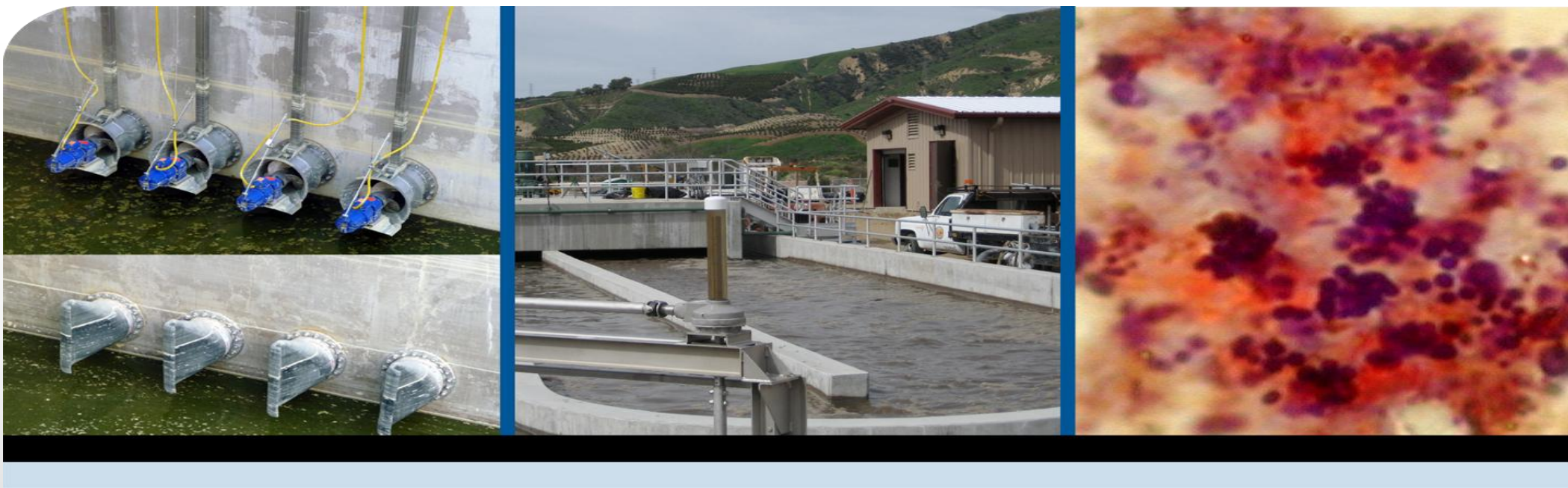




# FOUNDATIONAL ACTIVATED SLUDGE

**Bob Dabkowski, CWP**

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Special Thanks to Ronald Schuyler, CWP, PE, BCEE, WEF Fellow

 **PROCESS  
OPTIMIZATION** LLC  
TREAT WATER BETTER™

# LEARNING OBJECTIVES

- Understand What Makes Activated Sludge “Activated”
- Learn about different Activated Sludge processes



# AGENDA

1. History of Activated Sludge
2. Activated Sludge Processes

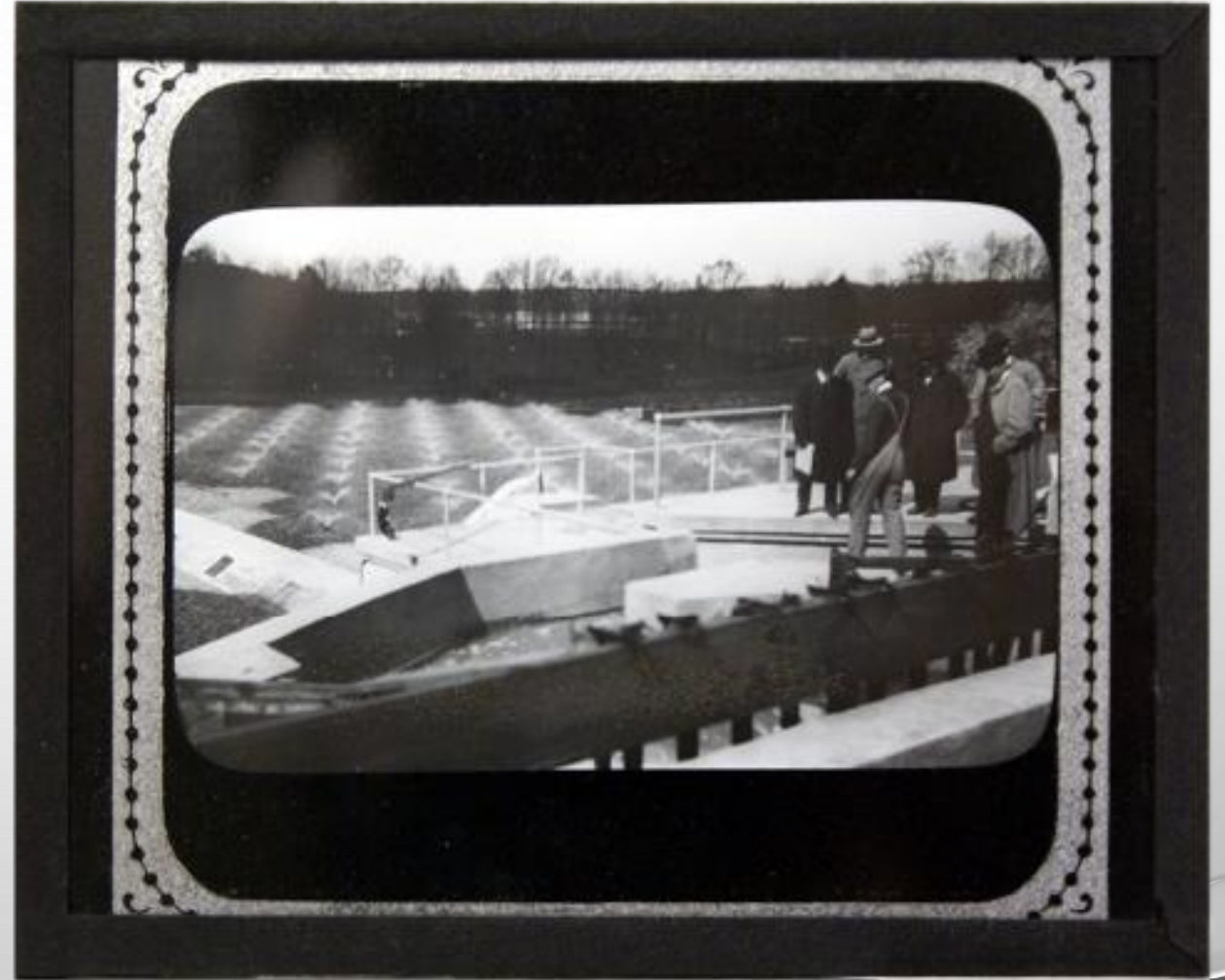


# WASTEWATER HISTORY

Early Treatment

Imhoff Tanks for liquid/solid separation

Spray Fields for biological treatment



# WASTEWATER HISTORY



**Hypothesis: There is a way to use aeration to intensify the process**

**Experiments since 1882**

**40 days for complete treatment  
(BOD removal and nitrification)**

# ACTIVATED SLUDGE HISTORY

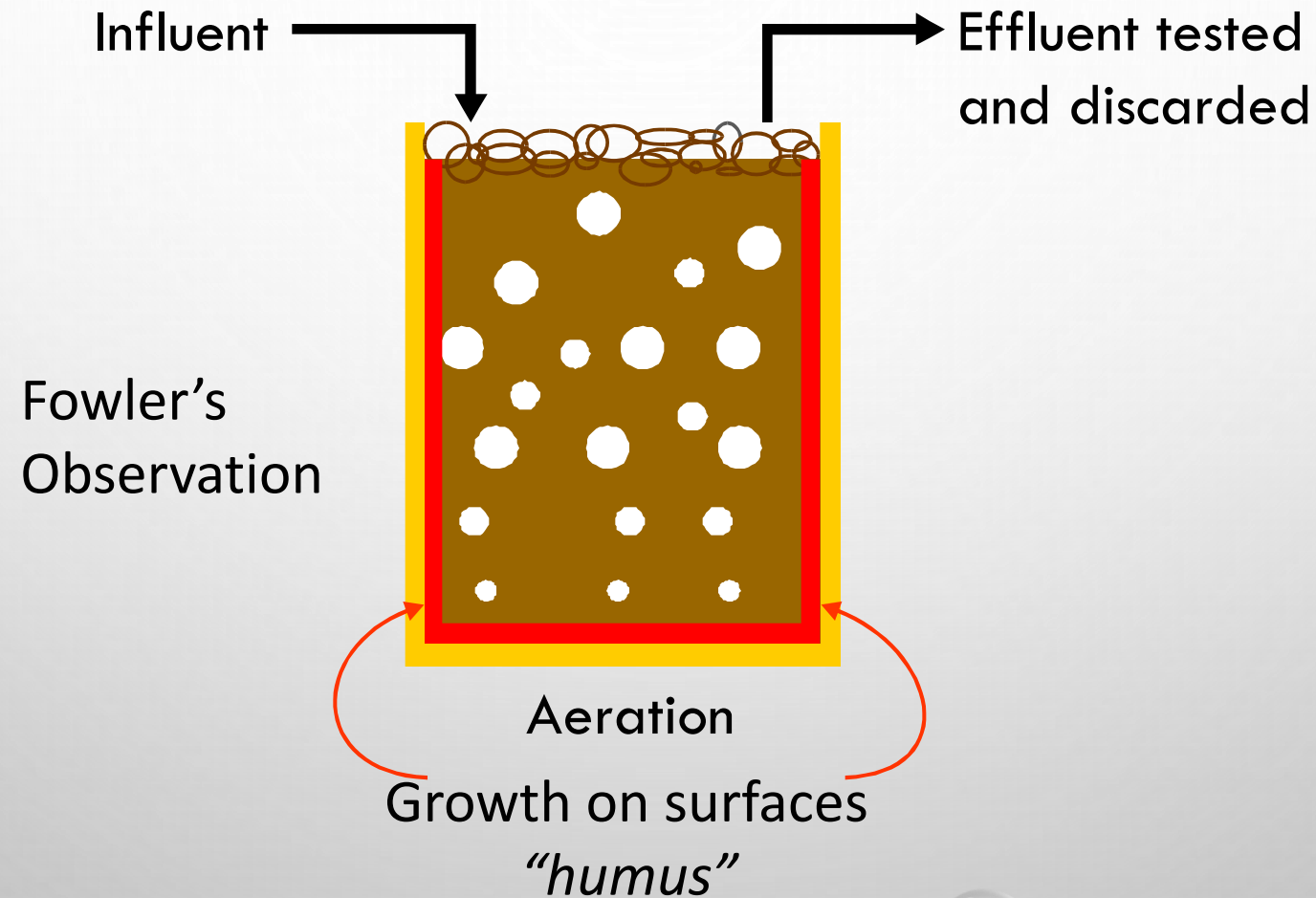
## Inspiration from US:

- Britain's Dr. Gilbert Fowler visits Lawrence (MA) Experiment Station 1912 on trip to look into New York Harbor Odor
- Observed wastewater aeration experiments
- Took ideas back to William Lockett and Edward Arden at the Manchester – Dayhulme WWTP



Gilbert J. Fowler

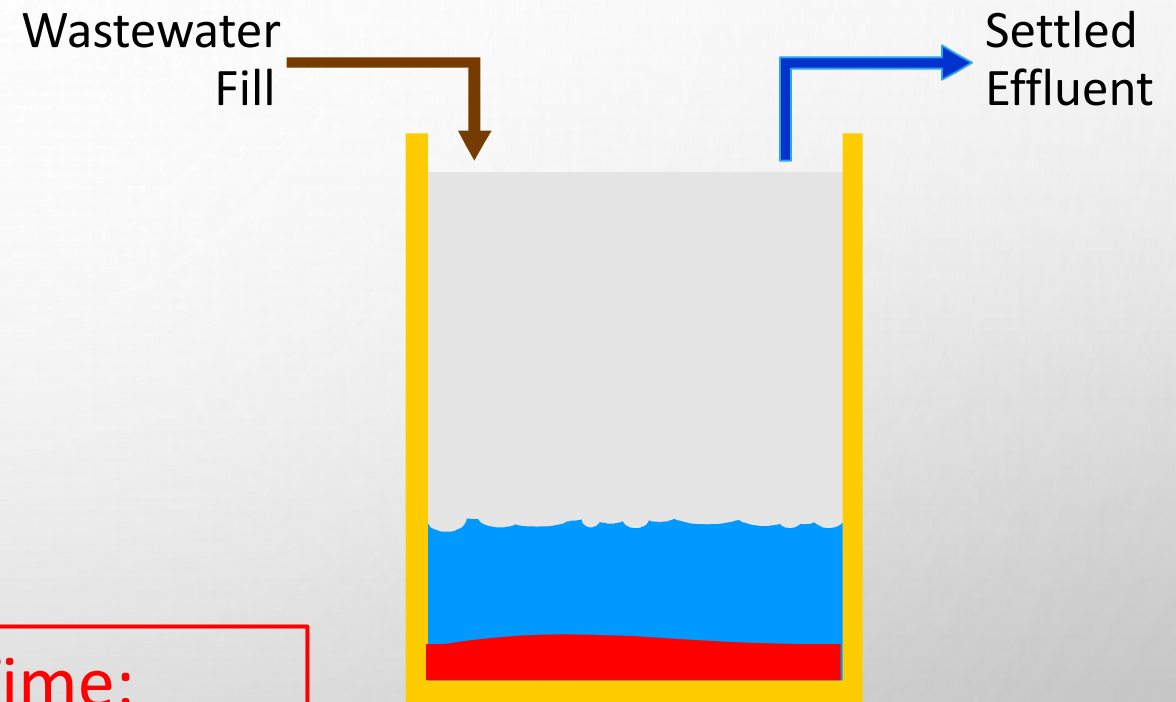
# LAWRENCE AERATION TEST PROCEDURES



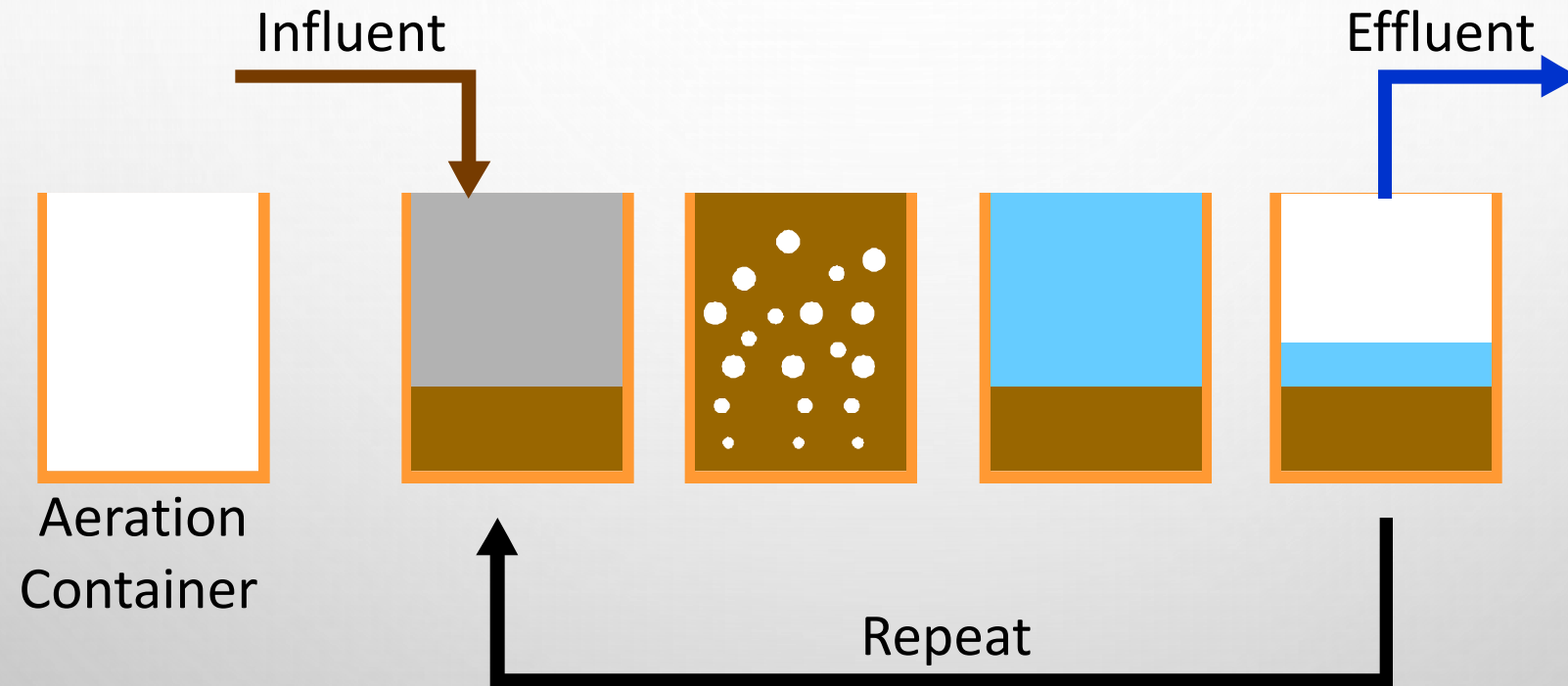
# FOWLER'S IDEA

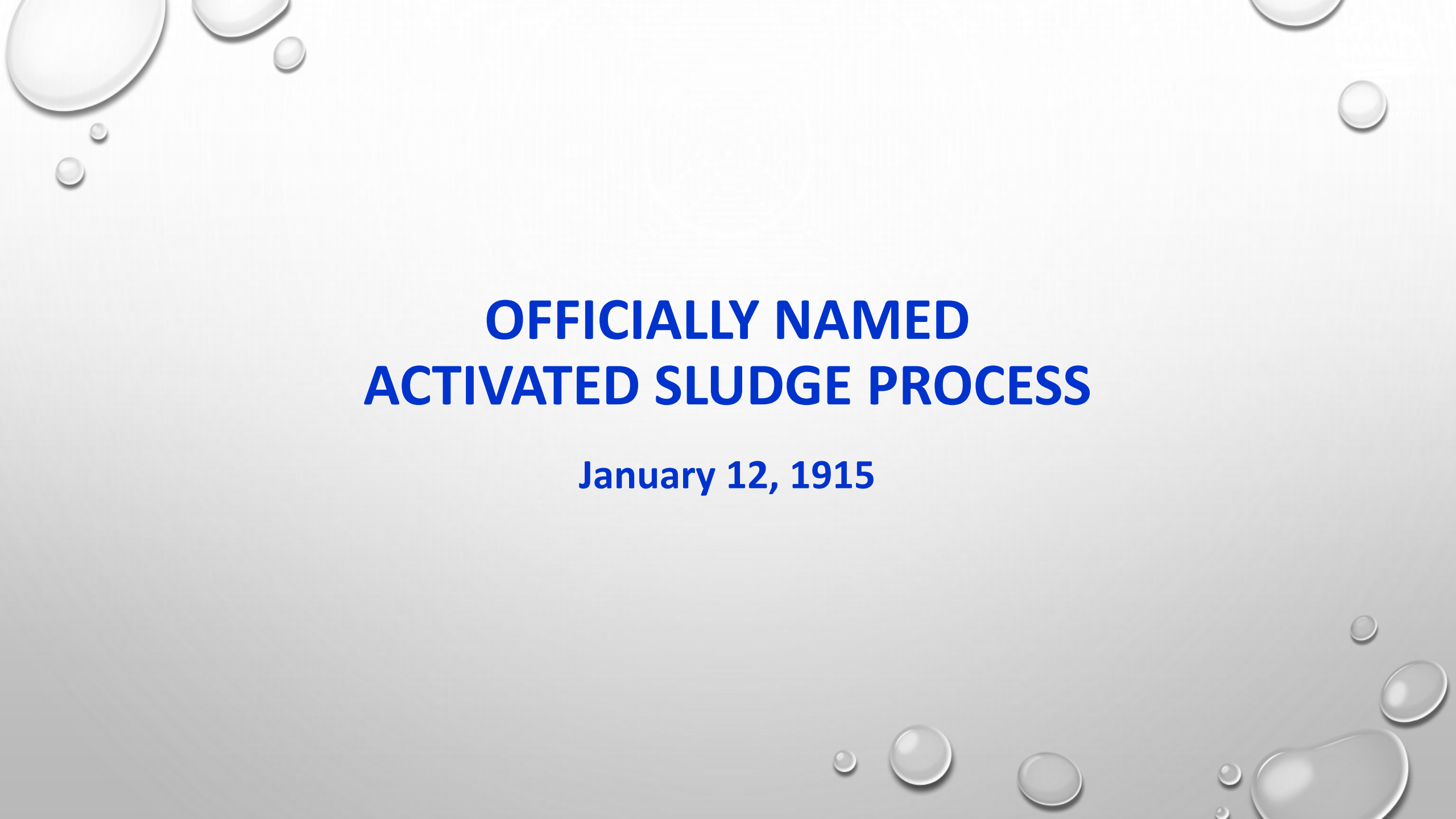
- After treatment completed, turn air off
- Scrape sides and bottom of container
- Collect scrapings and settled materials on the bottom
- Pour-off clear supernatant
- Refill with wastewater
- Begin aeration
- Repeat

Treatment Time:  
from 40 days to 24 hours



# ARDERN AND LOCKETT FILL AND DRAW PROCESS



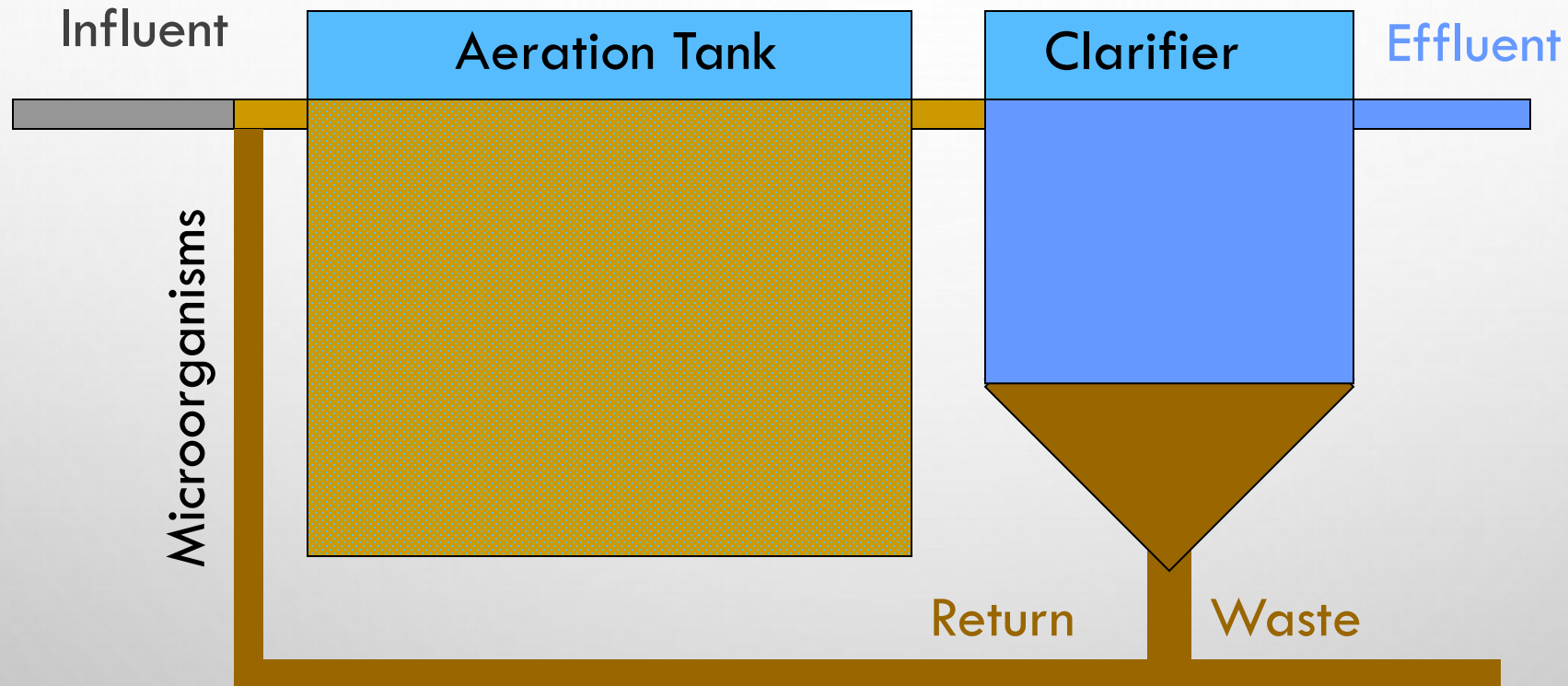


# **OFFICIALLY NAMED ACTIVATED SLUDGE PROCESS**

**January 12, 1915**



# ACTIVATED SLUDGE APPARATUS



# ACTIVATED SLUDGE PROCESS

“

The accepted current use of the word ‘process’ to define the ‘engineering apparatus’, such as the trickling filter process, etc., while convenient ..., frequently tends to obscure the essential *bio-chemical* nature of the treatment...

”

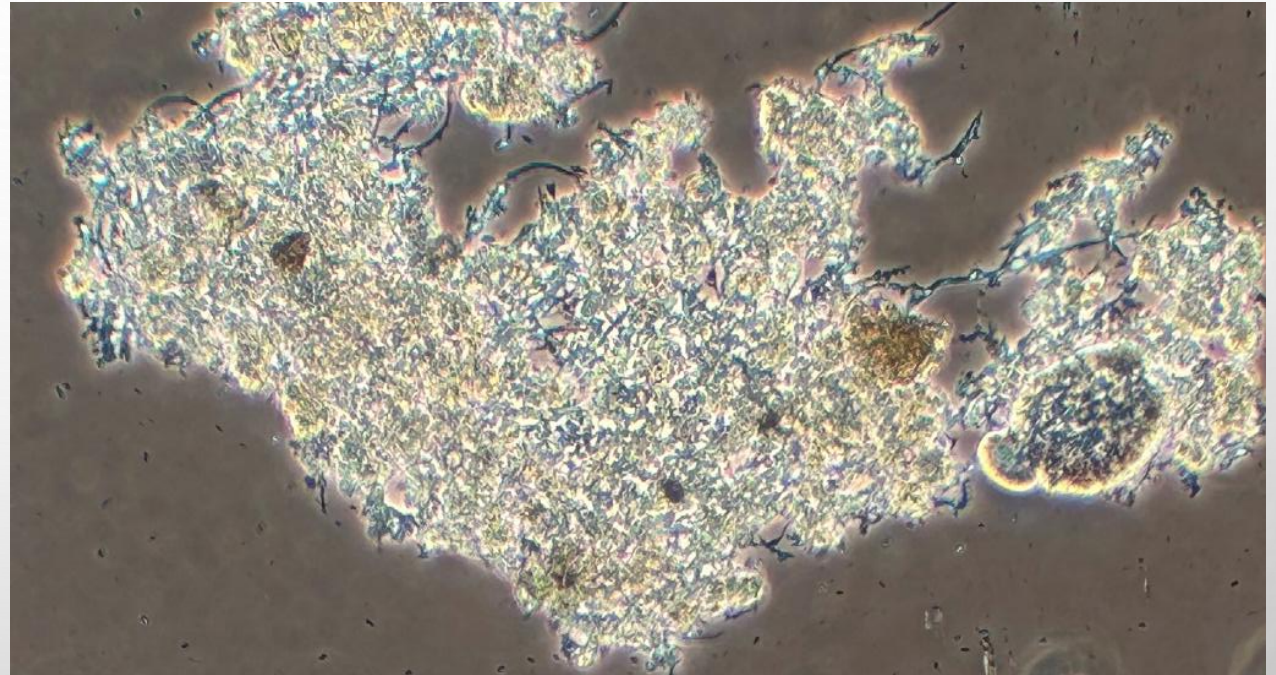
Earl B. Phelps, USPHS, 1917

**The microorganisms are the process!!**

# WHAT MICROBES DEFINE THE PROCESS?

- Bacteria and Archaea

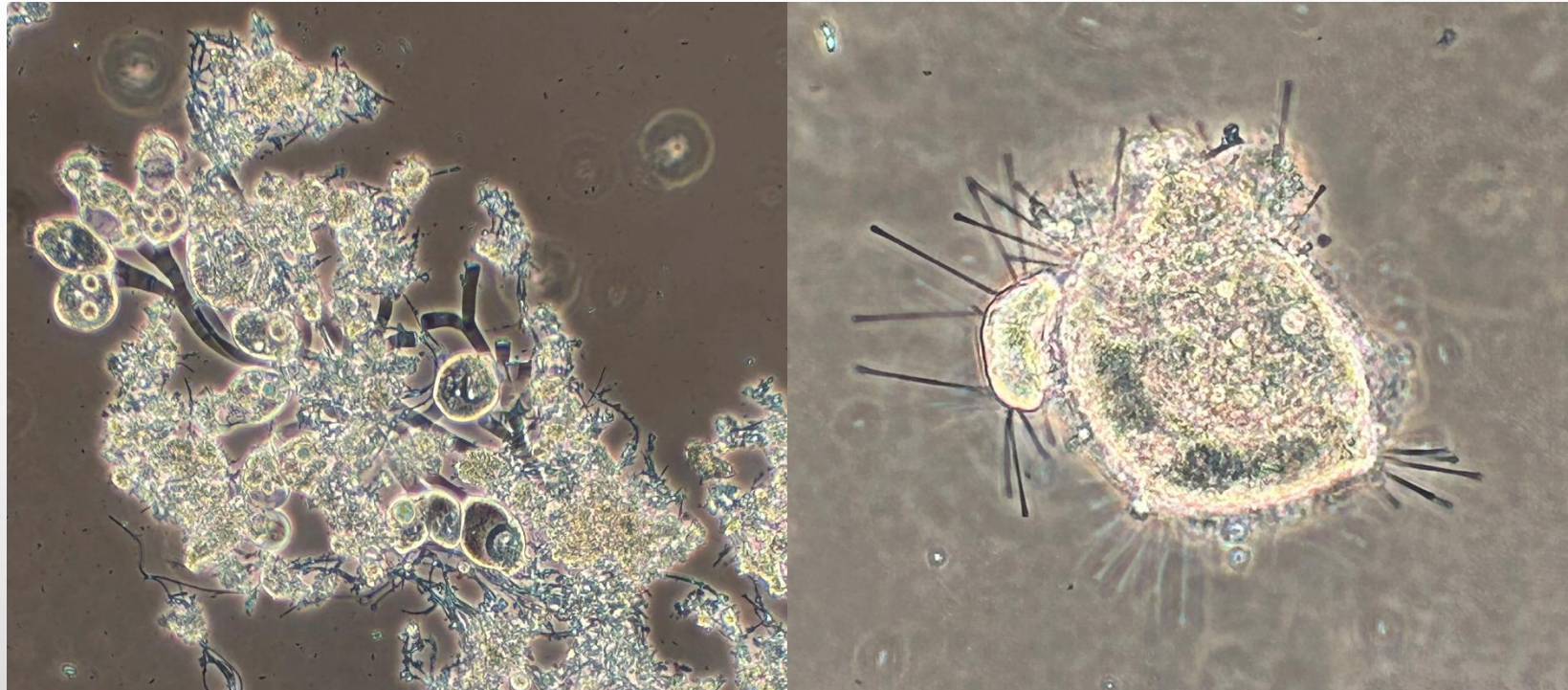
- Up to 99% by mass
- Feed on soluble and particulate BOD
- Convert Ammonia to Nitrate
- Convert Nitrate to Nitrogen Gas
- Remove Phosphorus



# WHAT MICROBES DEFINE THE PROCESS?

- Protozoa Eat Bacteria

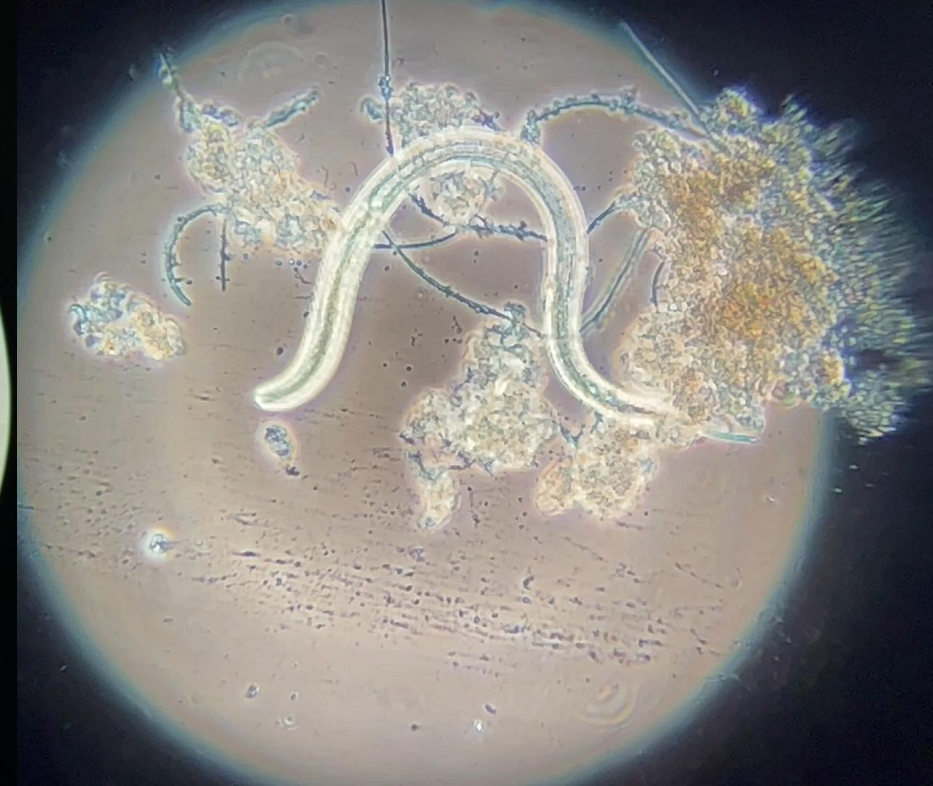
- Amoebas
- Flagellates
- Free-swimming Ciliates
- Crawling Ciliates
- Stalked Ciliates
- Suctoria



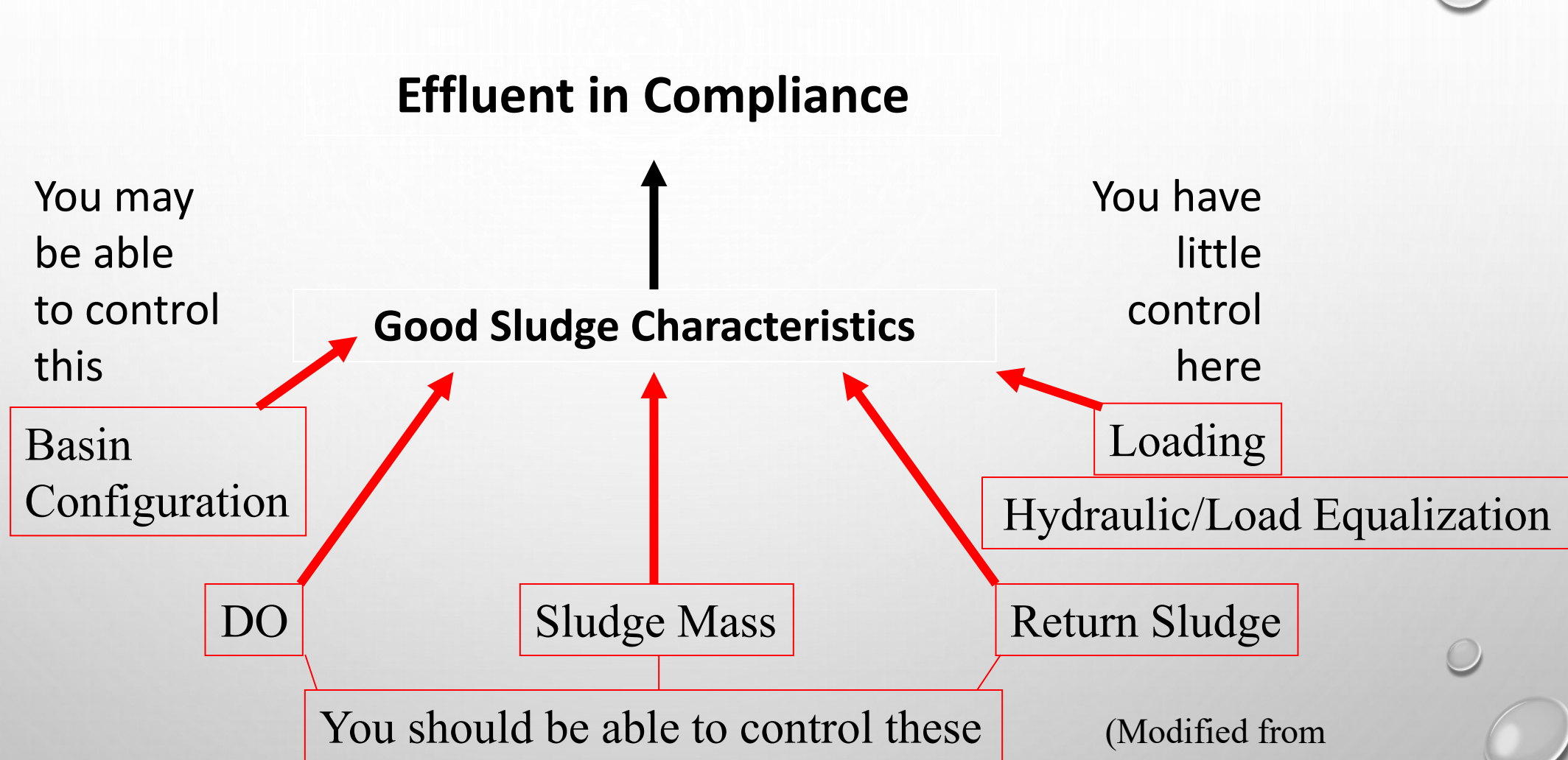
# WHAT MICROBES DEFINE THE PROCESS?

- Metazoa Eat All

- Rotifers
- Nematodes (Round Worms)
- Tardigrada (Water Bear)
- Annelida (Bristle Worms)
- Gastrotrichs



# OBJECTIVES AND CONTROLS



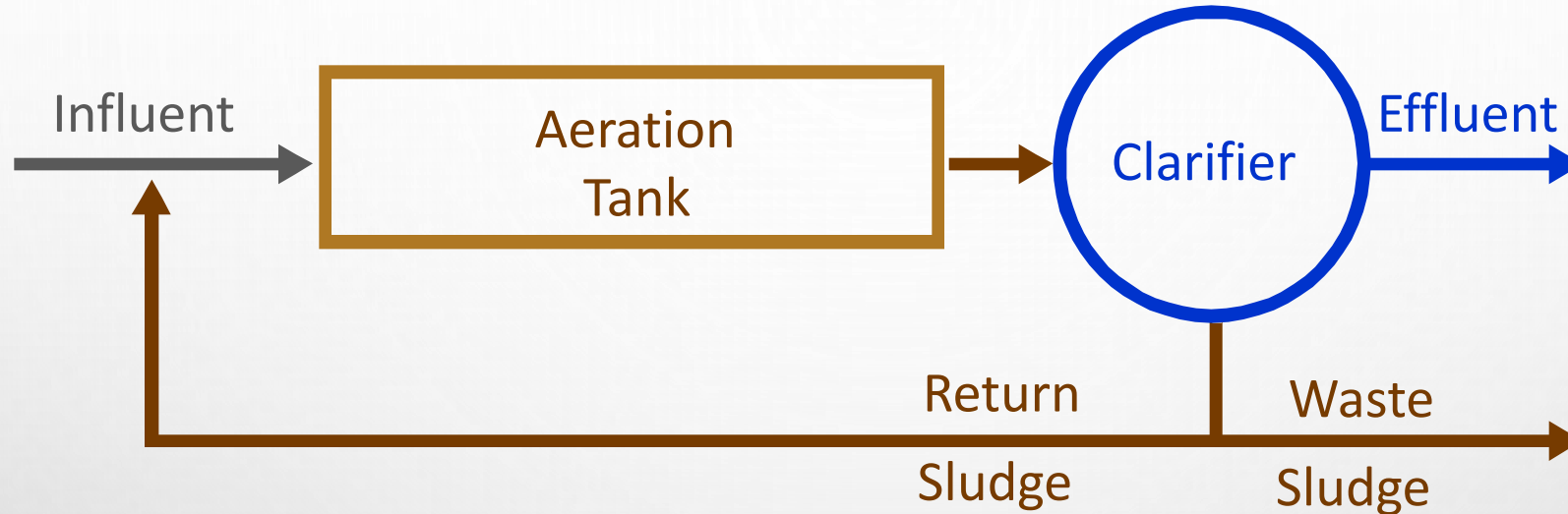
(Modified from  
Hegg, 1992)

# GOOD SLUDGE CHARACTERISTICS

- Removes soluble & particulate BOD (C & N)
- Is “activated” upon discharge to clarifier
- Flocculates well
  - Removes organic particles
  - Removes individual cells
- Settles well
  - Fast enough to control clarifier sludge blanket
  - Slow enough to provide clear effluent
- Minimizes clarifier denitrification



# APPARATUS: FLOW-THROUGH WITH TWO TANKS



## Objectives:

- Convert soluble & insoluble BOD to cell mass
- Develop sludge (cell mass) that will settle
- Remove the cell mass from the treated wastewater
- Waste cell mass to control the process



## PROCESS CHARACTERIZATION

- Loading variations
  - Hydraulic
  - Organic
- Flow configurations
  - Aeration
  - Misc.

## DESIGN PARAMETERS

- DT - Detention Time (hydraulic)
  - MCRT – Mean Cell Residence Time
    - SRT – Solids Retention Time  
(w/o clarifier solids)
  - F/M – Food to Microorganism Ratio
    - SL – Space Loading
    - SP – Solids Production
- 

# MATH REVIEW

- Mass = Concentration x Volume
  - $\text{mg/L} * \text{L} = \text{mg}$
- Best to use meaningful units
  - $\text{Lb} = \text{C (mg/L)} * \text{V (MG)} * 8.34$
  - Units of 8.34 factor are lb/gallon

## DETENTION TIME

$$DT = \frac{ATank\ Volume * 24}{Q + RSF}$$

- Q = Influent flow rate in MGD
- RSF = Return sludge flow rate in MGD
- Volume in MG
- DT in hours

# SLUDGE RETENTION TIME

## MEAN CELL RETENTION TIME

$$SRT = \frac{lb\ MLSS\ in\ ATank}{lb\ TSS\ Wasted\ / day}$$

$$MCRT = \frac{lb\ MLSS\ in\ ATank + lb\ TSS\ in\ Clarifier}{lb\ TSS\ Wasted\ / day\ in\ Waste\ Line + Effluent}$$

## FOOD TO MICROORGANISM RATIO

$$F / M = \frac{\text{lb BOD Removed / day}}{\text{lb MLVSS in System}}$$

## SPACE LOADING

$$SL = \frac{\textit{lb BOD Applied / day}}{\textit{ATank Volume in } 10^3 \textit{ ft}^3}$$

## SOLIDS PRODUCTION

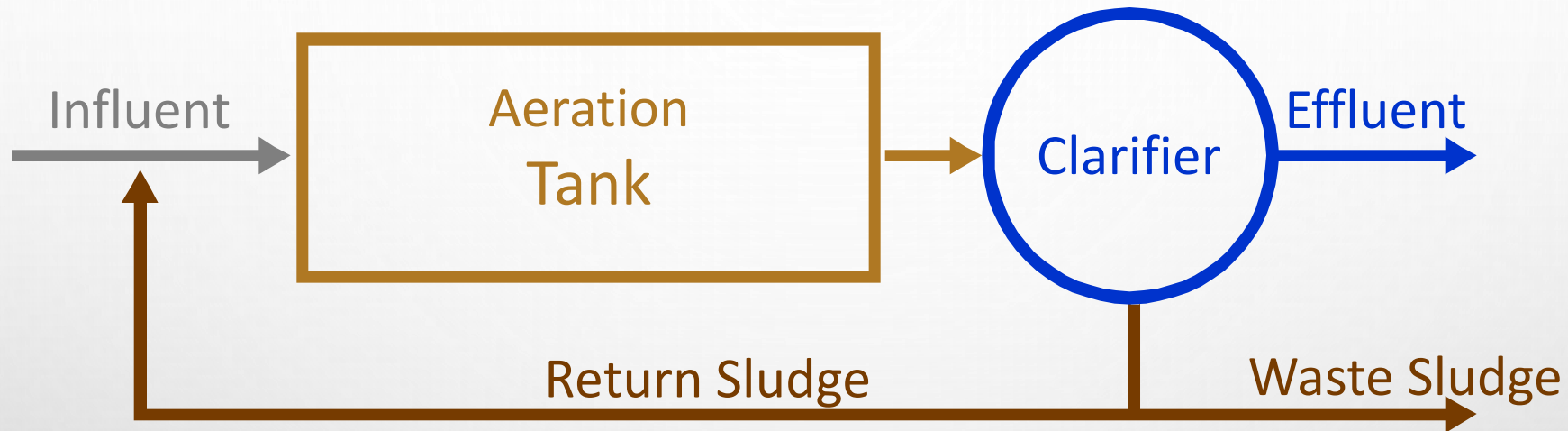
$$SP = \frac{lb\ TSS\ produced}{lb\ BOD\ removed}$$

# PROCESS CHARACTERIZATION

- **Loading variations**
  - Hydraulic
  - Organic
- Flow configurations
- Aeration
- Misc.

| Variation         | DT    | F/M      | MCRT  | SL     |
|-------------------|-------|----------|-------|--------|
| Extended Aeration | 16-36 | 0.04-0.1 | 15-40 | 5-25   |
| Conventional      | 4-8   | 0.2-0.4  | 3-15  | 20-40  |
| Step-feed         | 3-5   | 0.2-0.5  | 3-15  | 50     |
| Contact Stab.     | 0.5/4 | 0.2-0.6  | 5-10  | 60-75  |
| Complete mix      | 3-5   | 0.2-0.6  | 3-15  | 20-100 |
| High Rate         | 1.5-3 | 1.5-2    | 0.5-2 | 75-150 |

# EXTENDED AERATION



DT = 18 - 36 hr  
F/M = 0.05 - 0.2  
SL < 25 lb/10<sup>3</sup> ft<sup>3</sup>

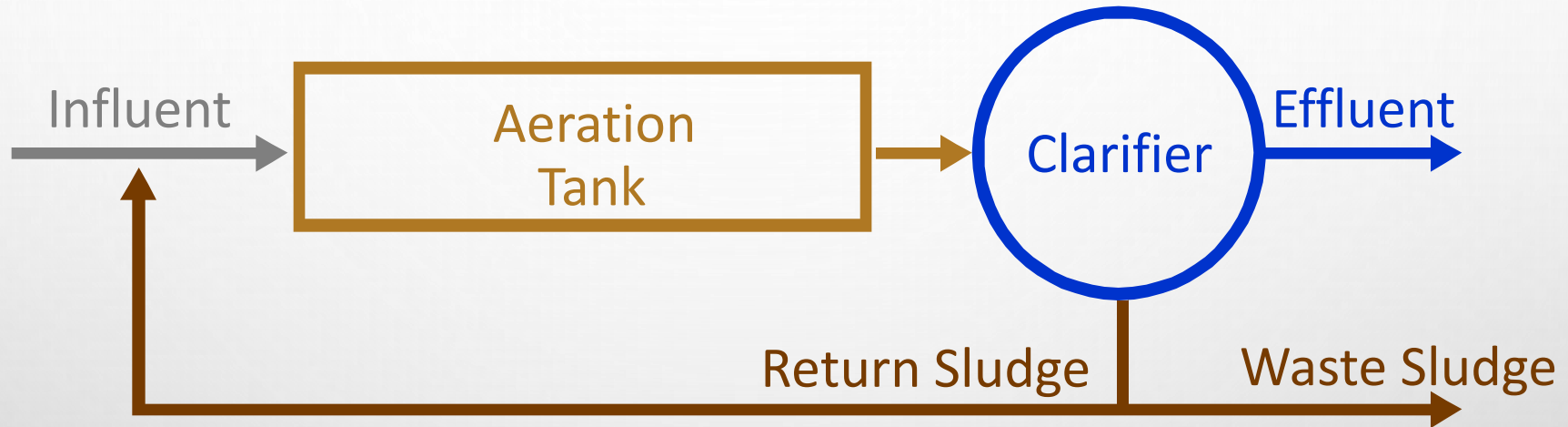
MLSS = 2000 - 6000 mg/L  
MCRT = 15 + days  
SP = 0.65 lb/lb

# PROCESS CHARACTERIZATION

- Loading variations
  - Hydraulic
  - Organic
- **Flow configurations**
- Aeration
- Misc.
- PLUG FLOW
- COMPLETE MIX (CERTAIN ISSUES)
- STEP FEED
- CONTACT STABILIZATION
- OXIDATION DITCH
- SEQUENCING BATCH REACTOR

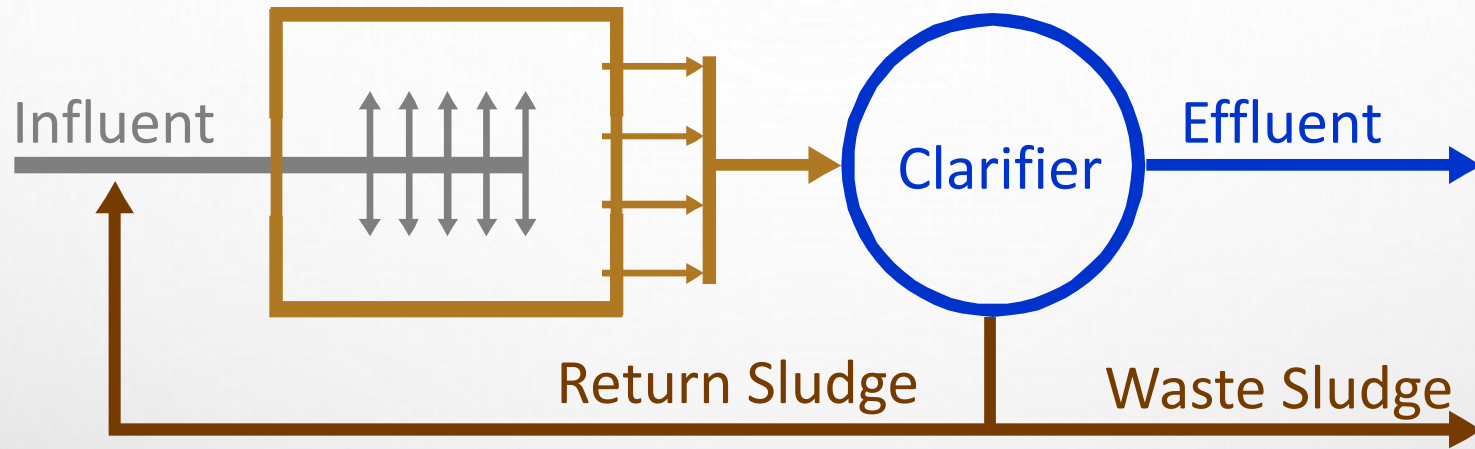
# PLUG FLOW

USUALLY CONVENTIONAL AND EXTENDED AERATION



High food concentration at head of tank,  
most efficient biologically

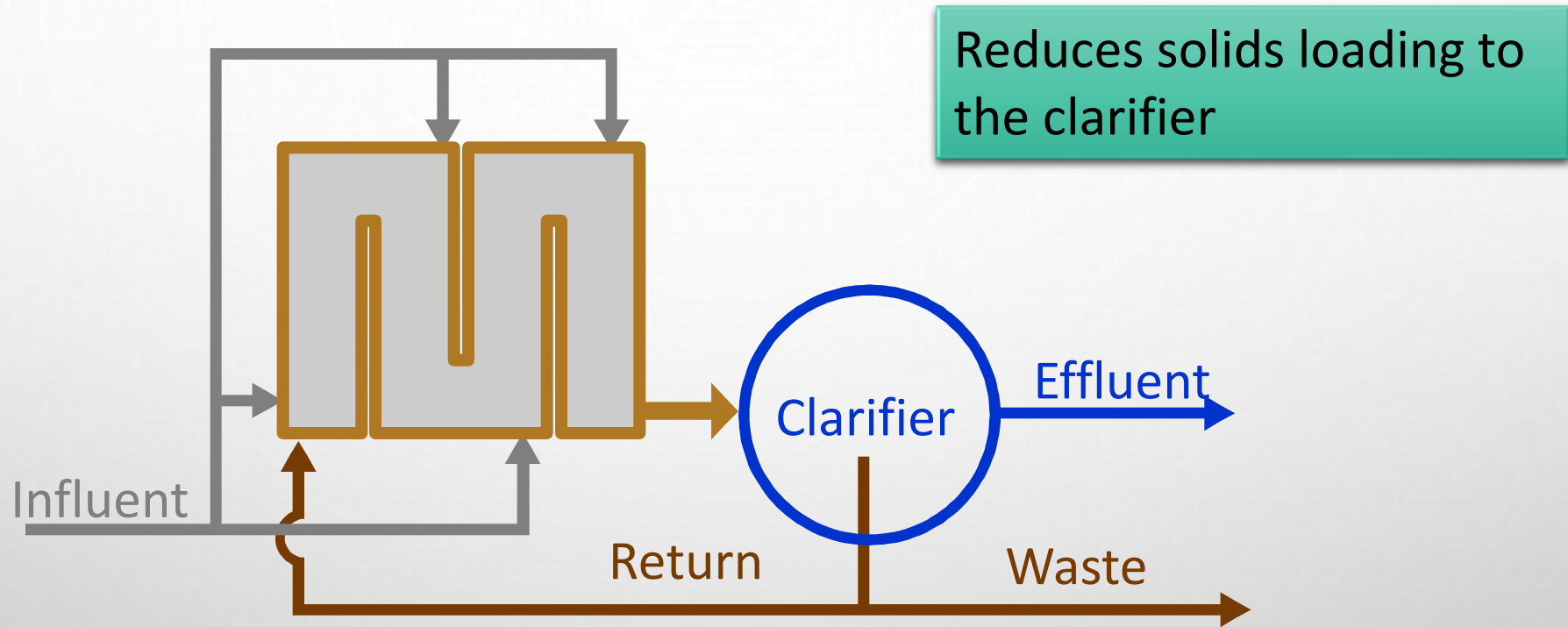
# COMPLETE MIX



Slower growth throughout tank

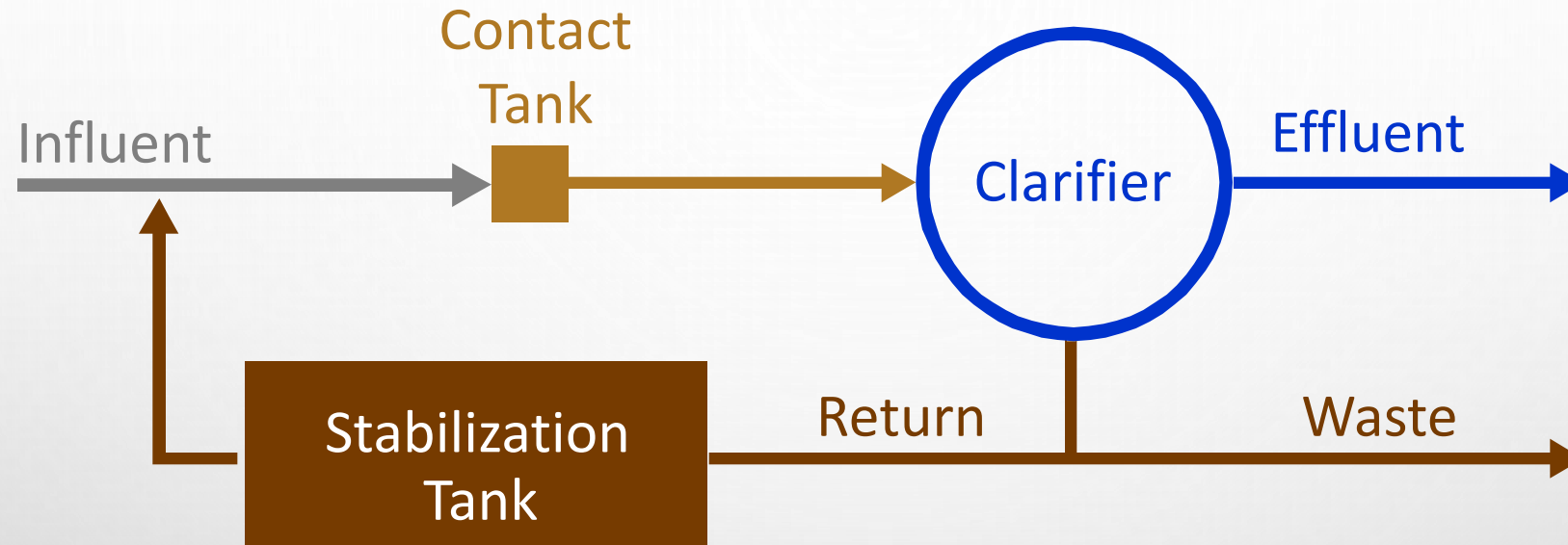
- $F/M < 0.5 \text{ lb/lb}$
- $SL < 50 \text{ lb/1000 ft}^3$
- Mixed liquor conditions are the same everywhere
- Effective control of toxics and high organic loading

# STEP FEED/STEP AERATION



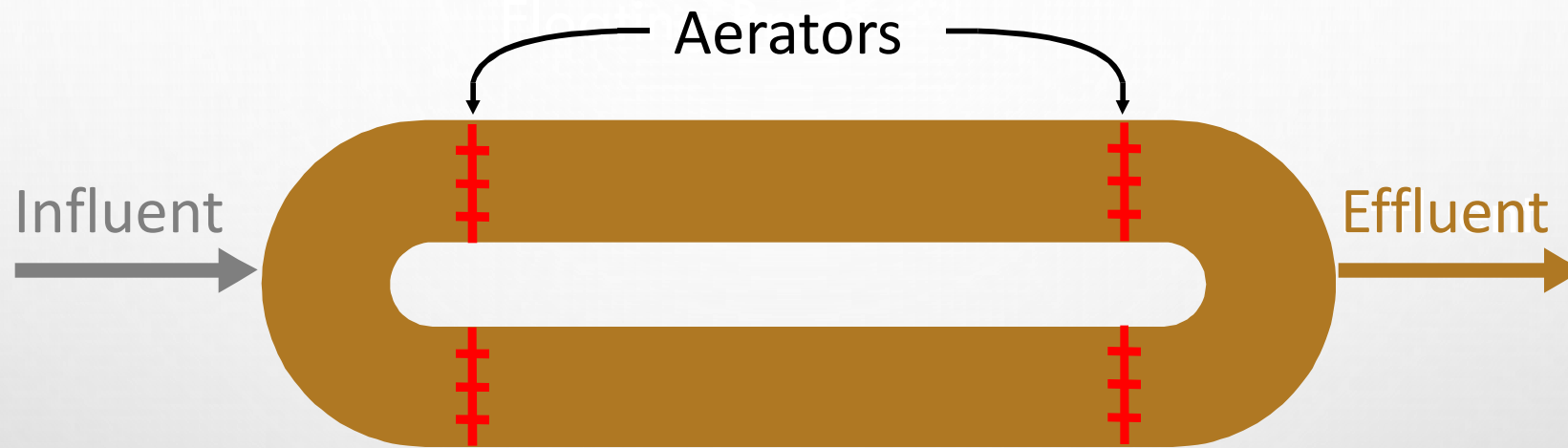
$SL < 50 \text{ lb BOD}/1000 \text{ ft}^3 - F/M < 0.5 \text{ lb/lb}$

# CONTACT STABILIZATION



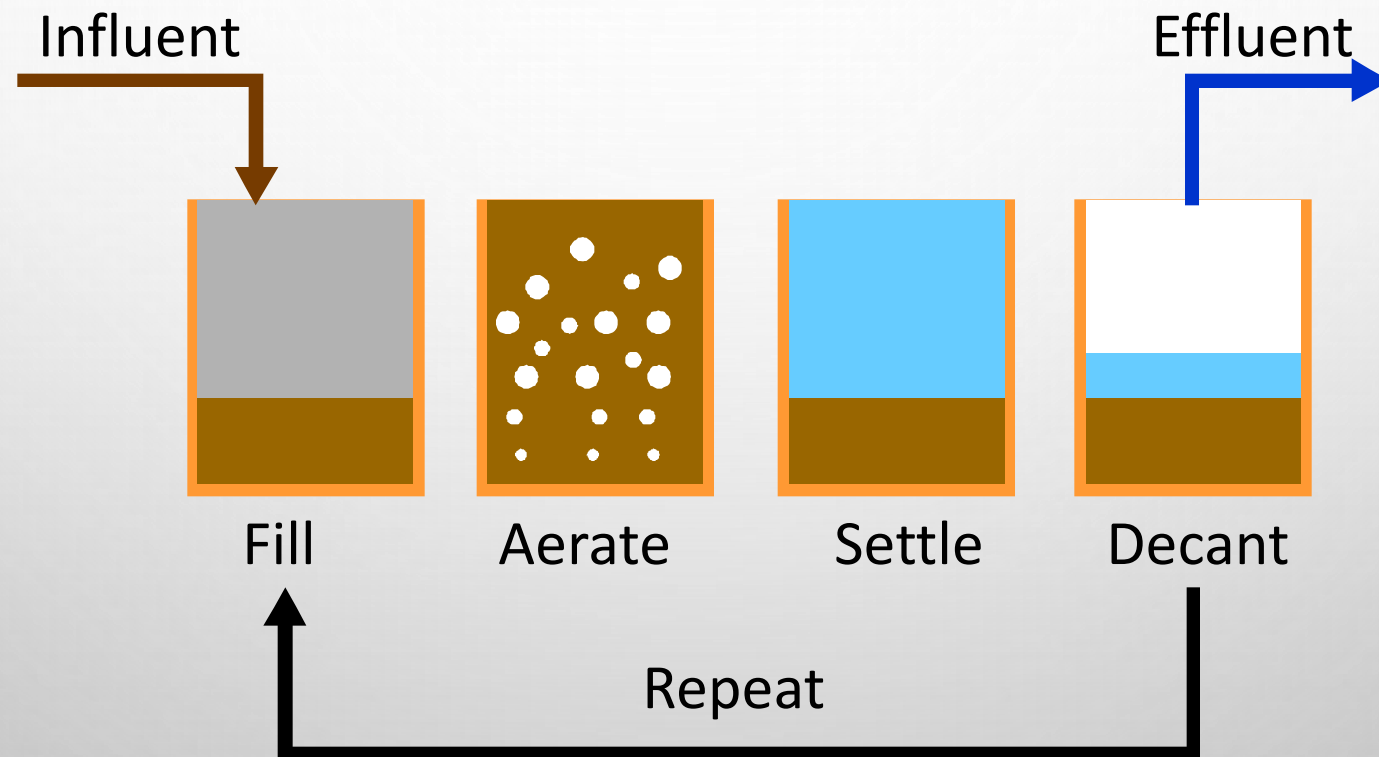
- $DT_{con} = 15 - 20 \text{ min}$
- $MLSS_{con} = 1000 - 3000 \text{ mg/L}$
- $F/M = 0.2 - 0.5$
- $DT_{stab} = 3 - 6 \text{ hr}$
- $MLSS_{stab} = 6000 - 8000 \text{ mg/L}$
- $SP = 1.0 \text{ lb/lb}$

# OXIDATION DITCH



Originally, no clarifier was used. It operated as an SBR.  
Secondary clarifiers are now used

# SEQUENCING BATCH REACTOR EXTENDED AERATION



# PROCESS CHARACTERIZATION

- Loading variations
  - Hydraulic
  - Organic
- Flow configurations
- **Aeration**
- Misc.
- Diffused
  - Fine bubble
  - Coarse bubble
- Mechanical
  - Surface
  - Brush
- Combination
  - Jet
  - Turbine & sparger
  - Aspirating
- Oxygen source
  - Air
  - Pure oxygen

# DIFFUSED AERATION





# THAMES WATER BECKTON, UK



# MECHANICAL AERATION



Floating Surface Aerator



Brush Aerator

# COMBINATION AERATORS



Aspirating Aerator

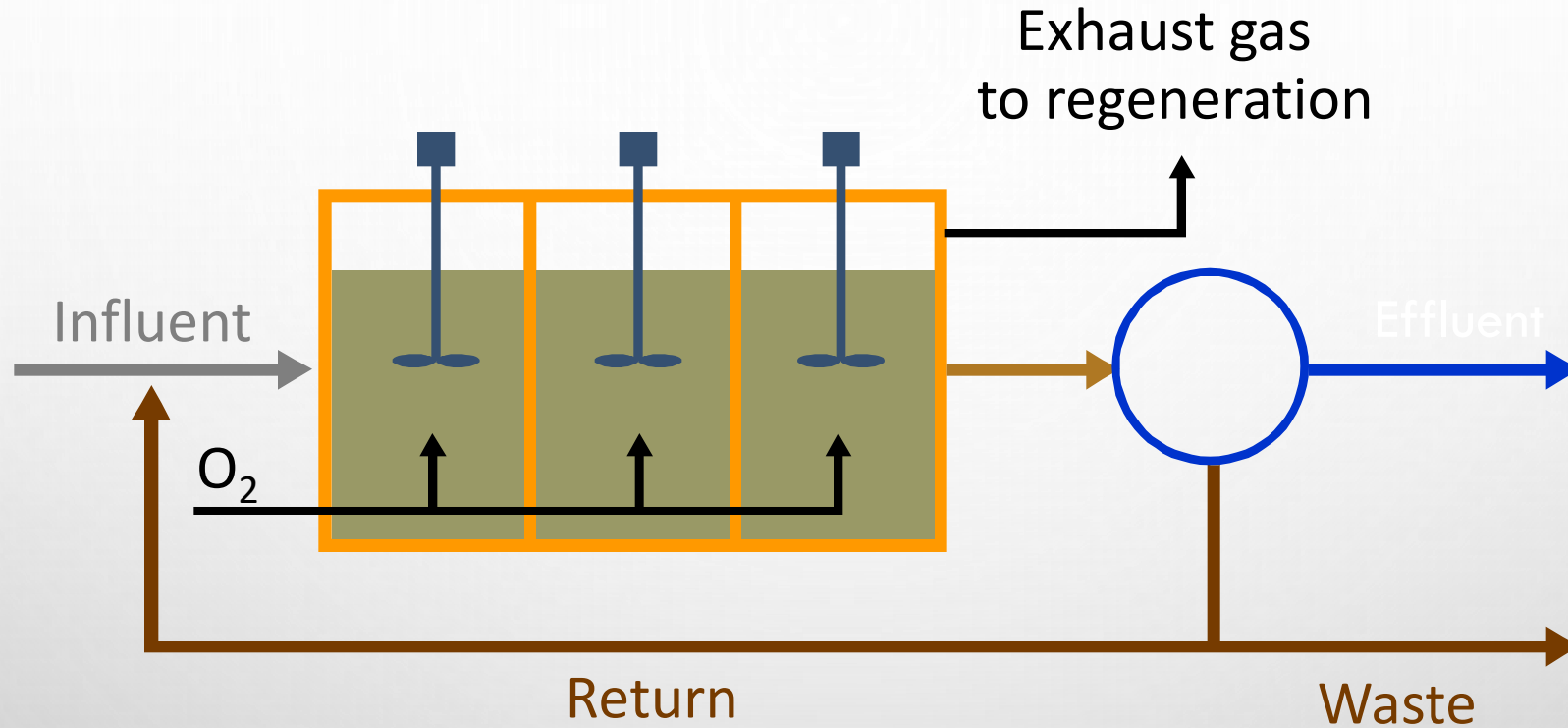


Jet Aerator



Turbine & Sparger

# OXYGEN ACTIVATED SLUDGE



DT = 1.0 - 3.0 hr  
F/M = 0.25 - 1.0  
SL >80-200 lb/10<sup>3</sup> ft<sup>3</sup>

MLSS = 3000 - 8000 mg/L  
MCRT = 3 - 10 days  
SP = 0.9-1.0 lb/lb

# PROCESS CHARACTERIZATION

- Loading variations
  - Hydraulic
  - Organic
- Flow configurations
- Aeration
- **Misc.**

## Selectors

- Aerobic: Oxygen Present
- Anoxic: Low Oxygen (<0.5mg/L), Nitrate Present
- Anaerobic: No Oxygen, No Nitrate

## Chemical Addition

- Alkalinity – Magnesium Hydroxide, Sodium Hydroxide
- Coagulants – Alum, Ferric, Polymer, etc
- Chlorine for Filamentous Bacteria Control
- Nitrogen or Phosphorus Addition – C:N:P 100:5:1
- Trace Metals – Iron, Cobalt, Molybdenum, etc

## Biological Nutrient Removal

- Nitrogen Removal
- Phosphorus Removal

# SUMMARY

- Numerous Activated Sludge processes, based on different microbiological principles
- Variable conditions require Flexibility
- You may be able to easily modify your process or operate it in a different way to accomplish improved treatment

Special Thanks to Ron Schuyler, COWAC  
for permission to use his slides & photos



# ACTIVATED SLUDGE SUMMARY

**The Apparatus**  
**The Process**  
**Enhancements**

Special Thanks to Ron Schuyler, COWAC  
for permission to use his slides & photos

