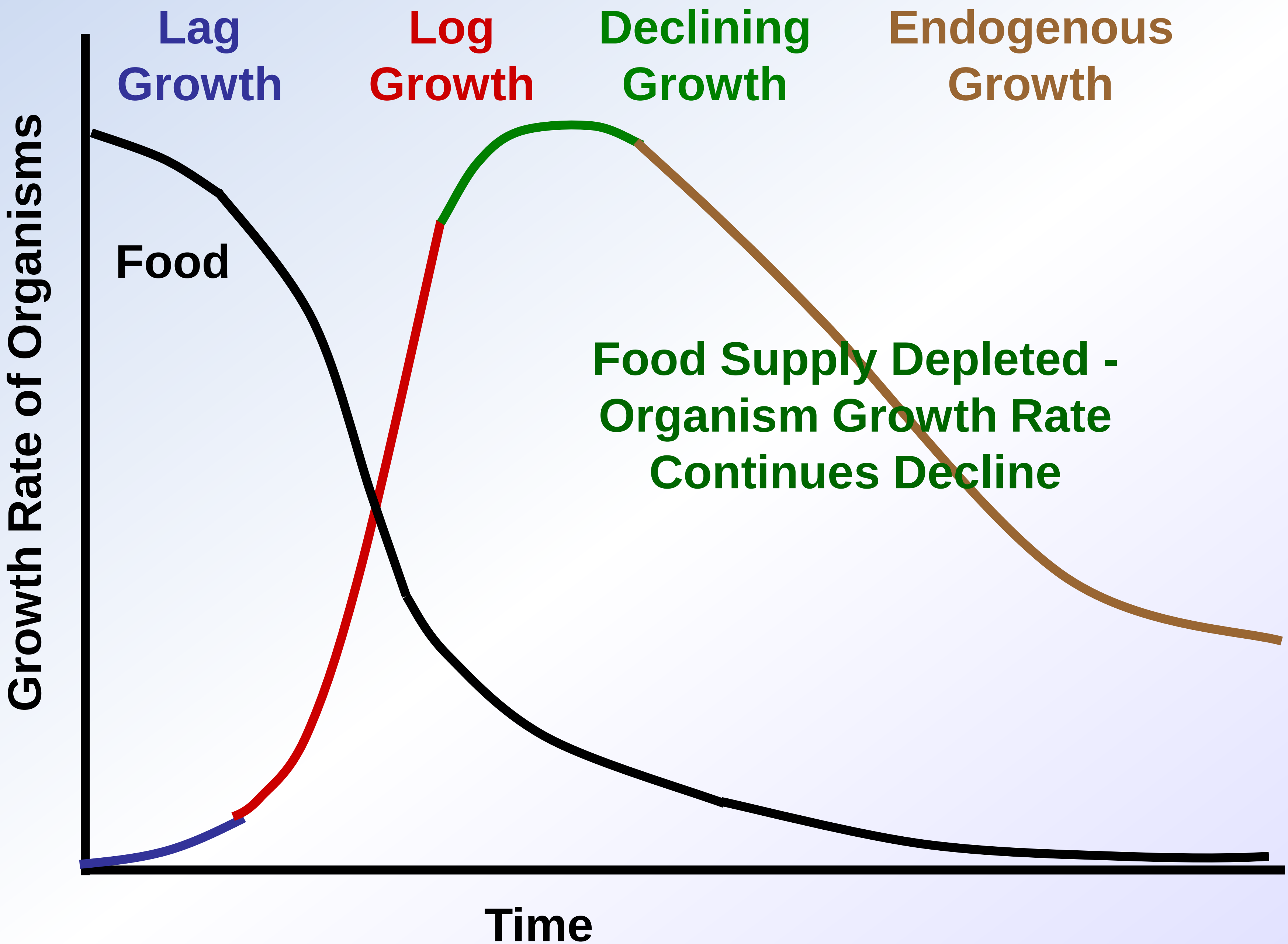
Graph Showing Growth Phases in a Biological System

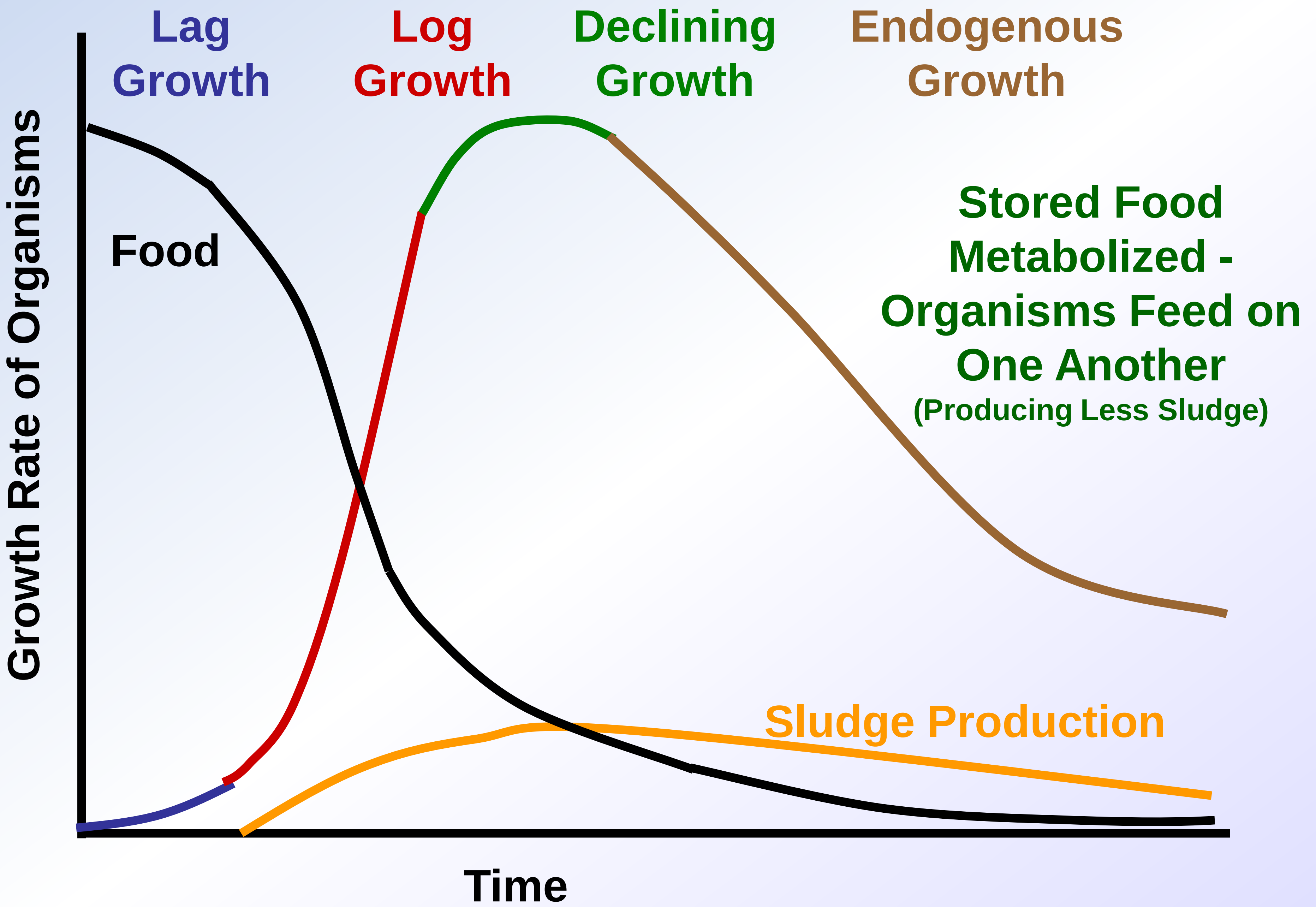




Lag
Growth
Log
Growth
Growth Rate of Organisms
Food
Rapidly
Consumed
Organisms Acclimated
Organism Population
Rapidly Increases
Time

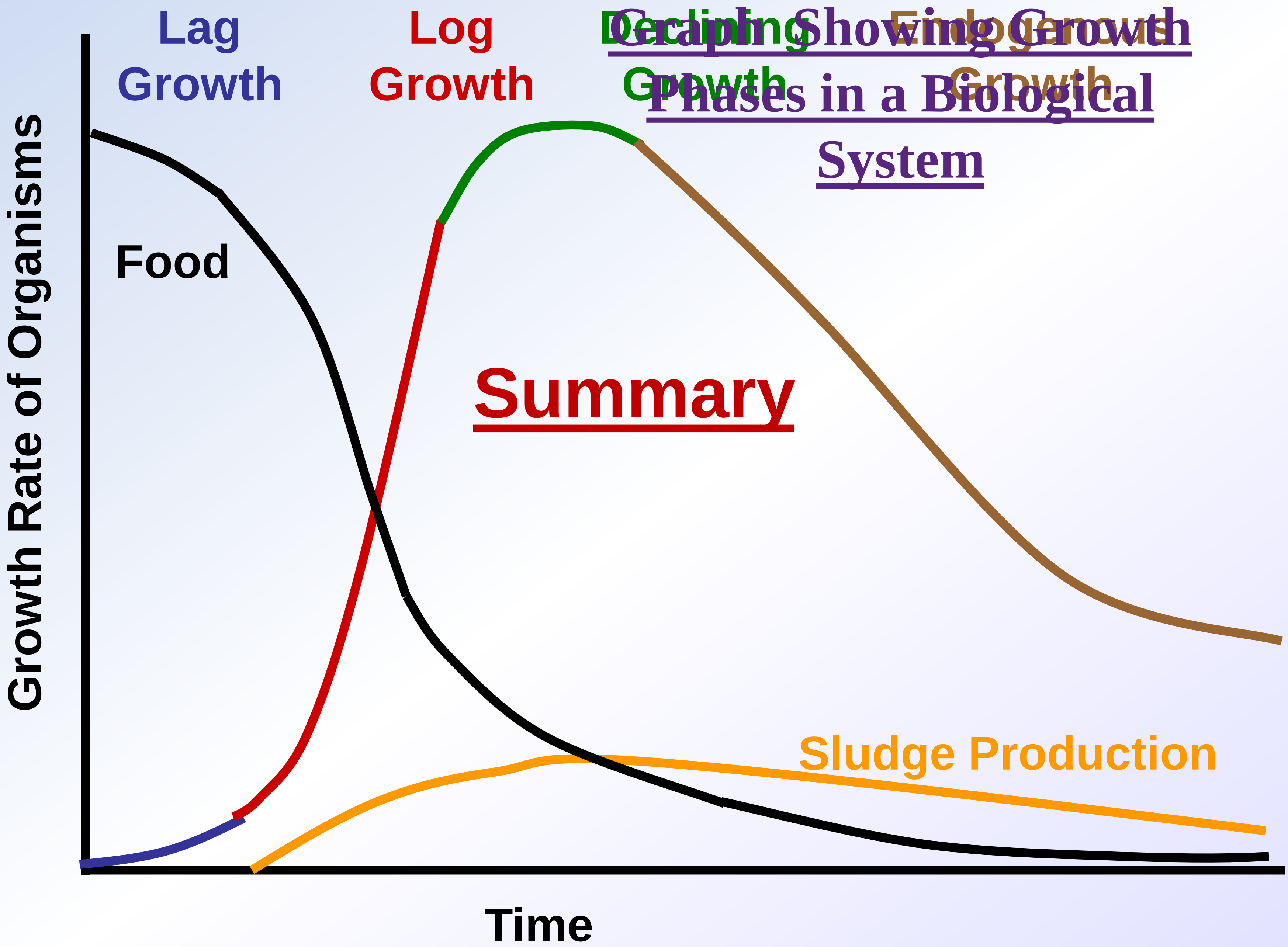

Lag
Growth
Log
Growth
Declining
Growth
Food
Organism Population
Growth Limited by Food
Supply
Growth Rate of Organisms
Time


Lag
Growth
Log
Growth
Declining
Growth
Endogenous
Growth
Food
Food Supply Depleted -
Organism Growth Rate
Continues Decline
Growth Rate of Organisms
Time


Lag Growth
Log Growth
Declining Growth
Endogenous Growth
Food
Stored Food Metabolized - Organisms Feed on One Another
(Producing Less Sludge)
Sludge Production
Growth Rate of Organisms
Time

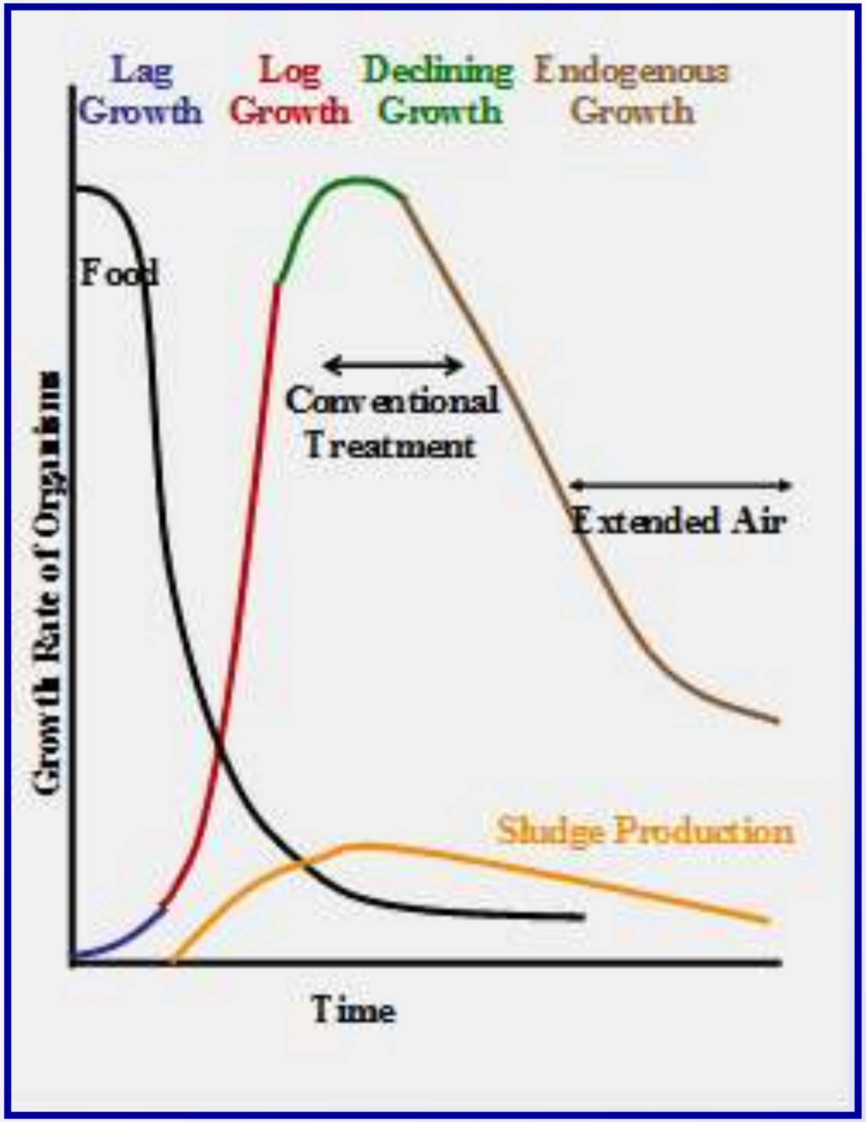
Graph Showing Growth Phases in a Biological System

Summary

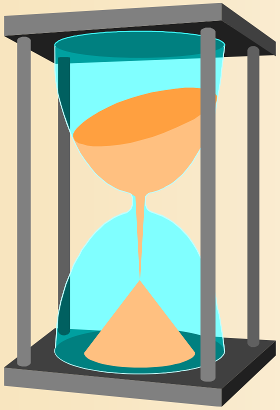


Graph Showing Growth Phases in a Biological System

This graph illustrates that the activities of Microorganisms in a biological treatment system is related to the Average Age of the Organisms in the System or the "CRT" of the System



Note: The CRT is Controlled in an Activated Sludge System by Wasting which will be discussed later.



Biomass Age

Cell Residence Time, CRT
Mean Cell Residence Time, MCRT
Sludge Age, SA

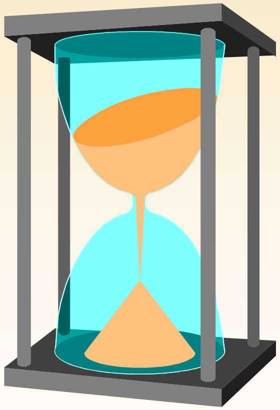
The Average Length of Time in Days that an Organism Remains in the Secondary Treatment System

$$\text{SA, days} = \frac{\text{Suspended Solids in Aerator, lbs}}{\text{Suspended Solids in PE, lbs/day}}$$

$$\text{MCRT} = \frac{\text{Total MLVSS, lbs (Aerator + Clarifier)}}{\text{Total MLVSS Wasted + Effluent TSS, lbs/d}}$$

The SA and MCRT Calculations are Seldom Used
The Most Common (and Best for Most Processes) Is the Cell Residence Time

Cell Residence Time

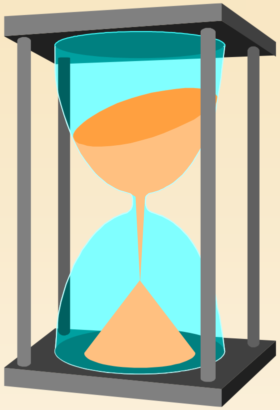


The Average Length of Time in Days that an Organism Remains in the Secondary Treatment System

Cell Residence Time, CRT

$$\text{CRT, days} = \frac{\text{Total MLVSS, lbs}}{\text{Total MLVSS Wasted, lbs/d}}$$

Cell Residence Time



The Average Length of Time in Days that an Organism Remains in the Secondary Treatment System

Cell Residence Time, CRT

$$\text{CRT, days} = \frac{\text{Total MLVSS, lbs}}{\text{Total MLVSS Wasted, lbs/d}}$$

Example:

MLVSS = 6681 lbs
MLVSS Wasted = 835 lbs/d

Calculate the CRT.

$$\text{CRT} = \frac{6681 \text{ lbs}}{835 \text{ lbs/d}}$$

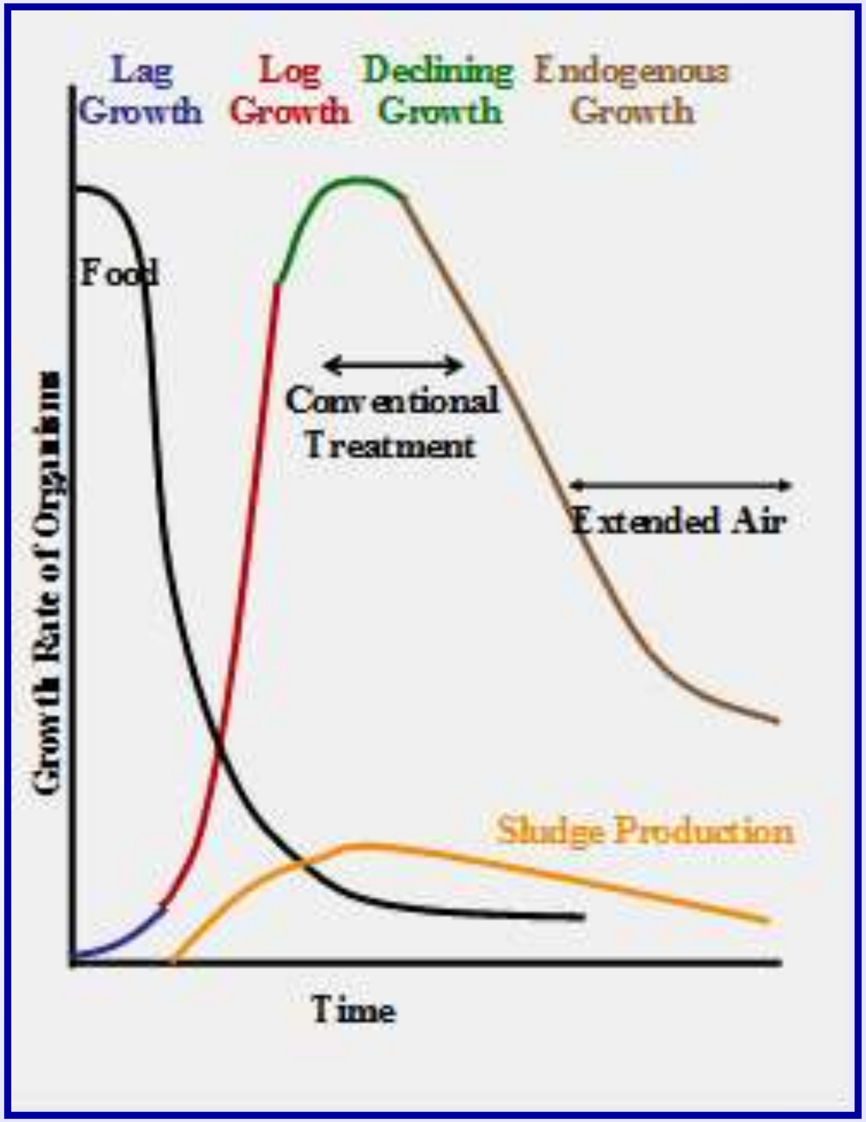
CRT = 8.0 Days

Cell Residence Time

Like The F/M Ratio The CRT for Best Treatment Will Vary for Different Facilities

Determined by Regular Monitoring and Comparing to Effluent Quality

Often Will Vary Seasonally

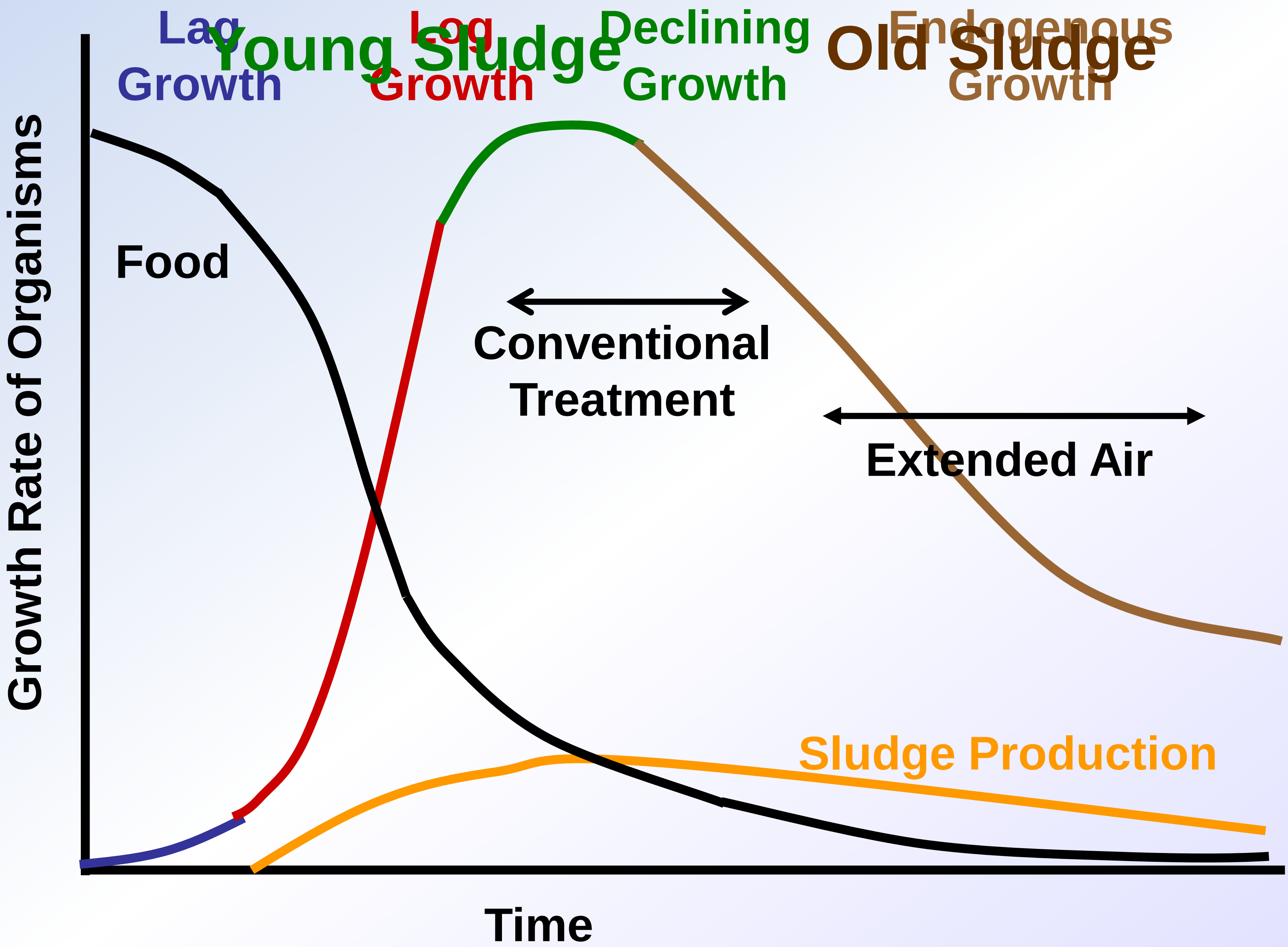


Conventional Activated Sludge

Aerator Detention Time	4 - 8 Hrs.
F:M	0.25 - 0.45
CRT	4 - 6 Days

Extended Aeration Activated Sludge

Aerator Detention Time	16 - 24 Hrs.
F:M	0.05 - 0.15
CRT	15 - 25 Days


Lag Growth
Young Sludge
Log Growth
Declining Growth
Old Sludge
Endogenous Growth
Growth Rate of Organisms
Food
Conventional Treatment
Extended Air
Sludge Production
Time

Young Sludge

- Start-up or High BOD Load
- Few Established Cells
- Log Growth
- High F:M
- Low CRT

Young Sludge

Poor Flocculation
Poor Settleability
Turbid Effluent

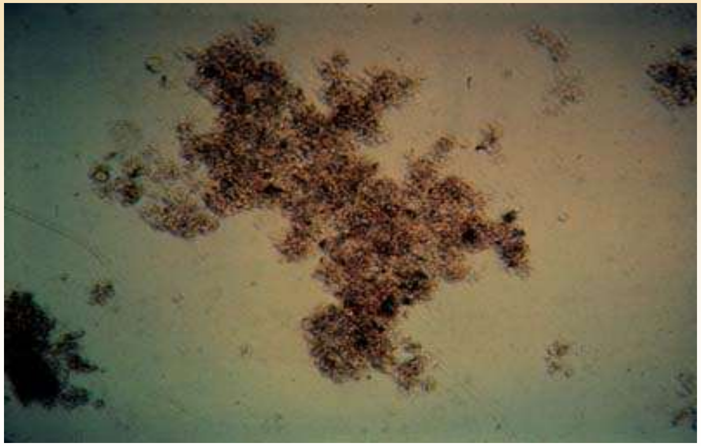
White
Billowing
Foam

High O_2
Uptake Rate

Old Sludge

- Slow Metabolism
- Decreased Food Intake
- Low Cell Production
- Oxidation of Stored Food
- Endogenous Respiration
- Low F:M
- High CRT
- High MLSS

Old Sludge

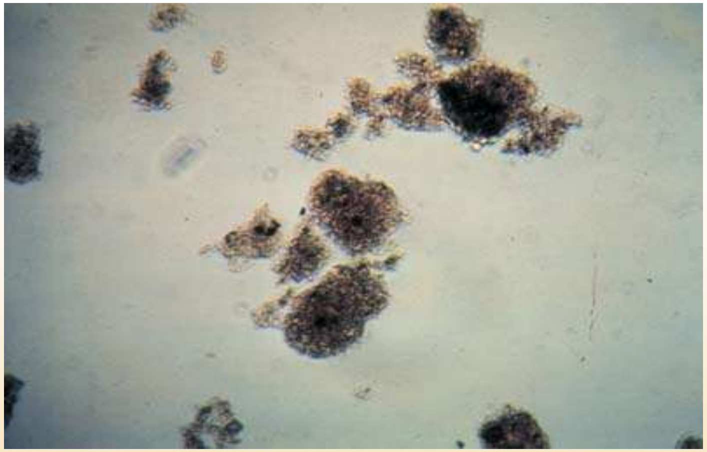


Dense, Compact Floc

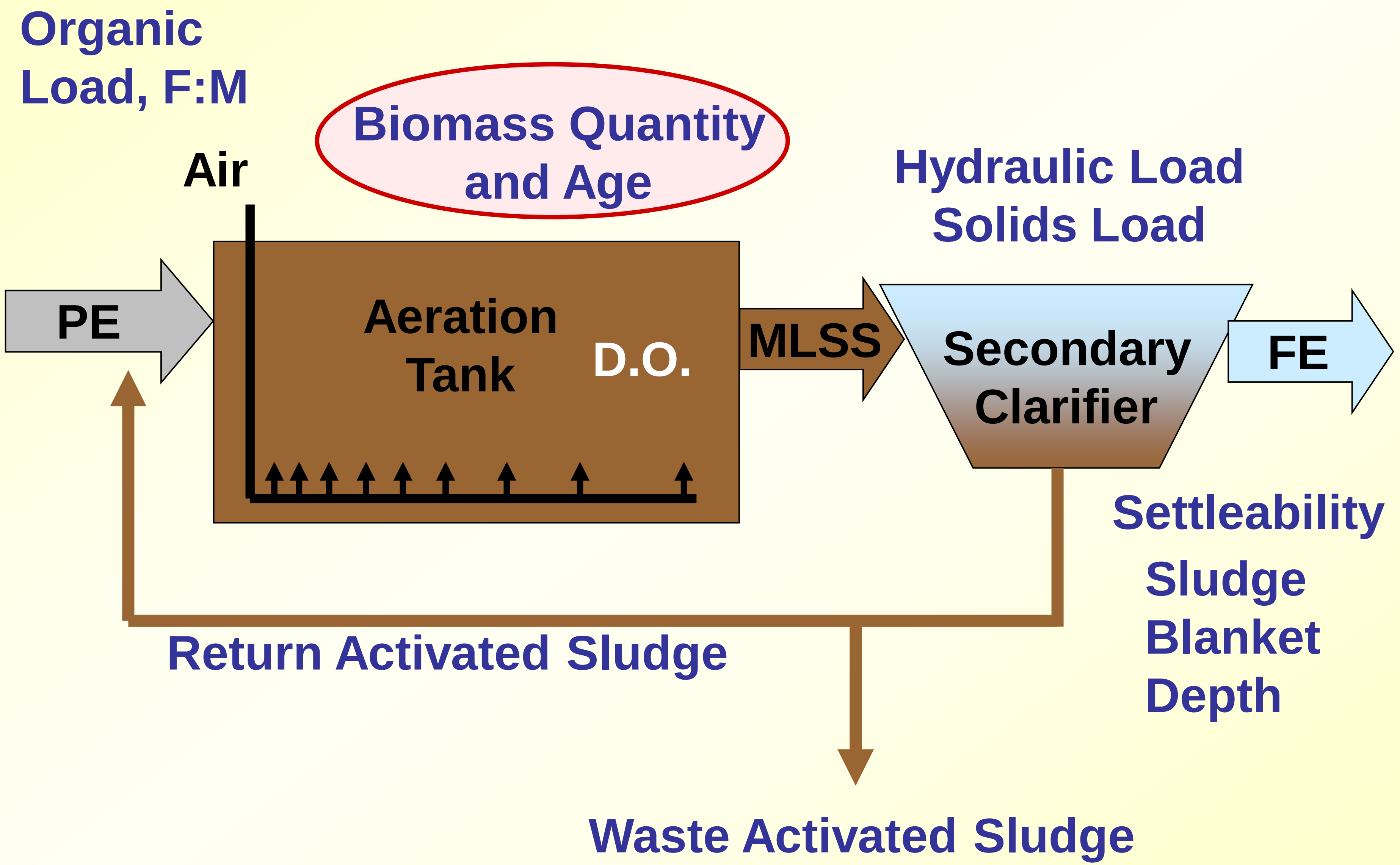
Fast Settling

Straggler Floc

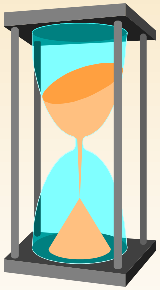
Slurp



Control Factors



Cell Residence Time



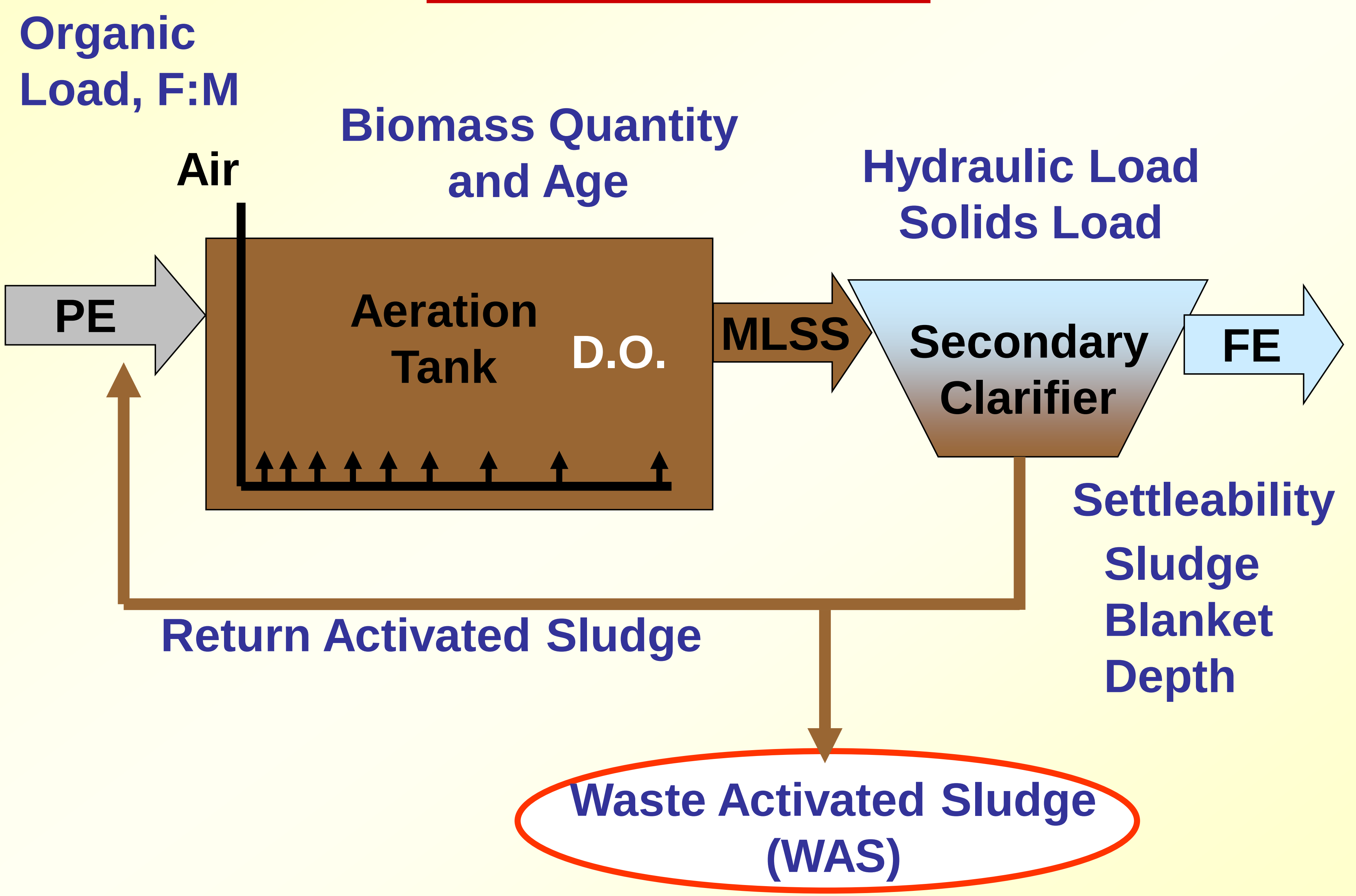
The Average Length of Time in Days that an Organism Remains in the Secondary Treatment System

$$\text{CRT, days} = \frac{\text{Total MLVSS, lbs}}{\text{Total MLVSS Wasted, lbs/d}}$$

The CRT for Facility is Controlled/Maintained by Wasting the Appropriate Amount of Excess Biomass

Waste Activated Sludge (WAS)

Control Factors



Sludge Wasting Rates

$$\text{CRT(days)} = \frac{\text{Lbs of MLVSS in aerators}}{\text{Lbs/day WAS VSS}}$$

Therefore:

$$\frac{\text{Lbs}}{\text{day}} \text{ WAS VSS} = \frac{\text{Lbs of MLVSS in aerators}}{\text{CRT (days)}}$$

Sludge Wasting Rates

With a known RAS VSS concentration, the WAS Flow in MGD can be calculated:

$$\frac{\text{Lbs/ day}}{} = \text{mg/L} \times 8.34 \frac{\text{lbs}}{\text{gal}} \times \text{? MGD}$$

$$\frac{\text{lbs/day WAS VSS}}{\text{RAS VSS (mg/L)} \times 8.34 \frac{\text{lbs}}{\text{gal}}} = \text{WAS (MGD)}$$

MGD x 1,000,000 = gallons per day

Sludge Wasting Rates

If wasting is to be done over a 24 hr. period:

$$\text{WAS (gpm)} = \frac{\text{gallons/day}}{\text{1440 minutes/day}}$$

If wasting is to be done over a shorter period:

$$\text{WAS (gpm)} = \frac{\text{gallons/day}}{\text{min wasting to be done/day}}$$

Sludge Wasting Rates
Example Calculations

Problem #1:

A cell residence time of 5.8 days is desired. With 5800 pounds of MLVSS in the aeration tanks, calculate the pounds of VSS that must be wasted per day.

Need to Waste 5800 lbs in 5.8 Days

$$\text{lbs/day} = \frac{5800 \text{ lbs}}{5.8 \text{ days}} = 1000 \text{ lbs/day}$$

Sludge Wasting Rates

Problem #2:
Calculate the flow rate in MGD that must be pumped in order to waste the number of pounds calculated in Problem #1 given a Return Sludge concentration of 9000 mg/L VSS.

lbs/day = conc. x 8.34 lbs/gal x MGD

$$1000\ \frac{\text{lbs}}{\text{day}} = 9000\ \text{mg/L} \times 8.34\ \text{lbs/gal} \times \text{MGD}$$

$$\frac{1000\ \text{lbs/day}}{9000\ \text{mg/L} \times 8.34\ \text{lbs/gal}} = \text{MGD Wasted}$$

= 0.0133 MGD = 13,300 gal/day

Sludge Wasting Rates

Problem #3:

Calculate the wasting rate in gallons per minute if the wasting was done in 24 hours.

$$13{,}300\ \frac{\text{gal}}{\text{day}} \times \frac{1\ \text{day}}{24\ \text{hrs}} \times \frac{1\ \text{hour}}{60\ \text{min}} = 9.24\ \frac{\text{gals}}{\text{min}}$$

Sludge Wasting Rates

Problem #4:

Calculate the wasting rate in gallons per minute if the wasting was done in 4 hours.

$$\frac{13{,}300 \text{ gal}}{4 \text{ hr}} \times \frac{1 \text{ hr}}{60 \text{ min}} = 55.4 \text{ gal/min}$$

Sludge Wasting

Excess Biological Solids eliminated from the secondary treatment system to control the cell residence time of the biomass

When to Waste:

Continuous (Whenever Possible)

Or If Necessary (Piping, Pumping or Valve Limitations)

Intermittent - During Low Load Conditions

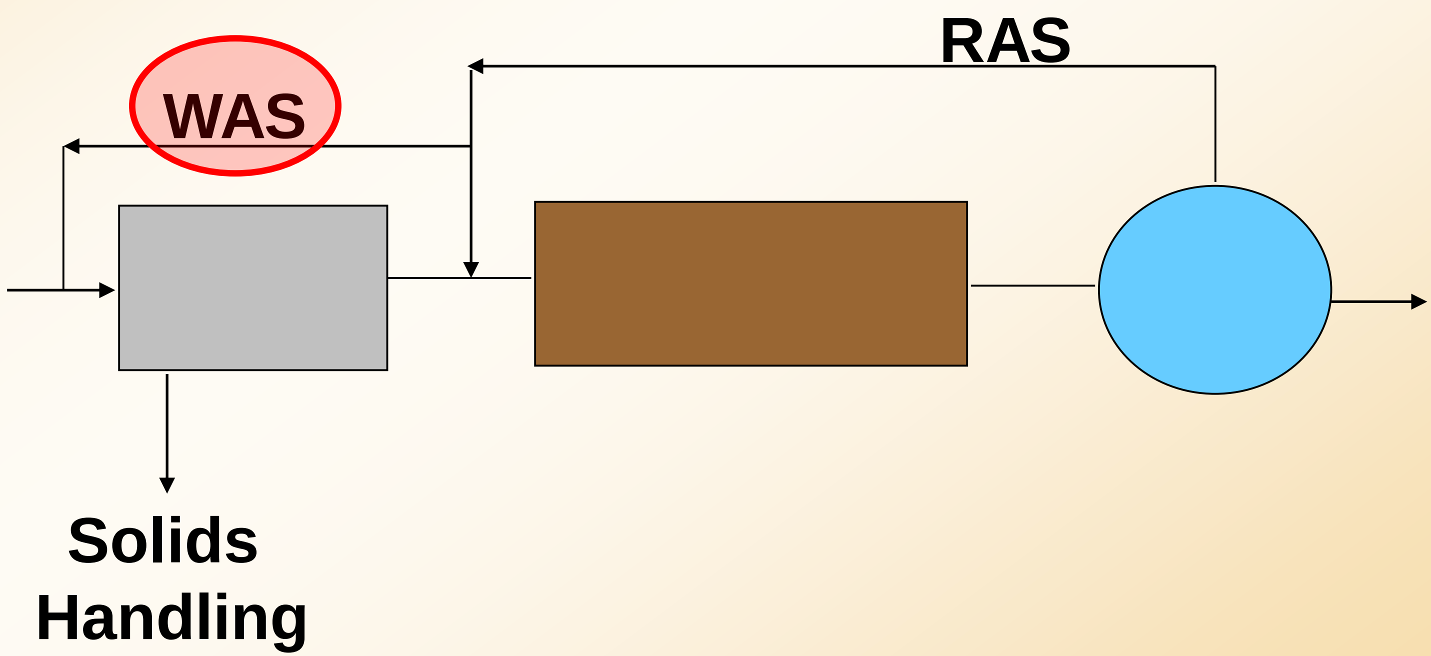
Sludge Wasting

Where to:

Primary Clarifiers

Advantage - Co-Settling

Disadvantage - Are Solids Really Wasted?



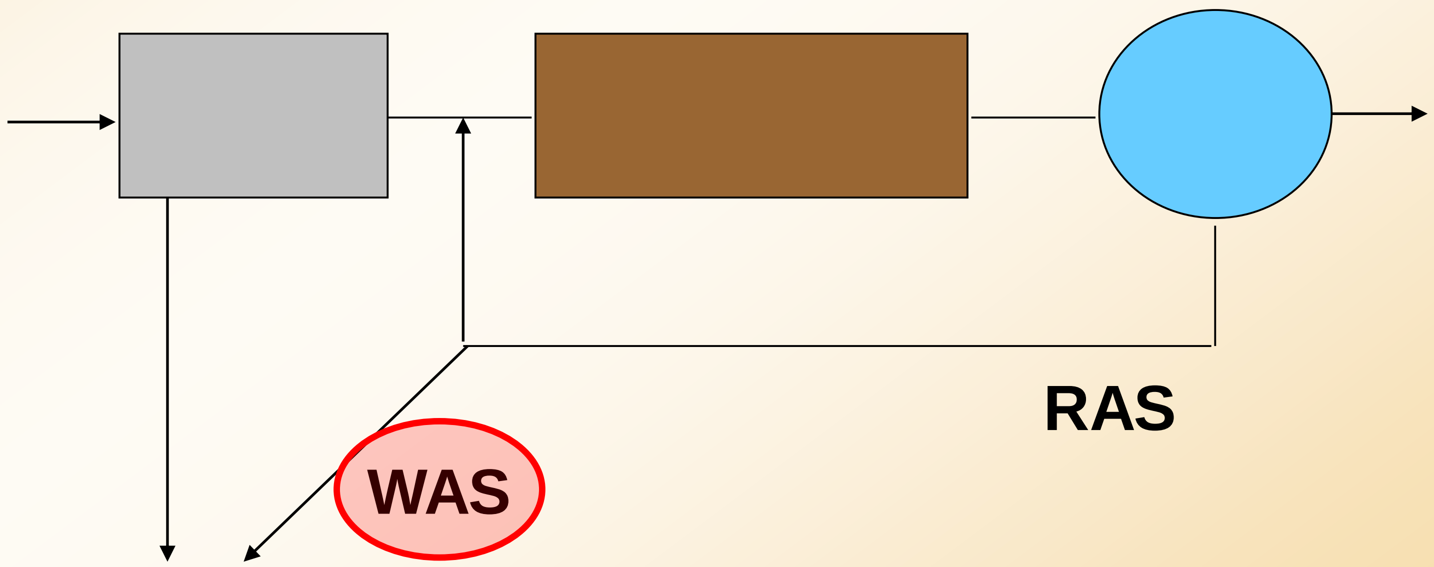
Sludge Wasting

Where to:

Solids Handling

Advantage – Know Solids are Out of the System

Disadvantage – Thinner Solids to Solids Process



Sludge Processing (Thickening, Stabilization, etc.)

Sludge Wasting

How Much:

Secondary Sludge Wasting One of the Most Important Controls

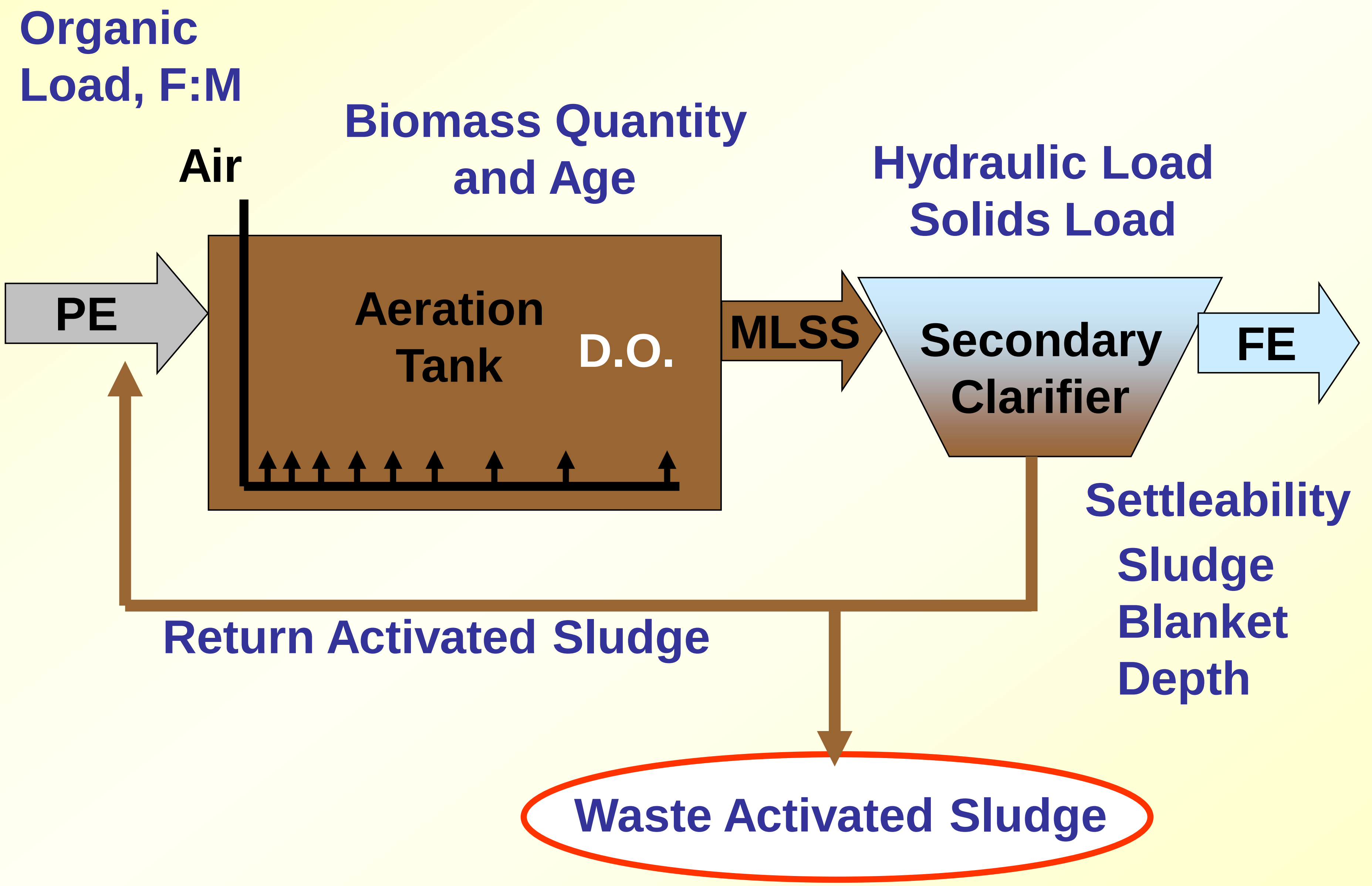
Wasting Controls the Most Important Aspect of Treatment, the Biomass Population

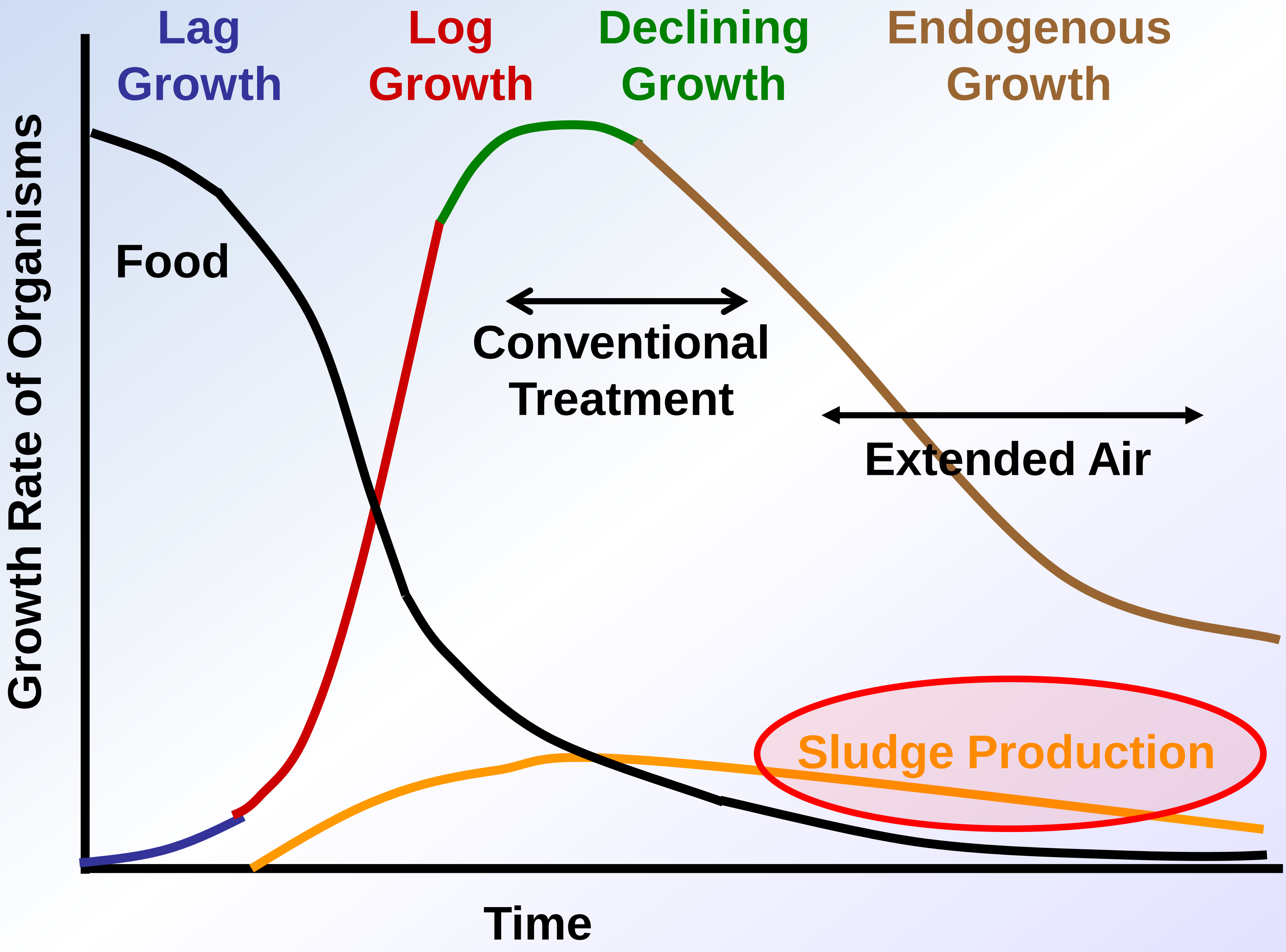
Sludge Wasting

How Much:

**Proper Wasting Control
And
Metering is Essential**

Control Factors

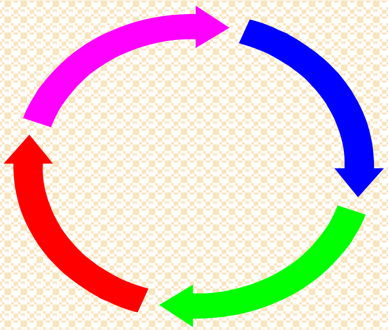



Lag Growth
Log Growth
Declining Growth
Endogenous Growth
Food
Conventional Treatment
Extended Air
Sludge Production
Growth Rate of Organisms
Time

Activated Sludge

Suspended Growth, Biological Treatment

Need favorable conditions for growth and for separation from the water



Biological solids are used over and over

Growth rate produces about 0.7 lbs of biological solids per lb BOD removed

Yield Coefficient (Y)

Growth Rate

Y =

Pounds of Biological Solids Produced

Per Pound of BOD Removed

Yield Coefficient (Y)

Growth Rate

Pounds of Biological Solids Produced

Per Pounds of BOD Removed

<u>Example</u>

Average Concentration Of BOD Entering Aeration
125 mg/L

Average Concentration of BOD from Secondary System
5 mg/L

Average Plant Flow
2.0 MGD

Average RAS Concentration (Wasting from Return)
8000 mg/L

Yield Coefficient (Y)

Growth Rate

Pounds of Biological Solids Produced

Per Pounds of BOD Removed

<u>Example</u>

BOD Removed = 125 mg/L – 5 mg/L = 120 mg/L

<u>At 2.0 MGD</u>

Lbs BOD Removed = 2 MGD X 8.34 X 120 mg/L
= 2002 Lbs/Day

<u>At Y= 0.7</u>

Biomass Produced = 2002 Lbs/Day X 0.7
= 1401 Lbs/Day

Yield Coefficient (Y)

<u>At 2.0 MGD</u>

Lbs BOD Removed = 2 MGD X 8.34 X 120 mg/L

= 2002 Lbs/Day

<u>At Y= 0.7</u>

Biomass Produced = 2002 Lbs/Day X 0.7

= 1401 Lbs/Day

Yield Coefficient (Y)

At 2.0 MGD

Lbs BOD Removed = 2 MGD X 8.34 X 120 mg/L

= 2002 Lbs/Day

At Y= 0.7

Biomass Produced = 2002 Lbs/Day X 0.7

= 1401 Lbs/Day

RAS at 8000 mg/L

$$\frac{1401 \text{ lbs/day}}{8000 \text{ mg/L} \times 8.34 \text{ lbs/gal}} = 20{,}998 \text{ gallons WAS}$$

(To Balance Solids Produced)

Yield Coefficient (Y)

At 2.0 MGD

Lbs BOD Removed = 2 MGD X 8.34 X 120 mg/L
= 2002 Lbs/Day

At Y= 0.5

Biomass Produced = 2002 Lbs/Day X 0.5
= 1001 Lbs/Day

RAS at 8000 mg/L

$$\frac{1001 \text{ lbs/day}}{8000 \text{ mg/L} \times 8.34 \text{ lbs/gal}} = 15{,}002 \text{ gallons WAS}$$

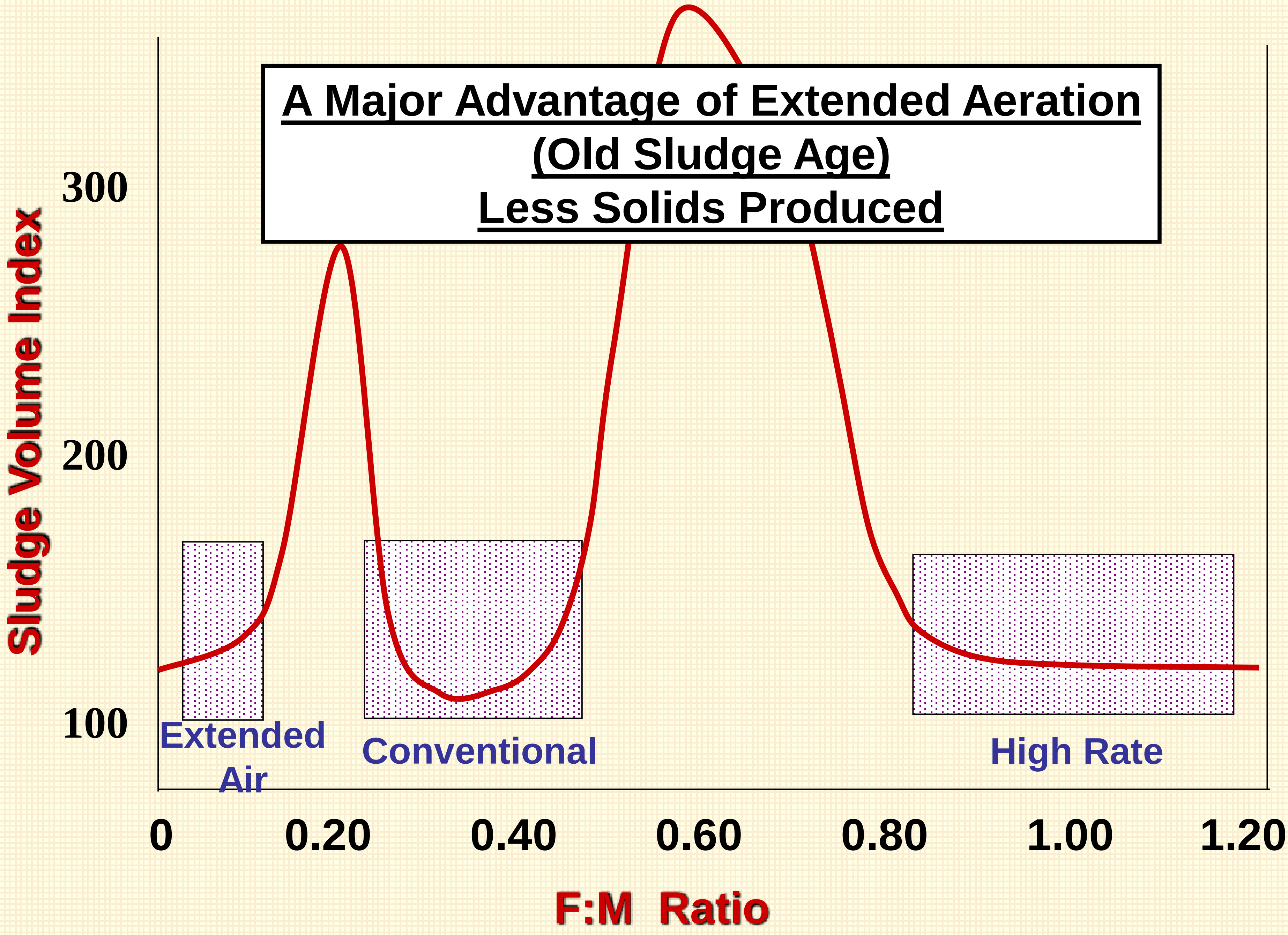
(To Balance Solids Produced)

Yield Coefficient (Y)

The Difference:

20,998 gallons
15,002 gallons
5,996 gallons **Per Day**

6000 gal/day X 365 day/year = 2,190,000 gallons per year


A Major Advantage of Extended Aeration
(Old Sludge Age)
Less Solids Produced
Sludge Volume Index
300
200
100
Extended
Air
Conventional
High Rate
0
0.20
0.40
0.60
0.80
1.00
1.20
F:M Ratio

Yield Coefficient (Y)

Growth Rate

Y =

Pounds of Biological Solids Produced

Per Pound of BOD Removed

<u>How to Determine Y for a Facility?</u>

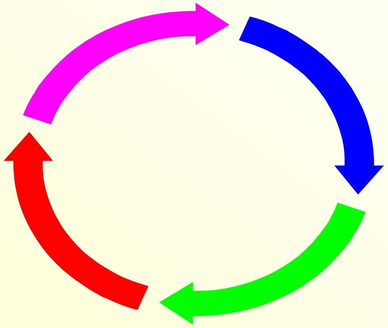
<u>Use Monthly Average of Pounds of Solids Wasted</u>
<u>Divided by</u>
<u>the Monthly Average of Pounds of BOD Removed</u>

Should be Monitored Regularly (Monthly)

Activated Sludge

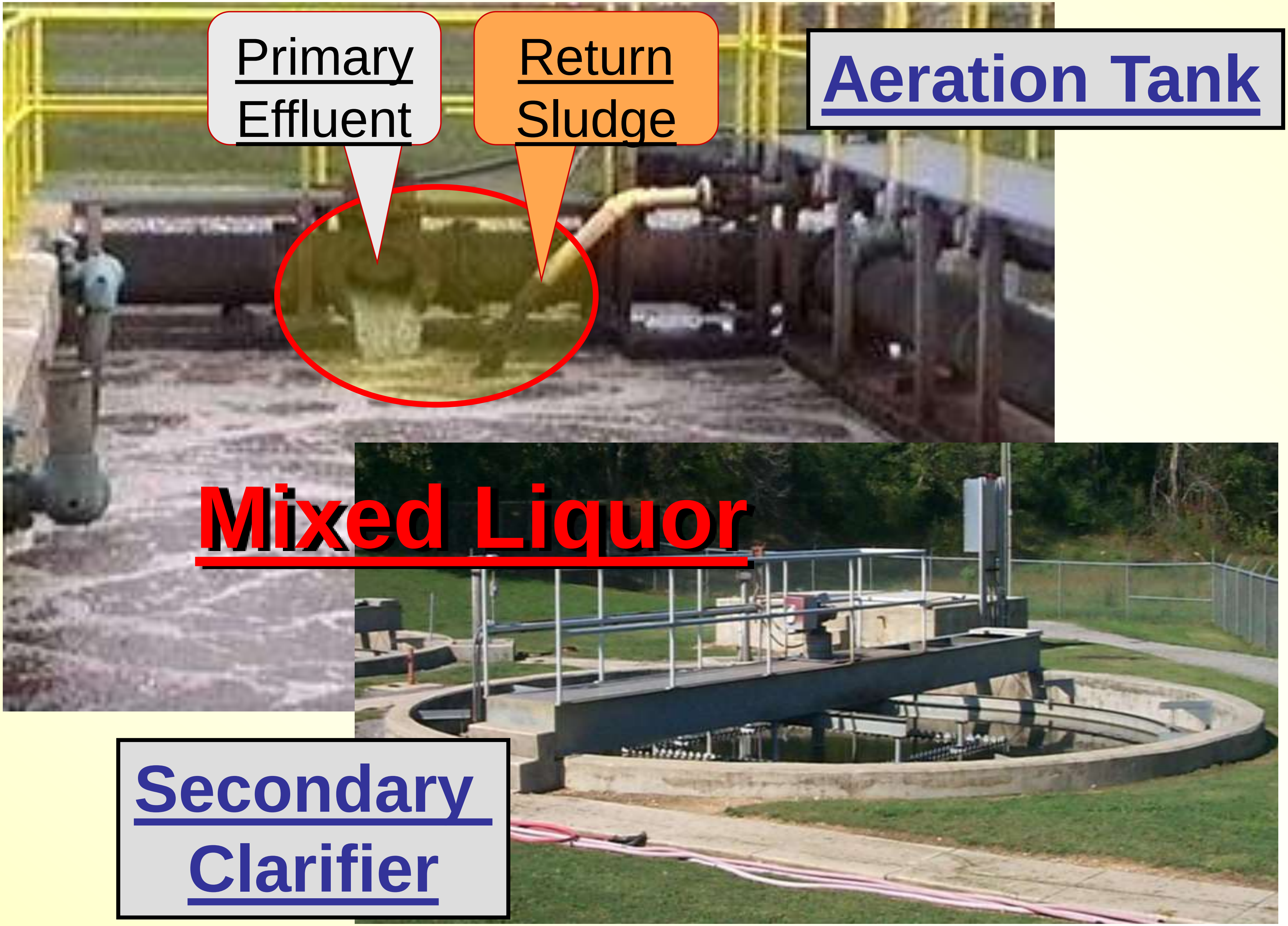
Suspended Growth, Biological Treatment

Need favorable conditions for growth and for separation from the water

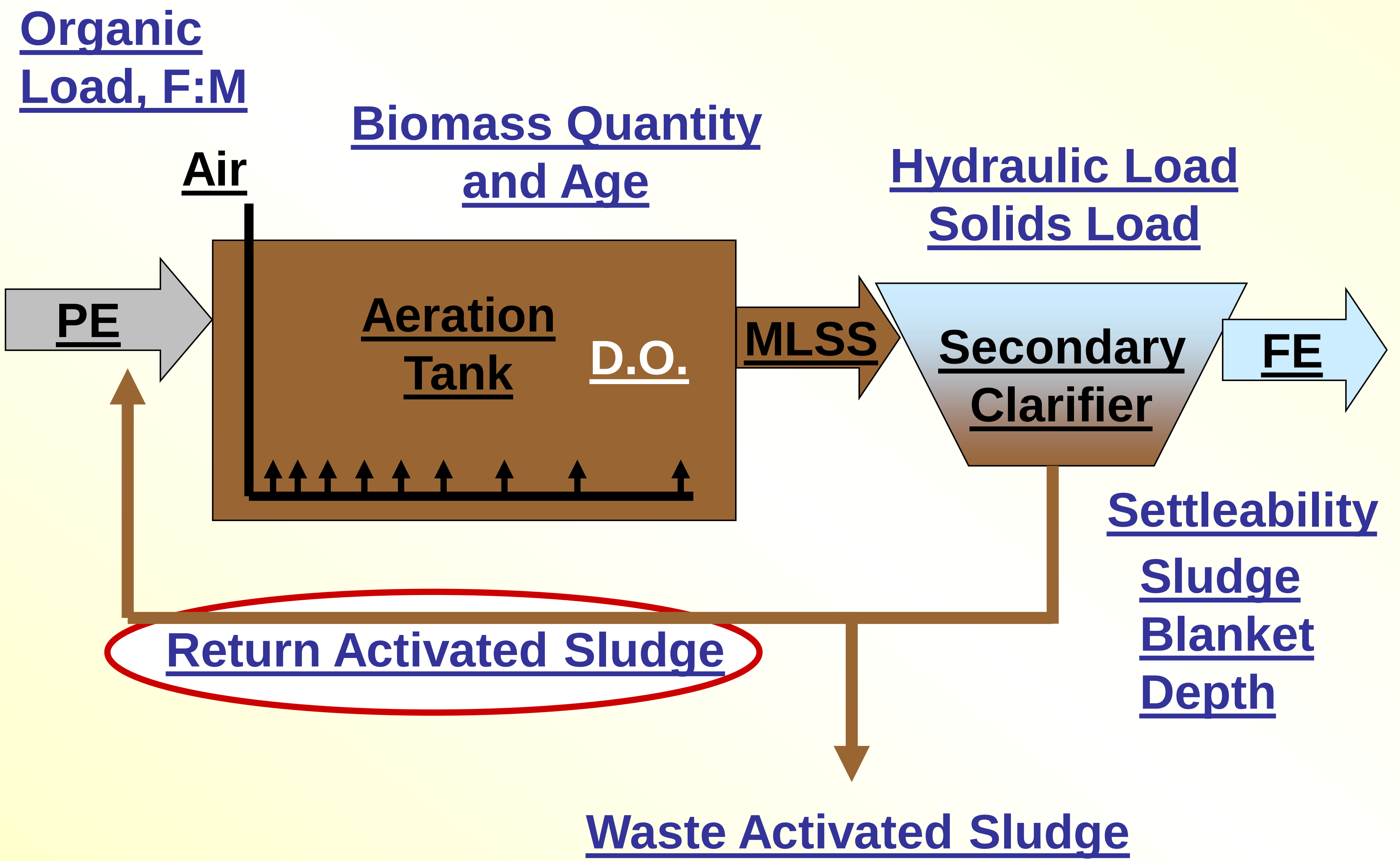


Biological solids are used over and over

Returned from Secondary Clarifier


Primary Effluent
Return Sludge
Aeration Tank
Mixed Liquor
Secondary Clarifier

Control Factors



Return Activated Sludge

Biological Solids (Mixed Liquor Solids) which have settled in the secondary clarifier, continuously returned to the aeration system.

Why:

- **Control sludge blanket in clarifier**
- **Maintain a sufficient population of active organisms in service**

It's Not the Food
It's the Bugs

Return Activated Sludge

Biological Solids (Mixed Liquor Solids) which have settled in the secondary clarifier, continuously returned to the aeration system.

Why:

- **Control sludge blanket in clarifier**
- **Maintain a sufficient population of active organisms in service**

Not a Means of Controlling MLSS

Return Activated Sludge

Biological Solids (Mixed Liquor Solids) which have settled in the secondary clarifier, continuously returned to the aeration system.

Why:

- **Control sludge blanket in clarifier**
- **Maintain a sufficient population of active organisms in service**

Controls Solids Depth in Seconday Clarifier

Return Activated Sludge

RAS Control:

- 1 – 3 Feet Depth
- Too Much – Solids Over Weir
- Too Little – Thin RAS Concentration
  (More Volume When Wasting)

Return Activated Sludge

RAS Control:

- Consistent Flow Rate
- % Influent Flow
- RAS Metering

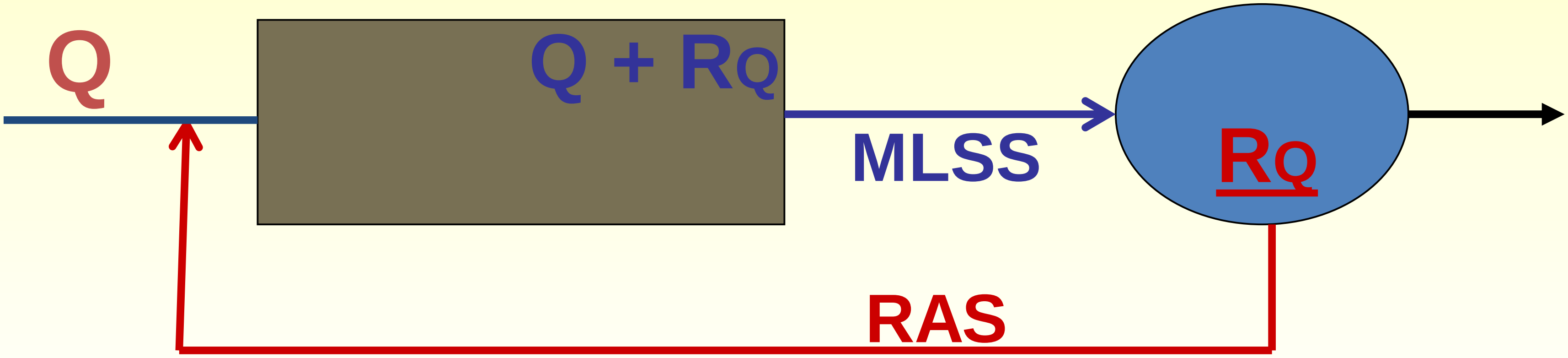
Setting the RAS Rate

How Much is Enough
(or Too Much)

Sludge Blanket Depth

Sludge Judging

RAS Mass Balance

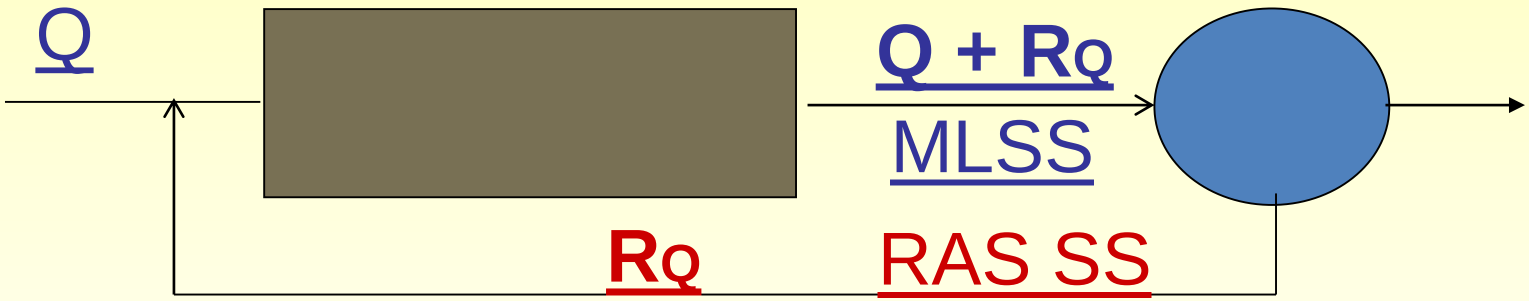


Lbs of Material Into Clarifier

(RQ + Q) X 8.34 lbs/gal X MLSS (mg/L)

Lbs of Material Out of Clarifier

RQ X 8.34 lbs/gal X RAS (mg/L)



RAS Mass Balance

Lbs Into Clarifier = Lbs Out of Clarifier

(Q + RQ) X 8.34X MLSS = RQ X 8.34 X RAS

(Q + RQ) X MLSS = RQ X RAS SS

(RQ X MLSS) + (Q X MLSS) = RQ X RAS SS

Q X MLSS = RQ X RAS SS - RQ X MLSS

Q X MLSS = RQ X (RAS - MLSS)

$$\frac{\text{Q X MLSS}}{\text{RAS SS - MLSS}} = \text{RQ}$$

Return Activated Sludge

Most People Forget the Derivation of the Formula and Just Memorize the Formula

$$R_Q = \frac{Q \times MLSS}{RAS\ SS - MLSS}$$

Return Activated Sludge

$$RQ = \frac{Q \text{ X } MLSS}{RAS\ SS - MLSS}$$

Units for RQ will Match Units for Q

To Express RQ as % of Influent Flow:

$$\%\ RQ = \frac{100 \text{ X } MLSS}{RAS - MLSS}$$

Return Rates - Example Calculations

Given: MLSS = 2400 mg/L
RAS SS = 6500 mg/L
Flow = 2.0 MGD

1. Calculate the Return Sludge Rate in MGD needed to keep the solids in the process in balance.

$$\text{RAS, MGD} = \frac{2.0 \text{ MGD X } 2400 \text{ mg/L}}{6500 \text{ mg/L} - 2400 \text{ mg/L}}$$

$$= \frac{4800}{4100} = 1.17 \text{ MGD}$$

Return Rates - Example Calculations

Given:

MLSS = 2400 mg/L

RAS SS = 6500 mg/L

2. Calculate the Return Sludge Rate in % of plant influent flow needed to keep the solids in the process in balance.

$$\% \text{ RAS} = \frac{100 \text{ X } 2400 \text{ mg/L}}{6500 \text{ mg/L} - 2400 \text{ mg/L}}$$

$$\% \text{ RAS} = \frac{240000}{4100} = 58.5\ \%$$

Return Rates - Practice Calculations

Work Calculations on Separate Paper
Answers Given on Next Slides

Given: MLSS = 2700 mg/L
RAS SS = 8200 mg/L
Flow = 2.5 MGD

1. **Calculate the Return Sludge Rate in MGD needed to keep the solids in the process in balance.**

2. **Calculate the Return Sludge Rate in % of plant influent flow needed to keep the solids in the process in balance.**

Return Rates - Practice Calculations

Given: MLSS = 2700 mg/L
RAS SS = 8200 mg/L
Flow = 2.5 MGD

1. Calculate the Return Sludge Rate in MGD needed to keep the solids in the process in balance.

$$\text{RAS, MGD} = \frac{2.5 \text{ MGD X } 2700 \text{ mg/L}}{8200 \text{ mg/L} - 2700 \text{ mg/L}}$$

$$= \frac{6750}{5500} = 1.23 \text{ MGD}$$

Return Rates - Example Calculations

Given:

MLSS = 2700 mg/L

RAS SS = 8200 mg/L

2. Calculate the Return Sludge Rate in % of plant influent flow needed to keep the solids in the process in balance.

$$\% \text{ RAS} = \frac{100 \text{ X } 2700 \text{ mg/L}}{8200 \text{ mg/L} - 2700 \text{ mg/L}}$$

$$\% \text{ RAS} = \frac{270{,}000}{5500} = 49.1\ \%$$

Return Activated Sludge

$$RQ = \frac{Q \text{ X } MLSS}{RAS\ SS - MLSS}$$

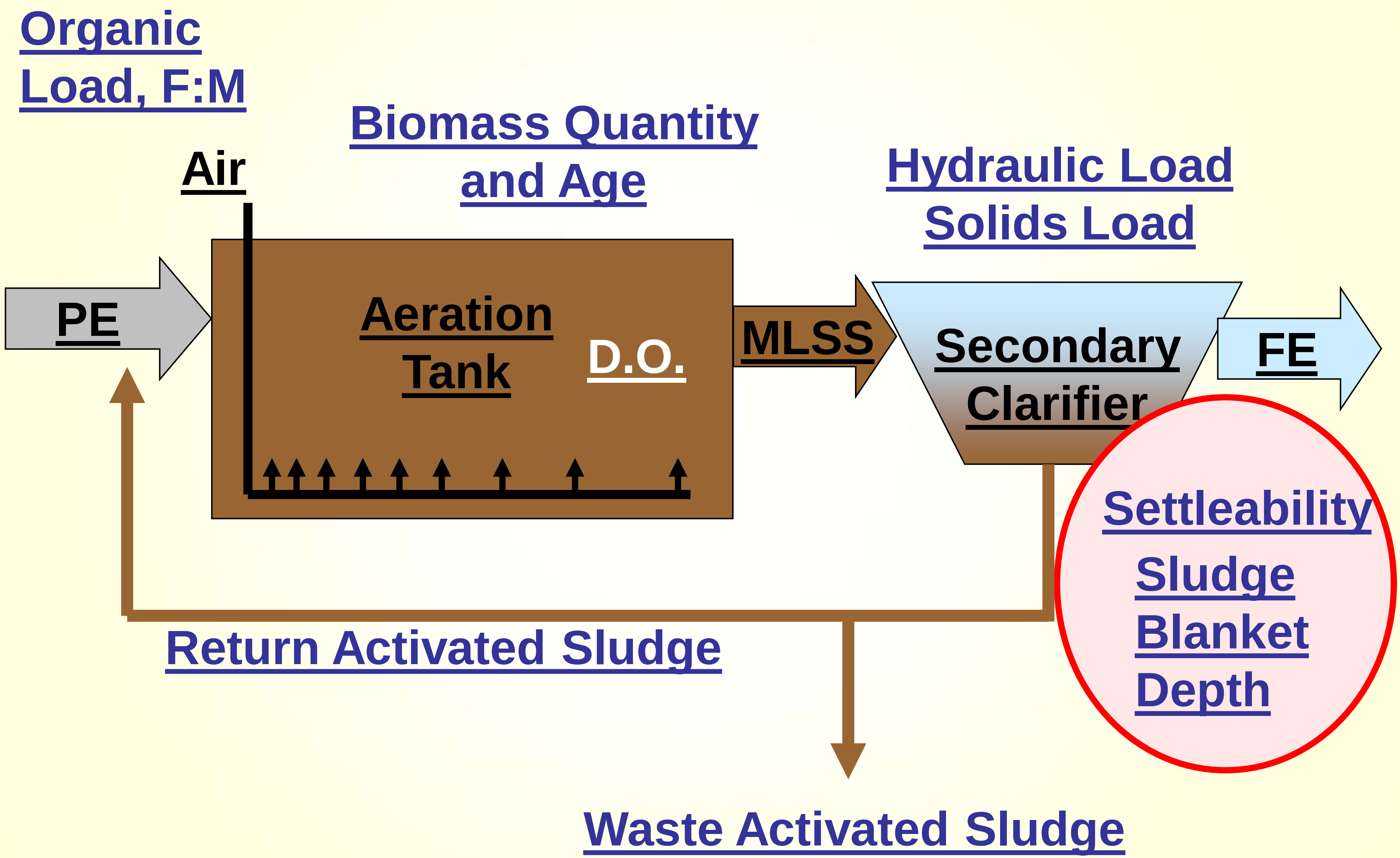
In Summary

Units for RQ will Match Units for Q

To Express RQ as % of Influent Flow:

$$\%\ RQ = \frac{100 \text{ X } MLSS}{RAS - MLSS}$$

Control Factors



Biological Wastewater Treatment

Three Steps

1. Transfer of Food from Wastewater to Cell.

2. Conversion of Food to New Cells and Byproducts.

3. Flocculation and Solids Removal

Biological Wastewater Treatment

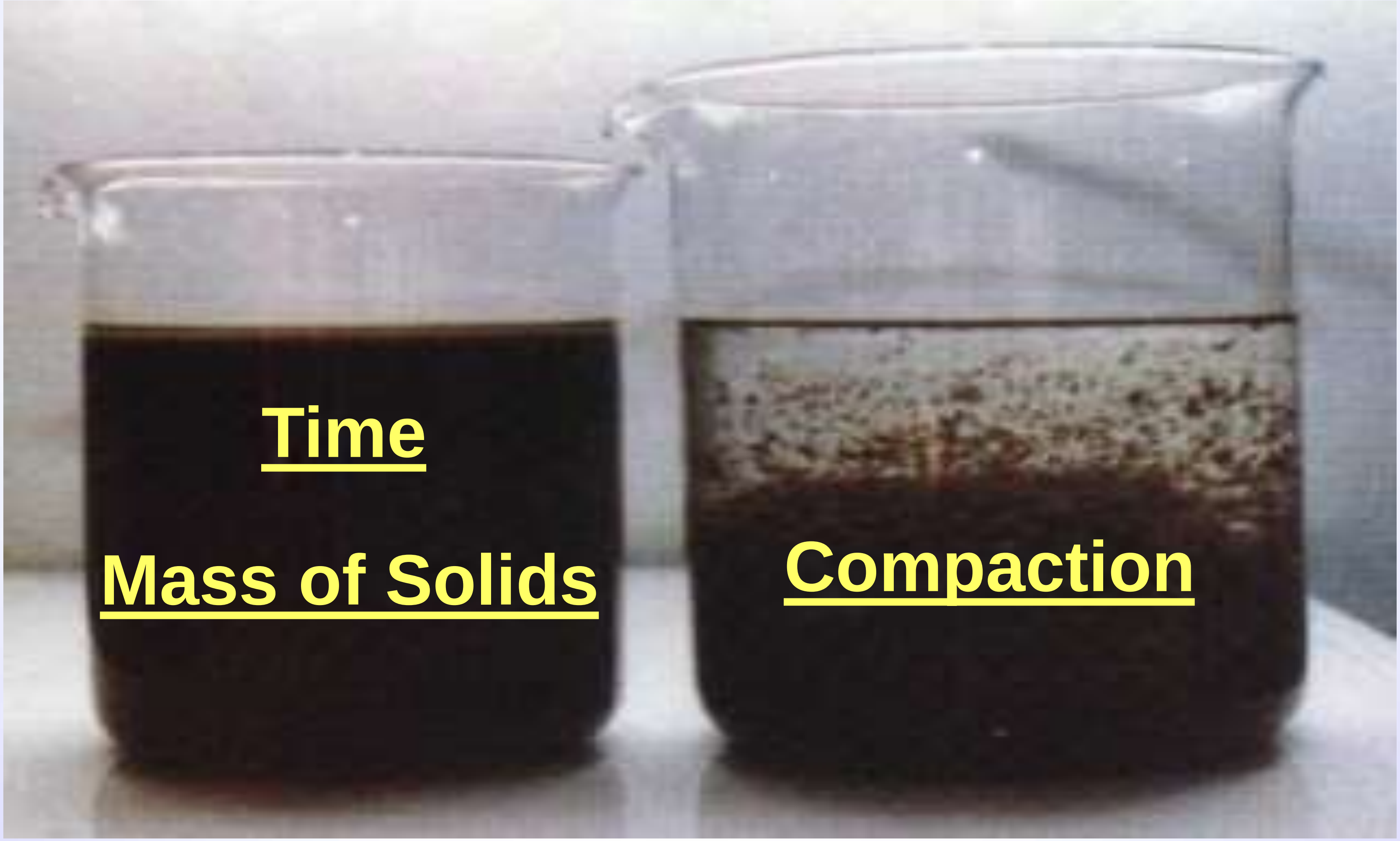
Three Steps

Even if the First Two Steps are Effective,
If Settling and Separation is Poor
RAS Will be Thin and/or Solids May Be Lost in the Effluent

3. Flocculation and Solids Removal

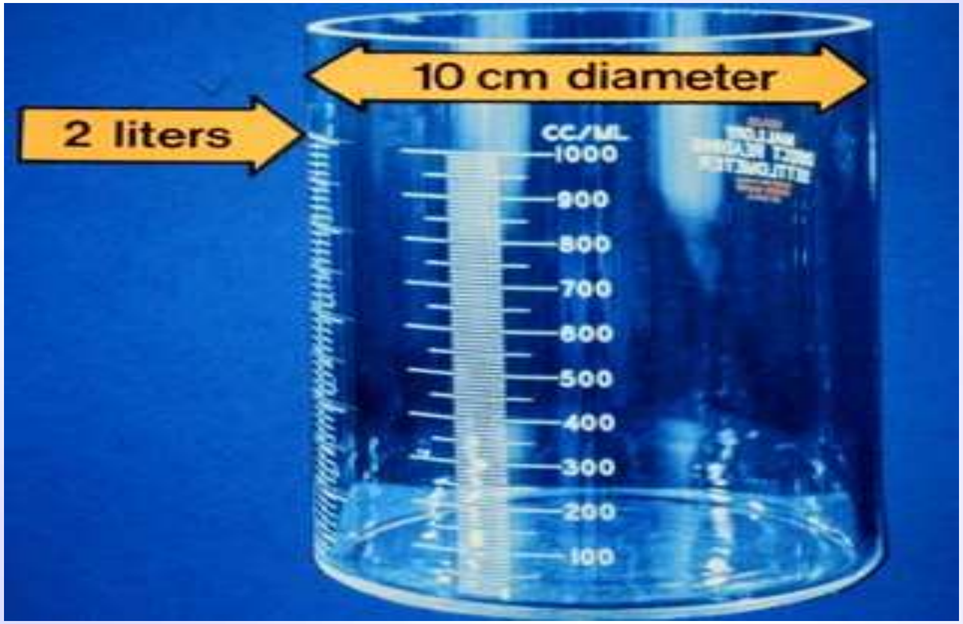
Settleometer Test

What Determines the Volume of Settled Sludge?



Determination of the Settling Properties (Compaction) of MLSS

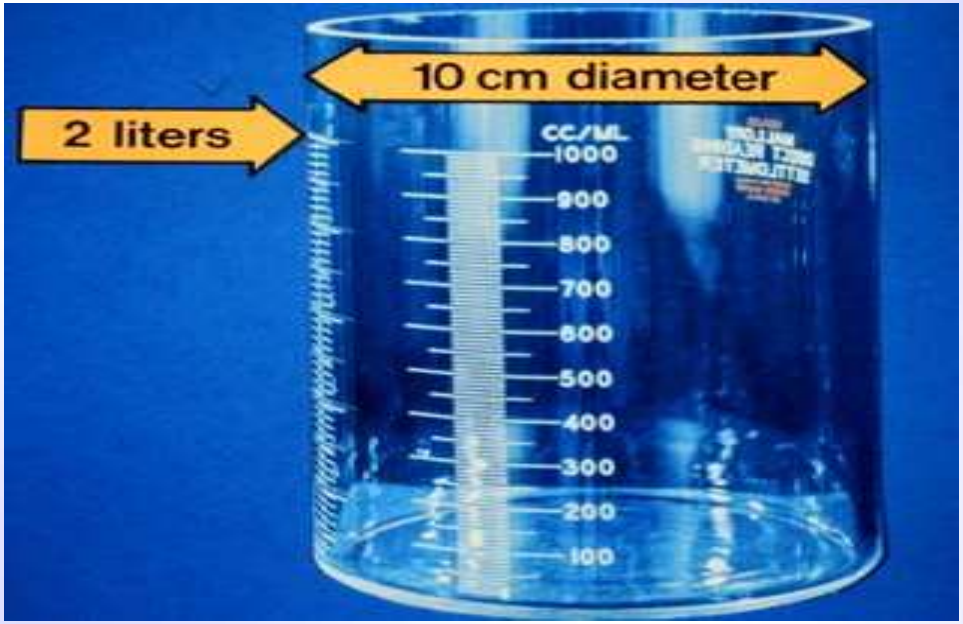
Settleometer Test



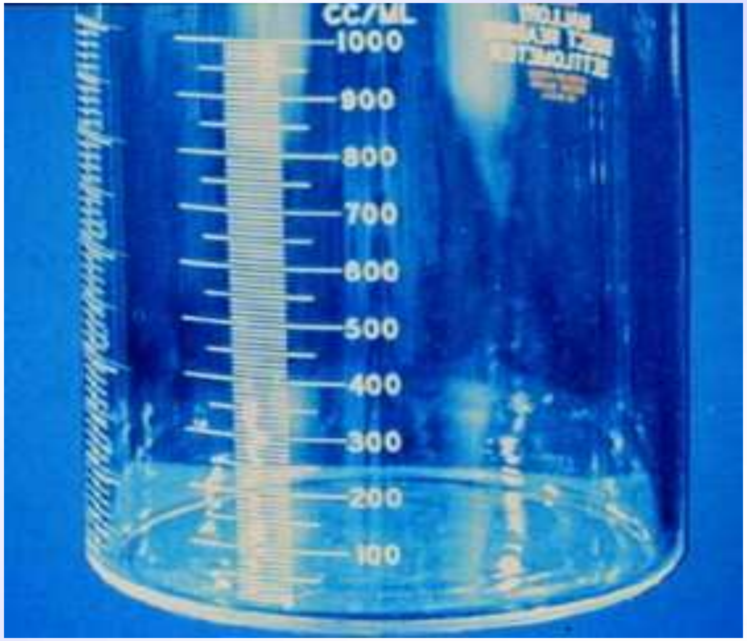
Although a 1000mL Graduated Cylinder May be Used A Settleometer Designed for this Test is Best

The Wider Container More Approximates a Clarifier

Settleometer Test



Although a 1000mL Graduated Cylinder May be Used A Settleometer Designed for this Test is Best



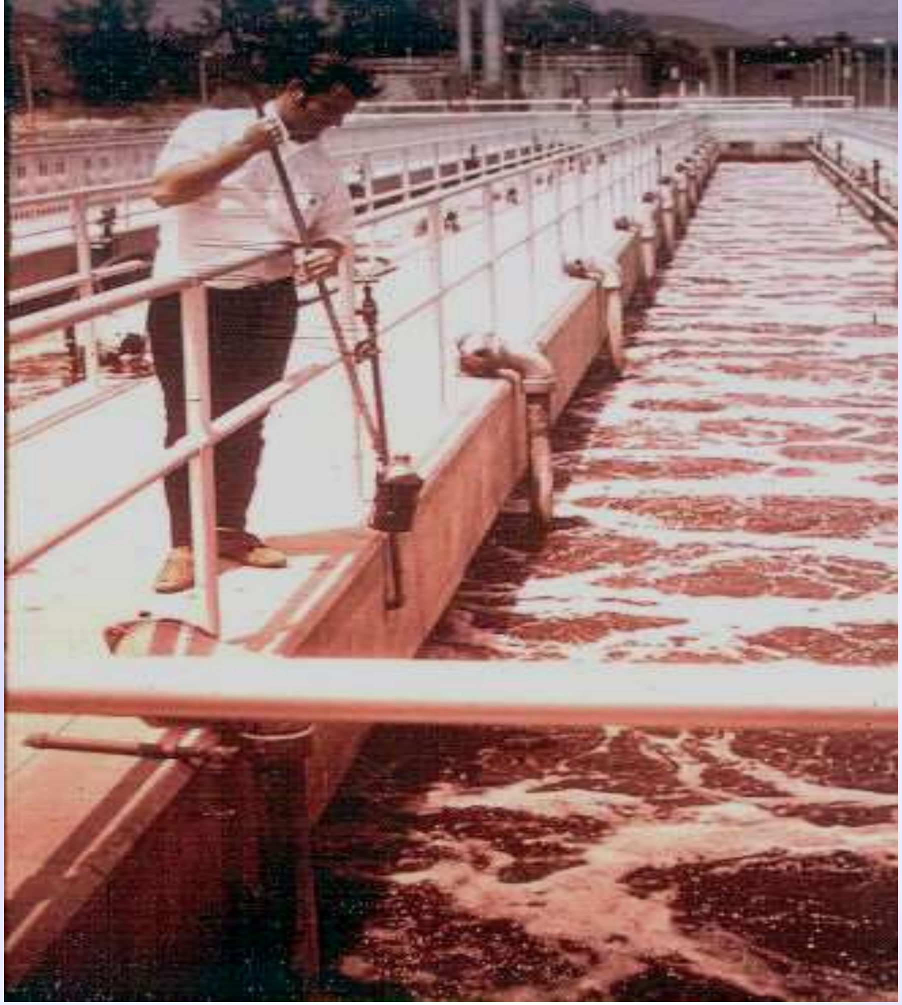
A Settleometer has a Capacity of 2000 mL

Graduated in mL/Liter

Settleometer Test

Collect Sample Below Scum Line

Set up Settling Test Immediately

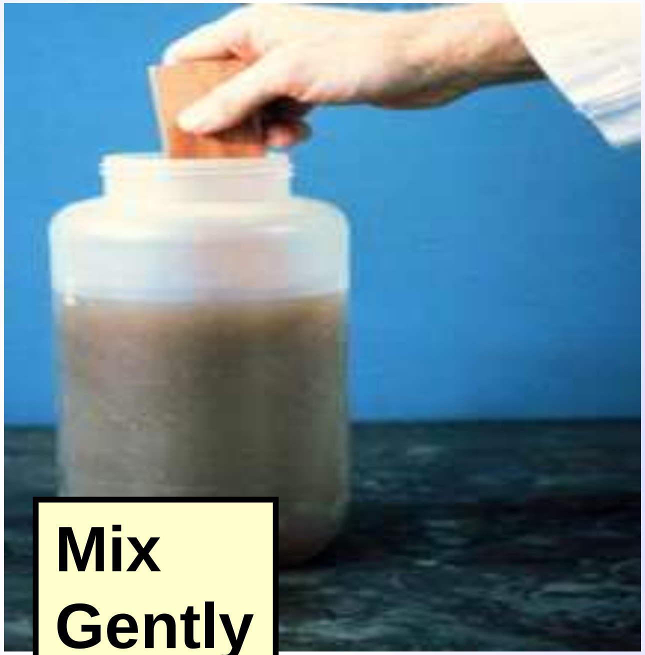


Also Determine MLSS, mg/L on a Portion of Same Sample

Settleometer Test

Fill Settleometer to
1000 Graduation

Start Timer



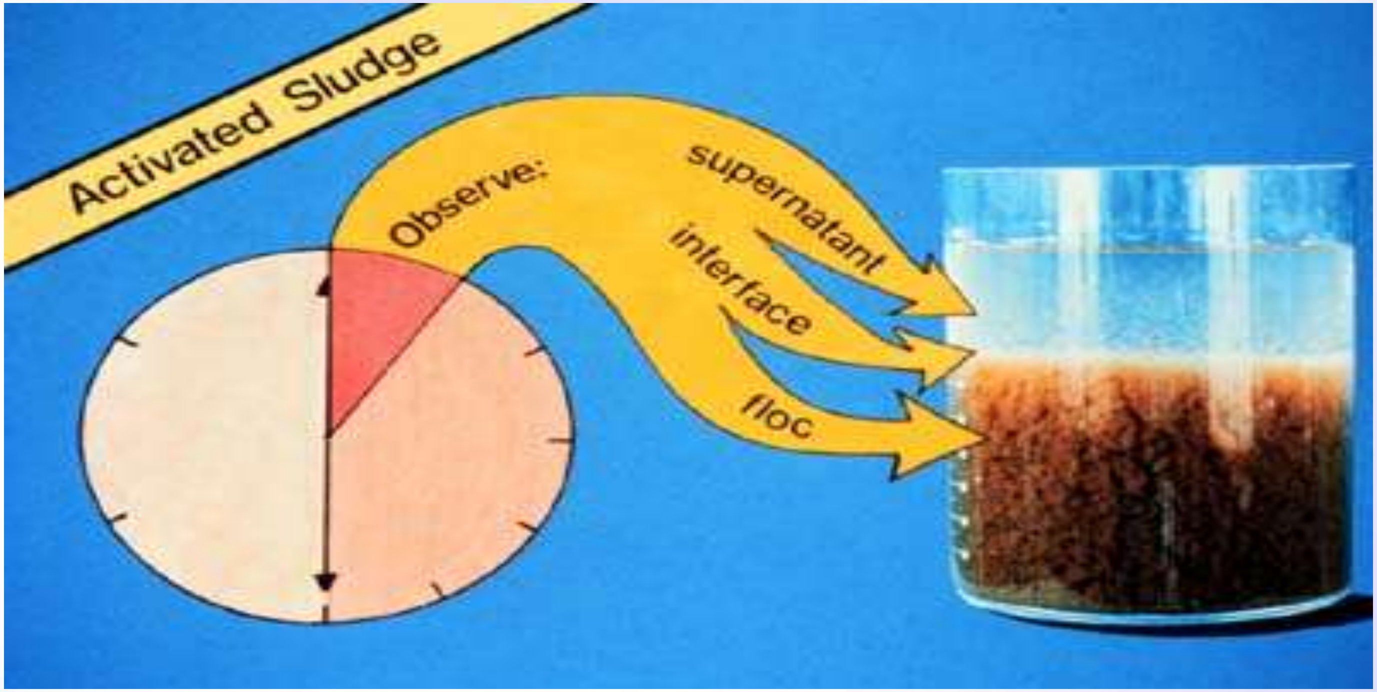
Mix
Gently

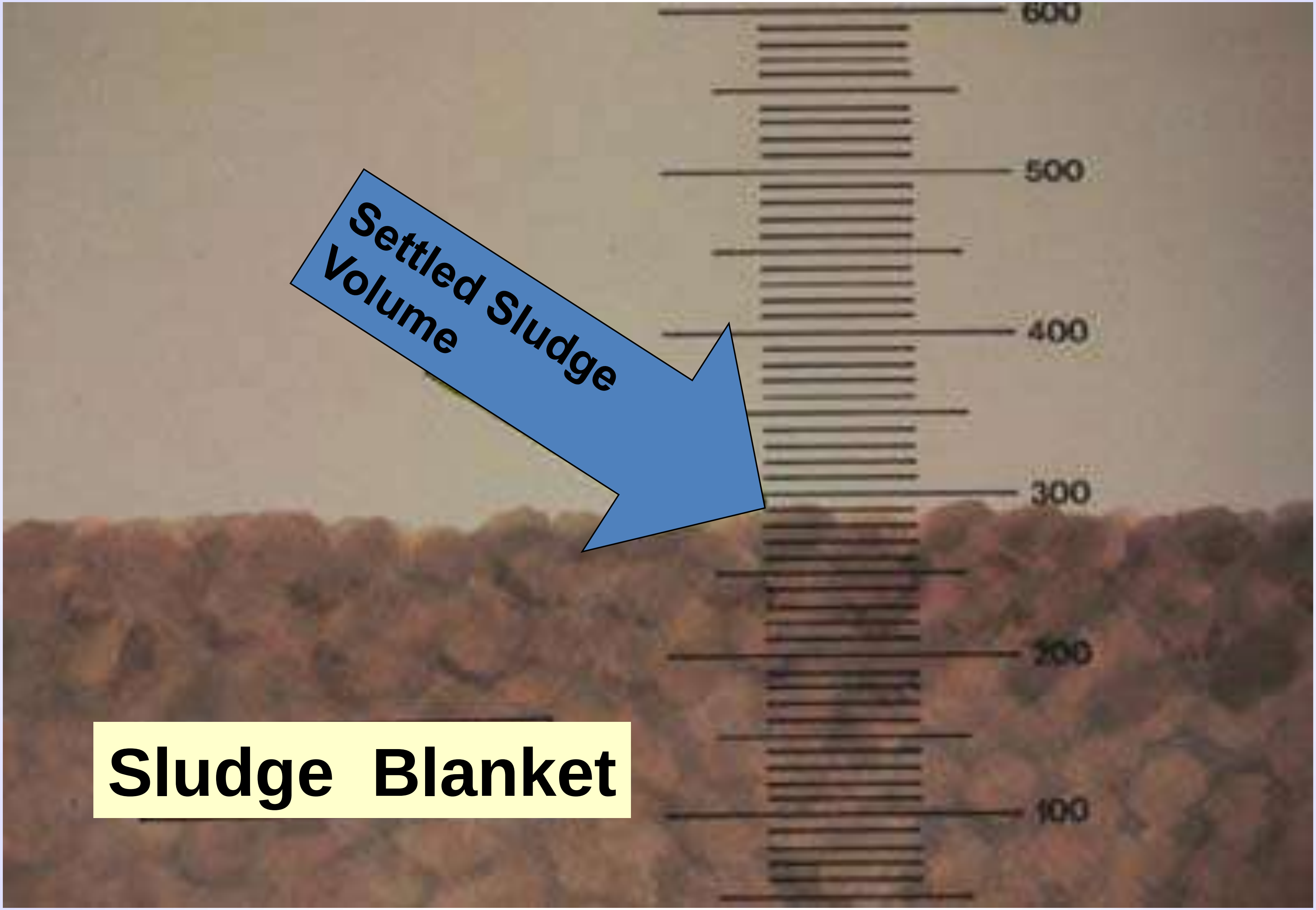
Settleometer Test

While Settling Observe:

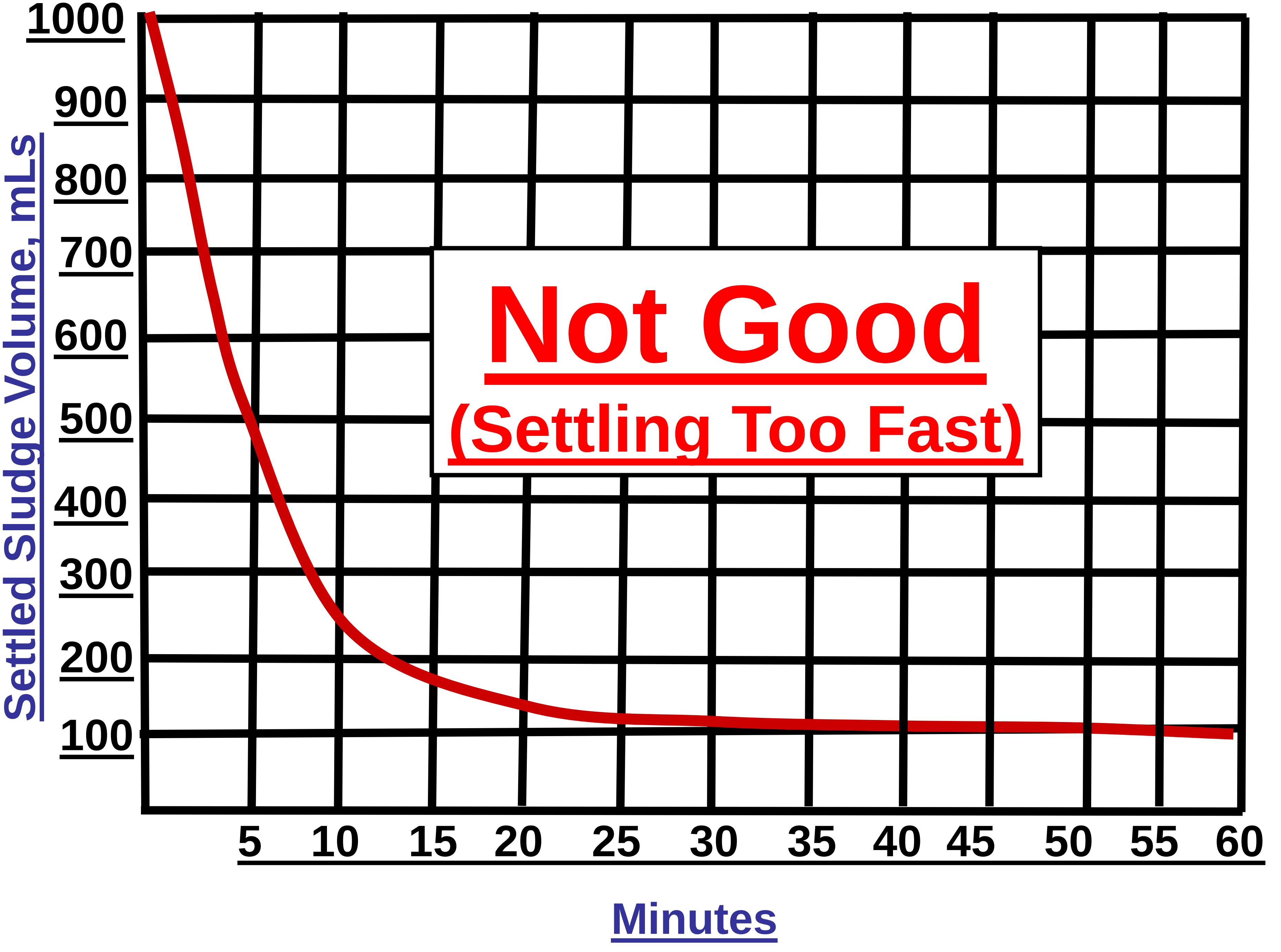
Color of ML and Supernatant
Supernatant Turbidity
Straggler Floc

Record Settled Sludge Volume Every 5 Minutes for 30 Minutes




600
500
400
300
200
100
Settled Sludge Volume
Sludge Blanket

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



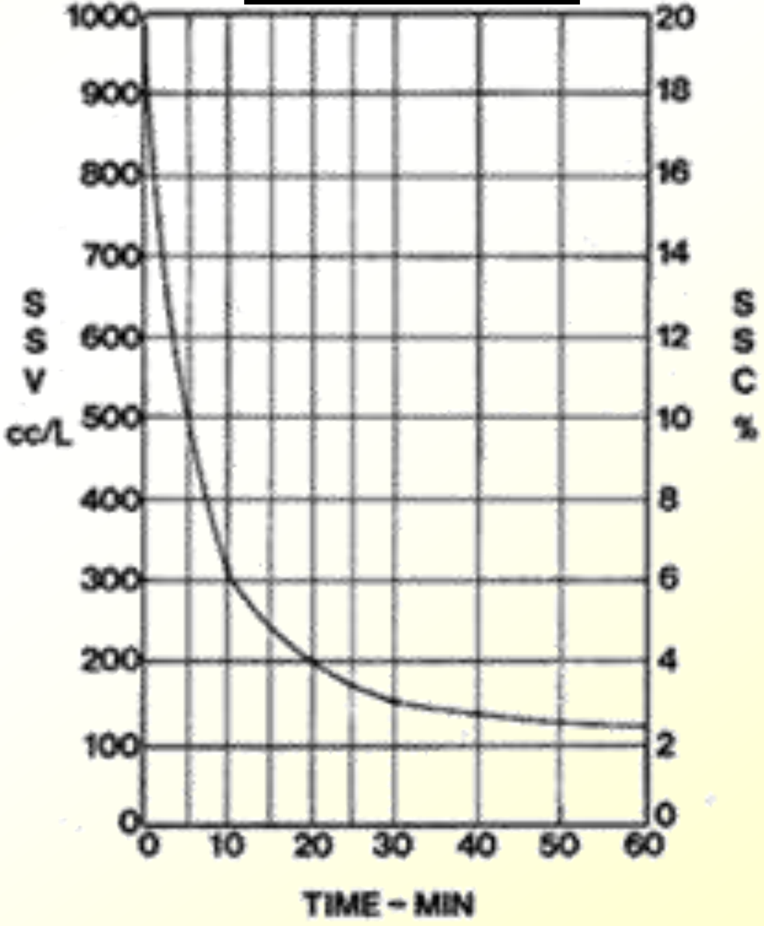
1000
900
800
700
600
500
400
300
200
100
Settled Sludge Volume, mLs
Not Good
(Settling Too Fast)
5
10
15
20
25
30
35
40
45
50
55
60
Minutes

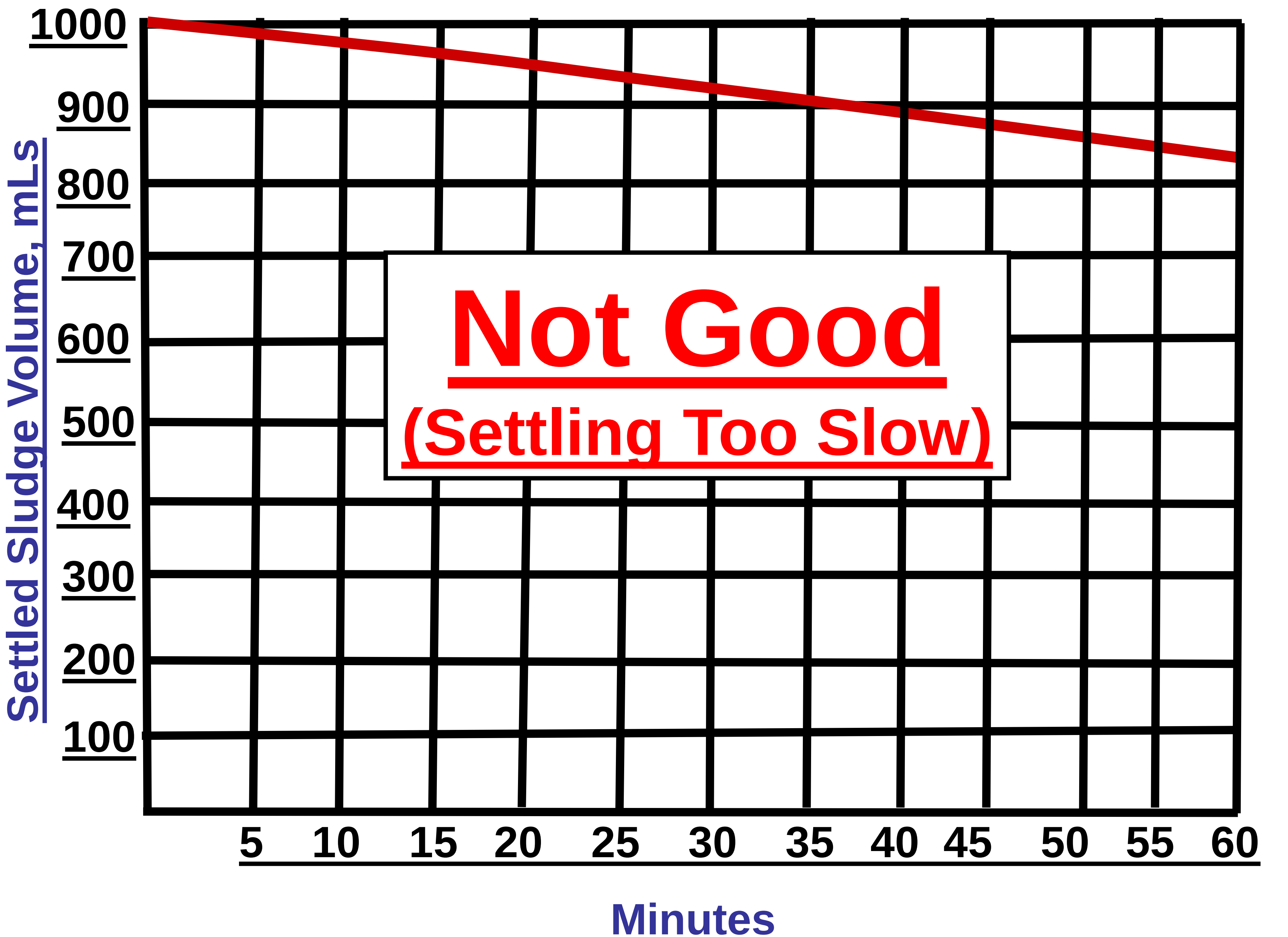
Settleometer Test

Indication of "Old" Sludge

Leaves Straggler Floc in Effluent

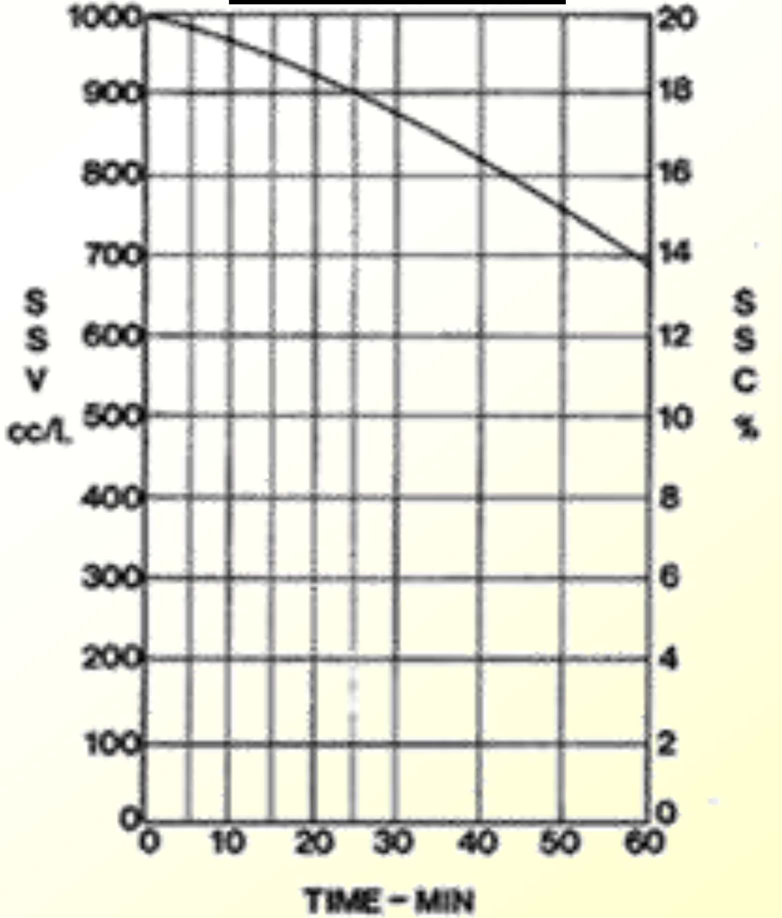
Too Fast




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

Settleometer Test

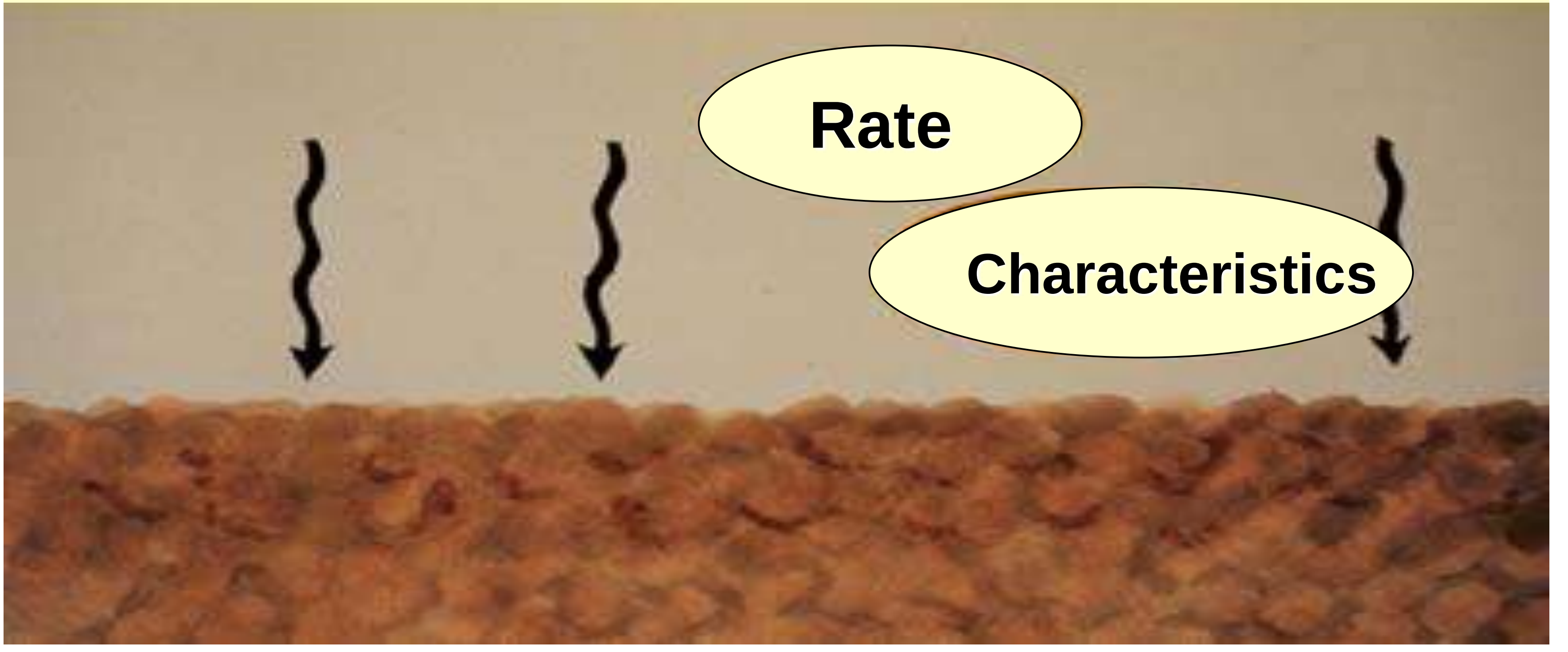
Too Slow



Not Compacting (Bulking)

Solids Washed Out in High Flows

Solids Separation



Watch for Indications of Denitrification

Gas Bubbles in Settled Sludge

Rising Sludge

Sludge Volume Index (SVI)

The volume in milliliters occupied by one gram of activated sludge which has settled for 30 min.

The volume compared to weight.

(Weight [in grams] of the solids that occupy the Volume.)

$$\text{SVI} = \frac{\text{mLs Settled in 30 min}}{\text{MLSS Conc, grams/L}} = \frac{\text{mLs Settled}}{\dfrac{\text{MLSS, mg/L}}{1000}}$$

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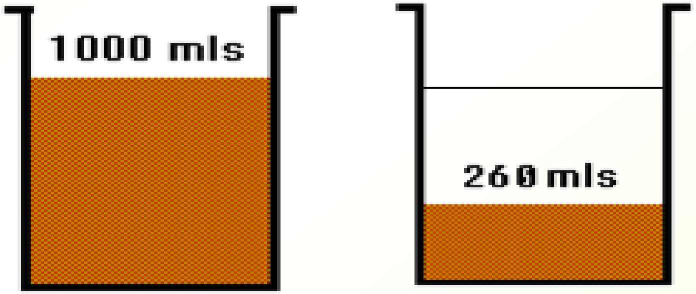
SVI Practice Problem:

30 minute settling	260 mL
MLSS Conc.	2400 mg/L



Work Calculations on Separate Paper Answer Given on Next Slide

Sludge Volume Index (SVI)

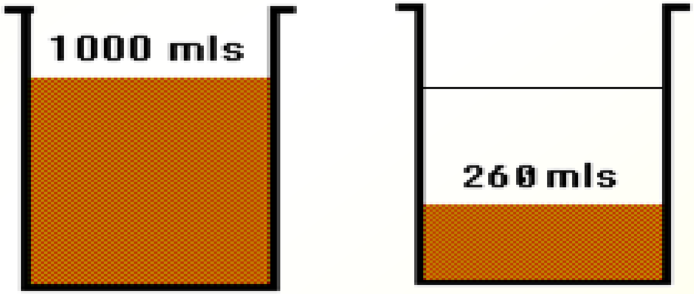
The volume in milliliters occupied by one gram of activated sludge which has settled for 30 min.

$$SVI = \frac{\text{mLs Settled in 30 min}}{\text{MLSS Conc, grams/L}} = \frac{\text{mLs Settled}}{\frac{\text{MLSS, mg/L}}{1000}}$$

SVI Practice Problem:

30 minute settling 260 mL
MLSS Conc. 2400 mg/L

$$SVI = \frac{260\text{ mL}}{\frac{2400\text{ mg/L}}{1000}}$$



$$SVI = \frac{260}{2.4} = 108$$

Sludge Volume Index (SVI)

The volume in milliliters occupied by one gram of activated sludge which has settled for 30 min.

$$\text{SVI} = \frac{\text{mLs Settled in 30 min}}{\text{MLSS Conc, grams/L}} = \frac{\text{mLs Settled}}{\frac{\text{MLSS, mg/L}}{1000}}$$

Typical Range for Good Settling 80 - 120

The higher the number, the less compact the sludge

Sludge Density Index (SDI)

The grams of activated sludge which occupies a volume of 100 mL after 30 min. of settling.

The weight compared to volume.

$$\text{SDI} = \frac{\text{grams/L of MLSS}}{\dfrac{\text{mLs settled in 30 min.}}{100}}$$

Sludge Density Index (SDI)

The grams of activated sludge which occupies a volume of 100 mL after 30 min. of settling

The weight compared to volume.

$$SDI = \frac{\text{MLSS / 1000}}{\text{30 min. Settling / 100}}$$

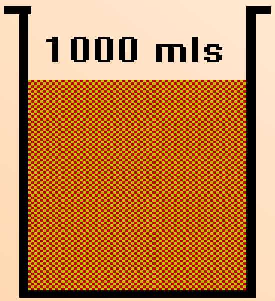
Sludge Density Index (SDI)

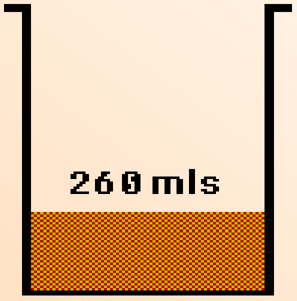
The grams of activated sludge which occupies a volume of 100 ml after 30 min. of settling

$$SDI = \frac{\text{grams/L of MLSS}}{\dfrac{\text{mLs settled in 30 min.}}{100}}$$

SDI Practice Problem:

30 minute settling 260 mL
MLSS Conc. 2400 mg/L





Work Calculations on Separate Paper Answer Given on Next Slide

Sludge Density Index (SDI)

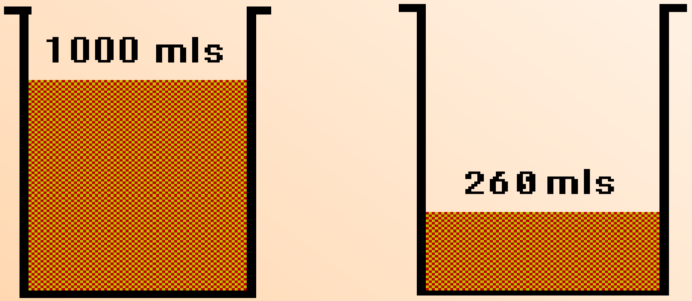
The grams of activated sludge which occupies a volume of 100 ml after 30 min. of settling

$$SDI = \frac{\text{grams/L of MLSS}}{\dfrac{\text{mLs settled in 30 min.}}{100}}$$

SDI Practice Problem:

30 minute settling 260 mL
MLSS Conc. 2400 mg/L

$$SDI = \frac{2400 \text{ mg/L} / 1000}{260 \text{ mL} / 100}$$



$$SDI = \frac{2.4}{2.6} = 0.92$$

Sludge Density Index (SDI)

The grams of activated sludge which occupies a volume of 100 ml after 30 min. of settling

$$\text{SDI} = \frac{\text{grams/L of MLSS}}{\dfrac{\text{mLs settled in 30 min.}}{100}}$$

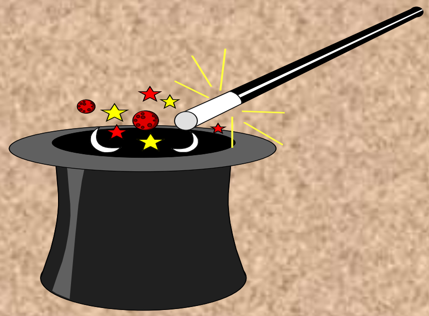
Typical Range for Good Settling 0.8 - 1.2

The lower the number, the less compact the sludge

SVI - SDI Relationship

$$SVI = \frac{100}{SDI}$$

$$SDI = \frac{100}{SVI}$$



SVI - SDI Relationship

$$SVI = \frac{100}{SDI} \qquad SDI = \frac{100}{SVI}$$

Practice Problems:

a) What is the SDI if the SVI is 133?

b) What is the SVI if the SDI is 0.6?

Work Calculations on Separate Paper
Answers Given on Next Slide

SVI - SDI Relationship

$$SVI = \frac{100}{SDI} \qquad SDI = \frac{100}{SVI}$$

Practice Problems:

a) What is the SDI if the SVI is 133?

100/133 = 0.75

b) What is the SVI if the SDI is 0.6?

100/0.6 = 167

Return Sludge Concentration and SDI

With the Clarifier Solids in Balance, the Settled Sludge Concentration in the Settleometer Will Approximate the RAS SS Concentration

Return Sludge Concentration and SDI

$$\text{SDI} = \frac{\text{MLSS, G/L}}{\dfrac{\text{mLs settled in 30 minutes}}{100}}$$

$$\text{SDI 1.0} = \frac{1.0\text{ G}}{100\text{ mLs settled}}$$

$$\frac{1\text{ G}}{100\text{ mL}} = \frac{1\text{ G}}{100\text{ G}} = 1\ \%$$

$$\frac{1\text{ G}}{100\text{ mL}} = \frac{1000\text{ mg}}{100\text{ mL}} = \frac{10{,}000\text{ mg}}{1{,}000\text{ mL}} = \frac{10{,}000\text{ mg}}{\text{L}}$$

Return Sludge Concentration and SDI

With Clarifier Solids in Balance :

SDI = RAS SS Conc. in Percent

SDI of 0.8

RAS SS = 0.8 % Solids

SDI X 10,000 = RAS SS in mg/L

SDI = 0.8

RAS SS = 8,000 mg/L

Sludge Volume Index

The volume in milliliters occupied by one gram of activated sludge which has settled for 30 min.

In Summary

The volume compared to weight.

Sludge Density Index

The grams of activated sludge which occupies a volume of 100 mL after 30 min. of settling.

The weight compared to volume.

Sludge Volume Index

$$SVI = \frac{\text{mLs Settled}}{\dfrac{\text{MLSS, mg/L}}{1000}}$$

Sludge Density Index

$$SDI = \frac{\text{grams/L of MLSS}}{\dfrac{\text{mLs settled in 30 min.}}{100}}$$

SVI - SDI Relationship

$$SVI = \frac{100}{SDI}$$

$$SDI = \frac{100}{SVI}$$

SVI - SDI

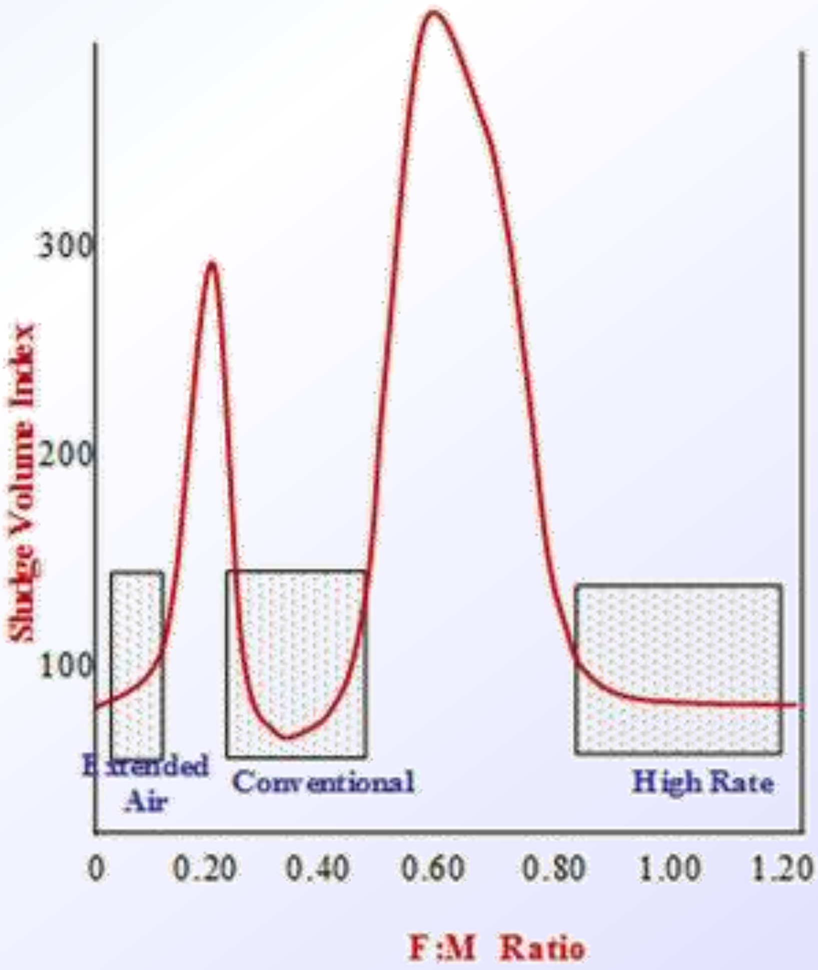
Typical SVI Range for Good Settling 80 - 120

Typical SDI Range for Good Settling 0.8 - 1.2

Relationship of F:M to Settleability System

This graph illustrates the Relationship Between The F:M of a System to the Ability of the Biomass to Settle in Clarifier

It Shows that there are Three Areas of Operation where the Biomass Normally Settles Well



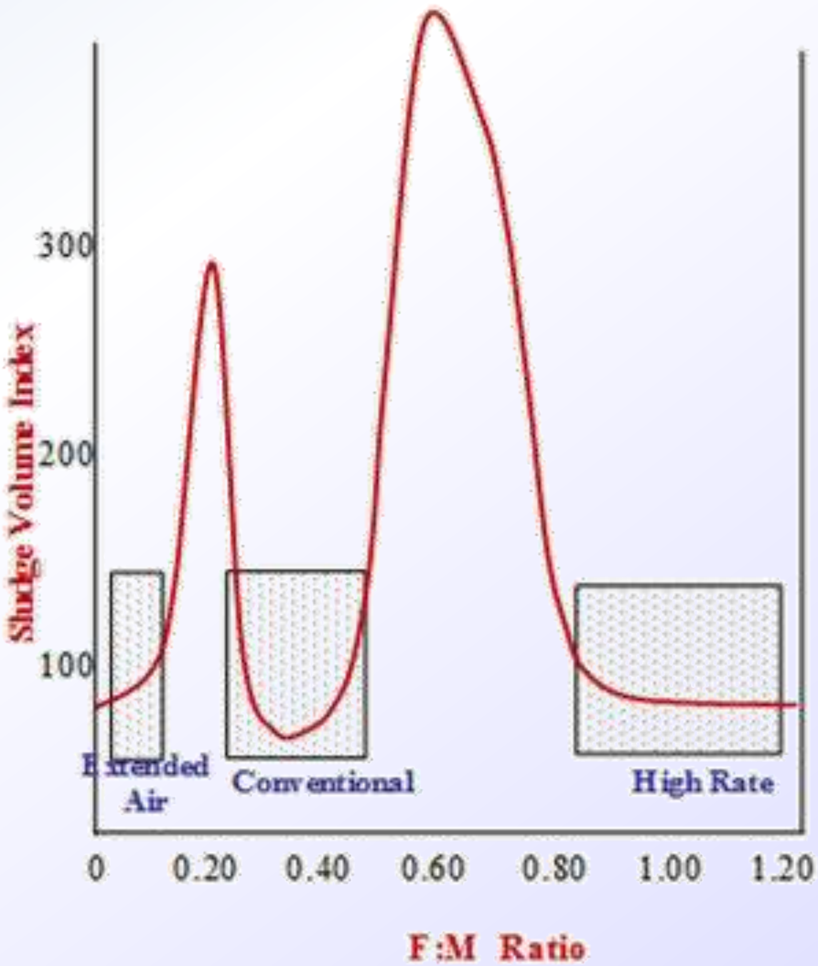
Relationship of F:M to Settleability System

These Areas as Defined by F:M Ratio Are

High Rate
F:M 0.9 to 1.2

Conventional
F:M 0.25 to 0.45

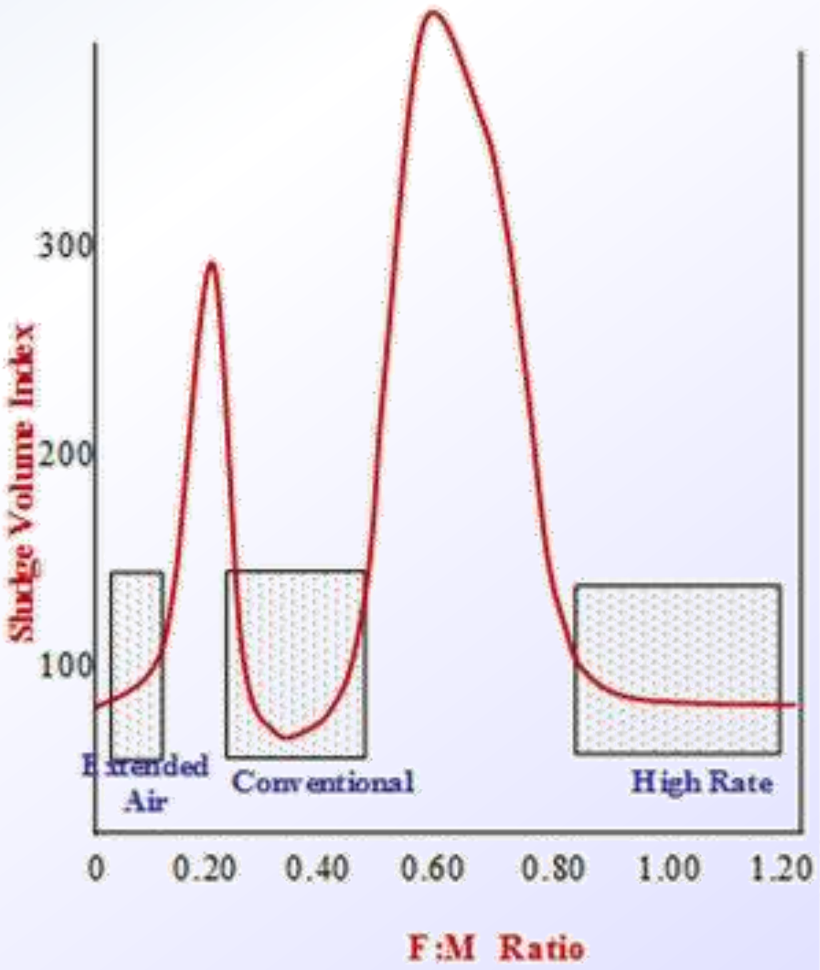
Extended Air
F:M Less than 0.2



Note: The High rate Mode is Seldom Used Except when Followed by Additional Treatment

Relationship of F:M to Settleability System

The Graph Also Shows the Potential Consequences of Operation with an F:M Out Of these Ranges



ACTIVATED SLUDGE PROCESS

Prepared by
Michigan Department of Environmental Quality
Operator Training and Certification Unit