Better Plants
U.S. DEPARTMENT OF ENERGY

Biological Wastewater Treatment Training Series
Presentation #6: Activated Sludge Process Modifications – Part II

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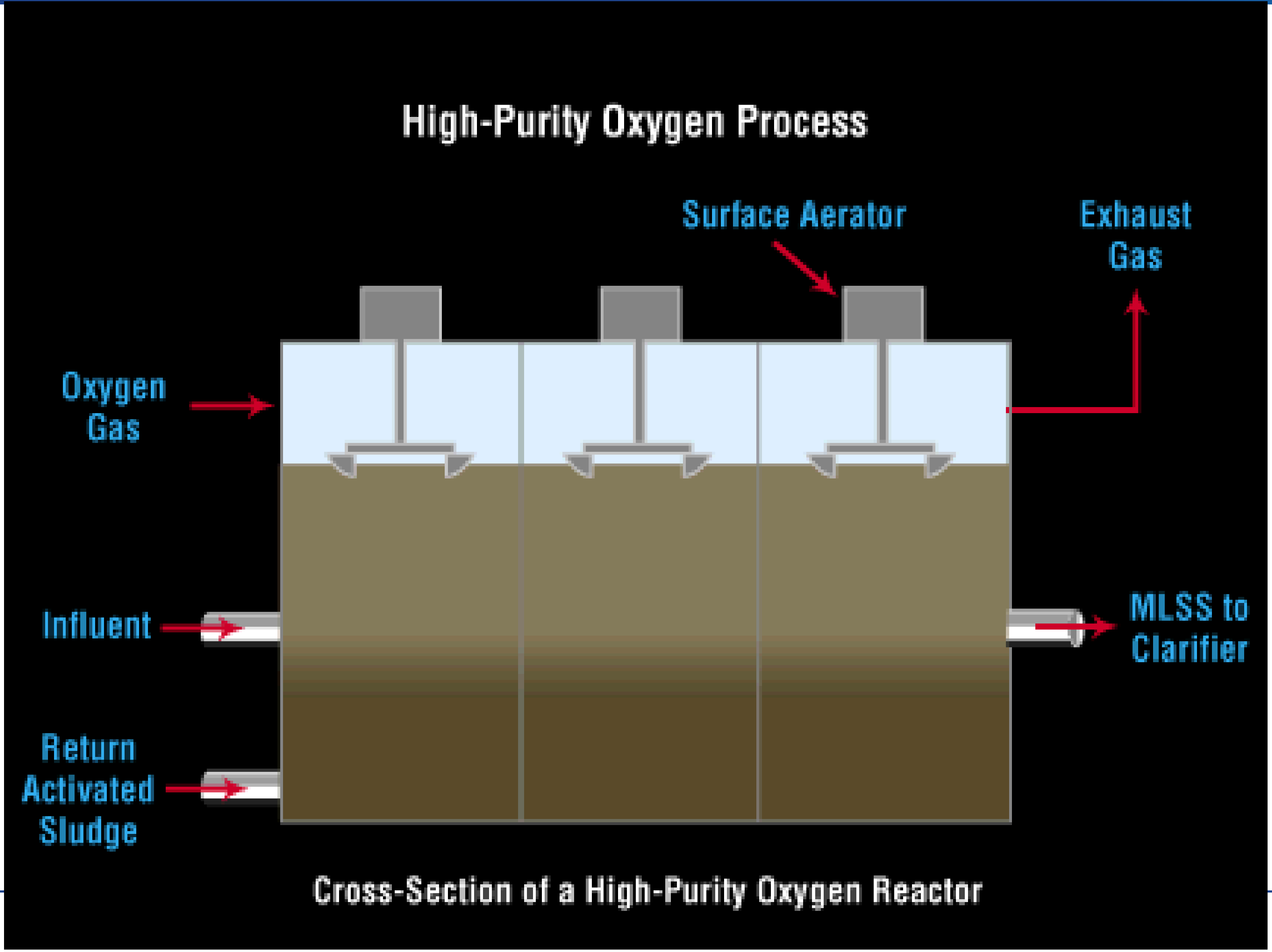
Pure Oxygen Activated Sludge Process



Pure Oxygen Activated Sludge Design

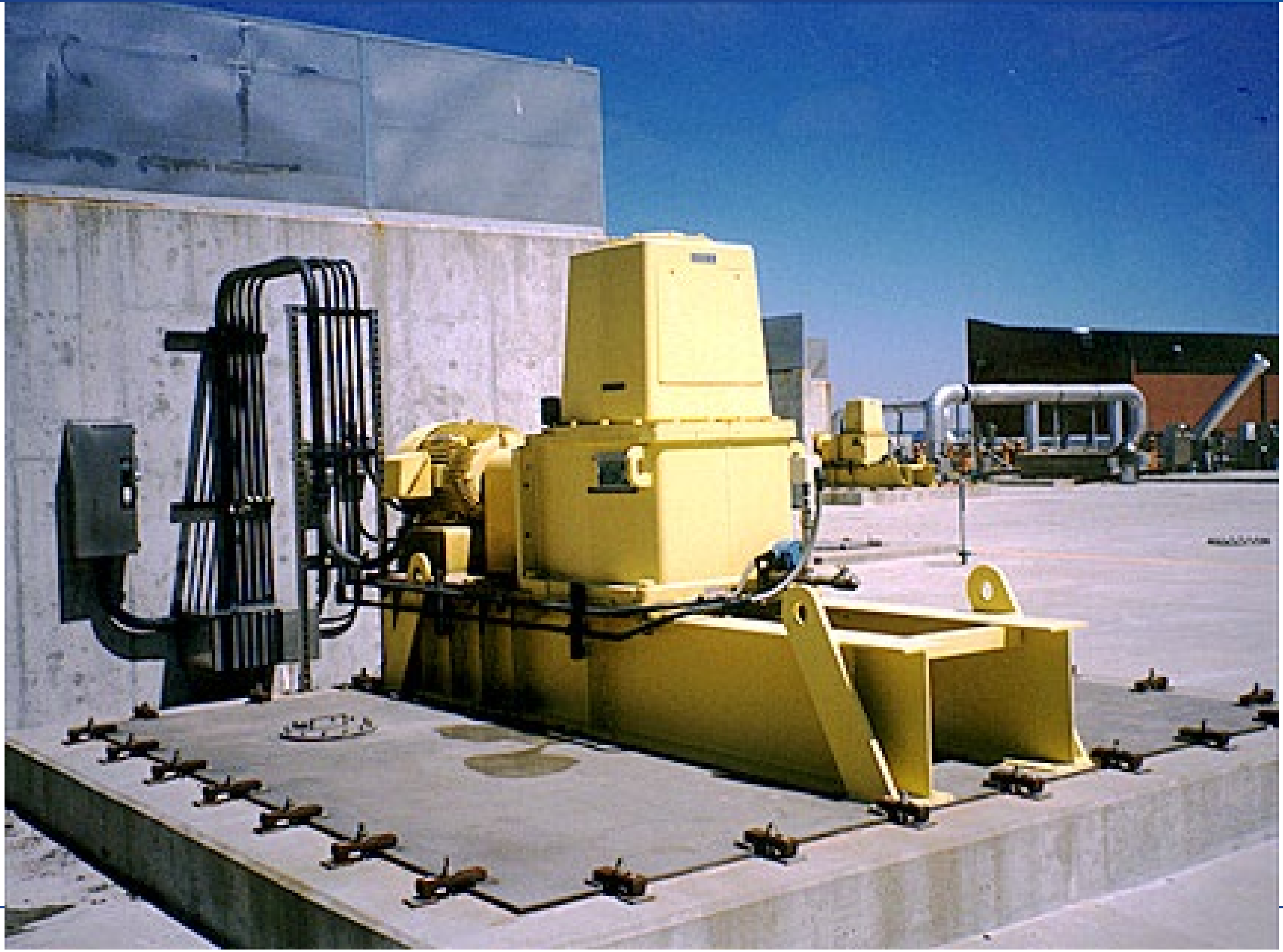
High-Purity Oxygen Process Typical Design Parameters

Application	Domestic and Industrial
BOD Removal Efficiency	85 - 95%
Aeration Type	Mechanical
SRT (Biological Reactor)	3 - 10 days
Aeration Time	1 - 3 hours
MLSS	2000 - 5000 mg/L
RAS Flow	25 - 50% of the Influent
F:M	3 - 12 mg BOD/kg MLVSS • s (0.25 - 1.0 lb BOD/d/lb MLVSS)
Organic Loading	2 - 3 kg BOD/m^3 • d (100 - 200 lb BOD/1000 cu ft)

Pure Oxygen Activated Sludge

- Higher oxygen transfer rates
- Can operate at higher MLSS levels
- Can operate at shorter detention time
- Requires less space
- Rate of oxygen addition is 2 to 3 times greater than conventional processes
- More complex because of on-site O_2 generation
- Nitrification ability is limited because of CO_2 buildup (pH $\leq$ 6.5)
- High capital and operating costs

Mixer for High-Purity Oxygen Reactor



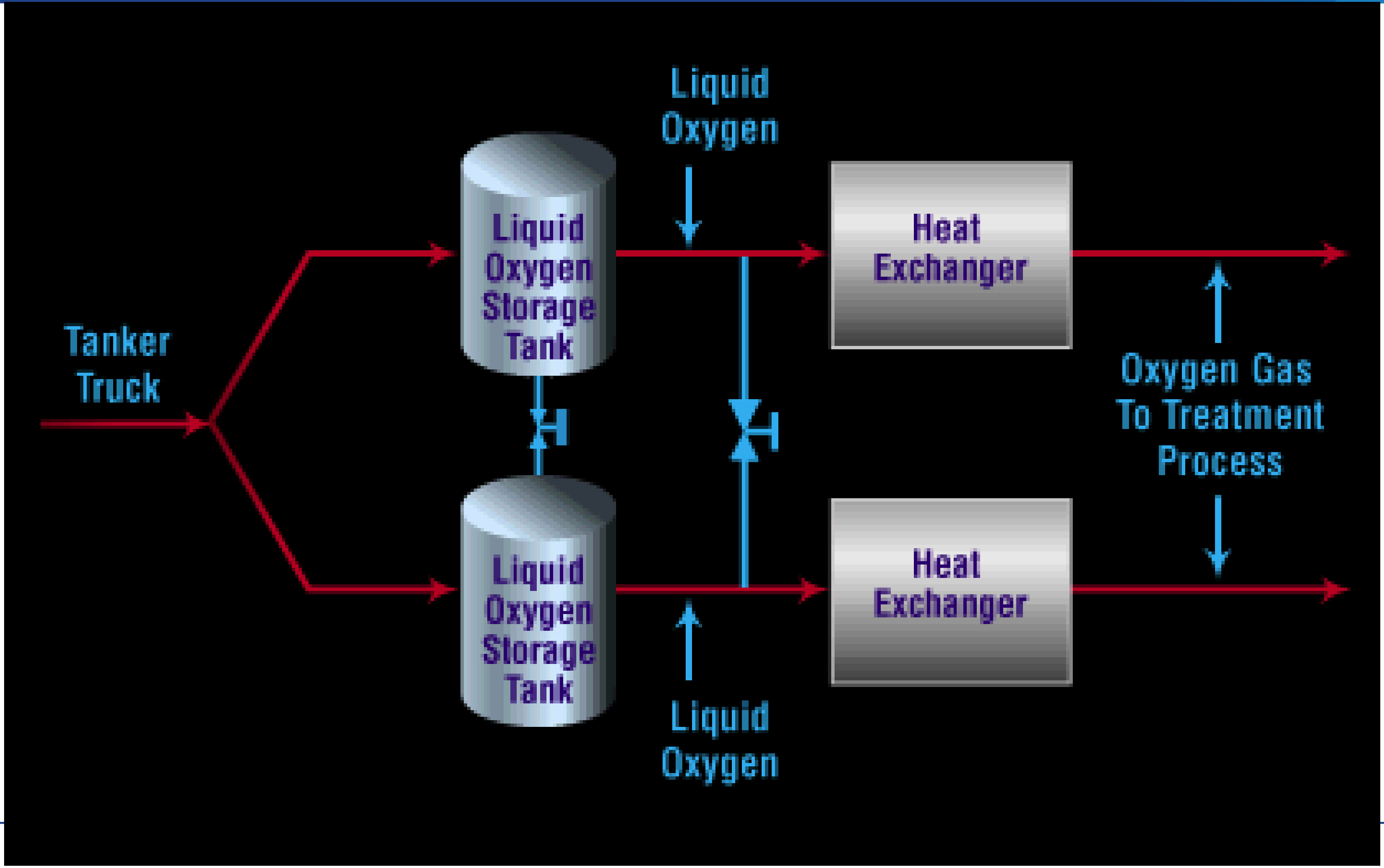
Disadvantages of High-purity Oxygen Processes:

- Higher capital costs
- Higher operating costs
- Complexity of operation
- Systems are more prone to operational problems
- Additional safety concerns

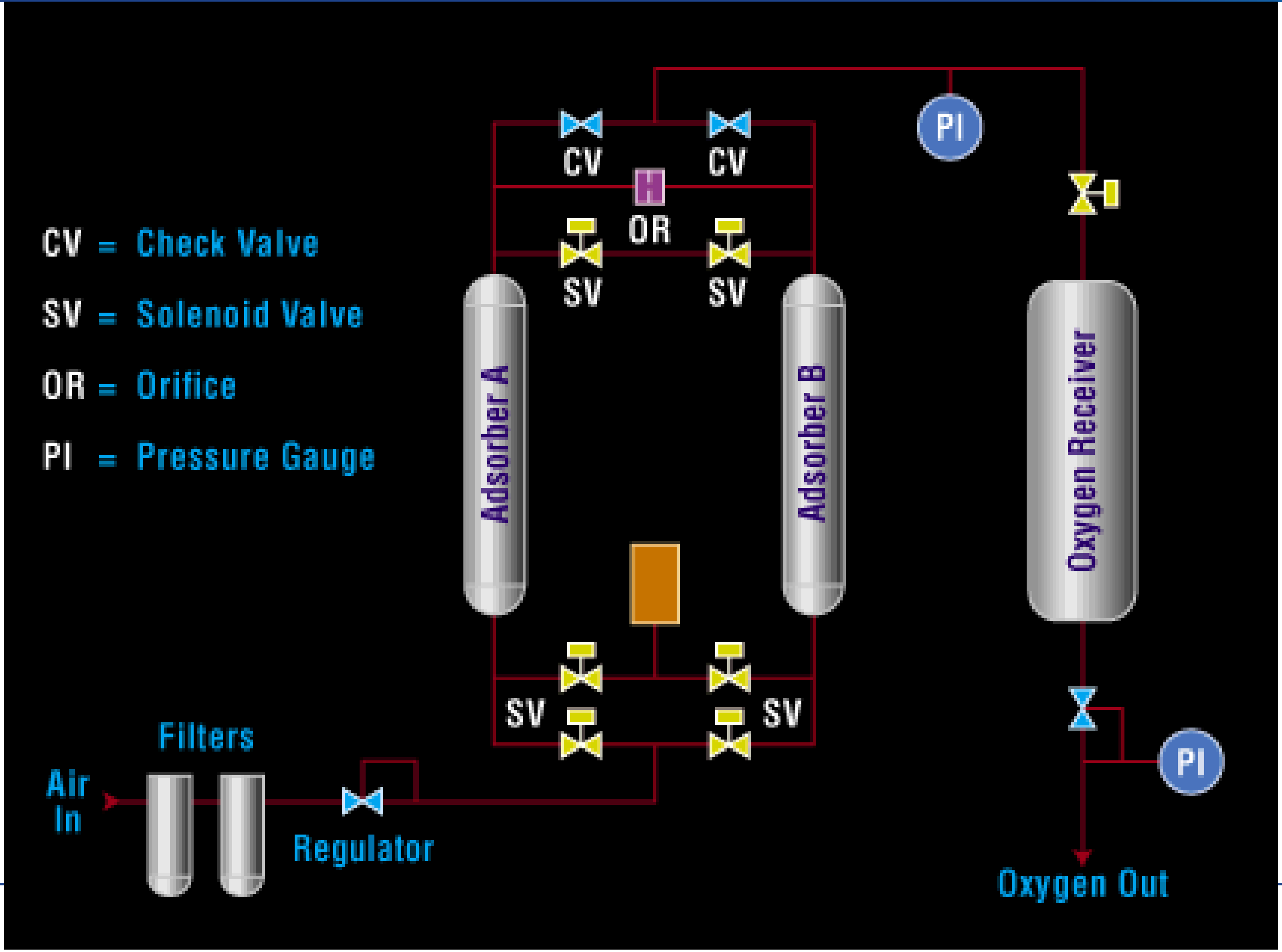
Sources of High-Purity Oxygen:

- Trucked-in liquid
- Onsite generation with:
  - Pressure-swing adsorption
  - Vacuum pressure-swing adsorption
  - Cryogenic system

Liquid Oxygen Process Schematic



Pressure-Swing Adsorption Schematic



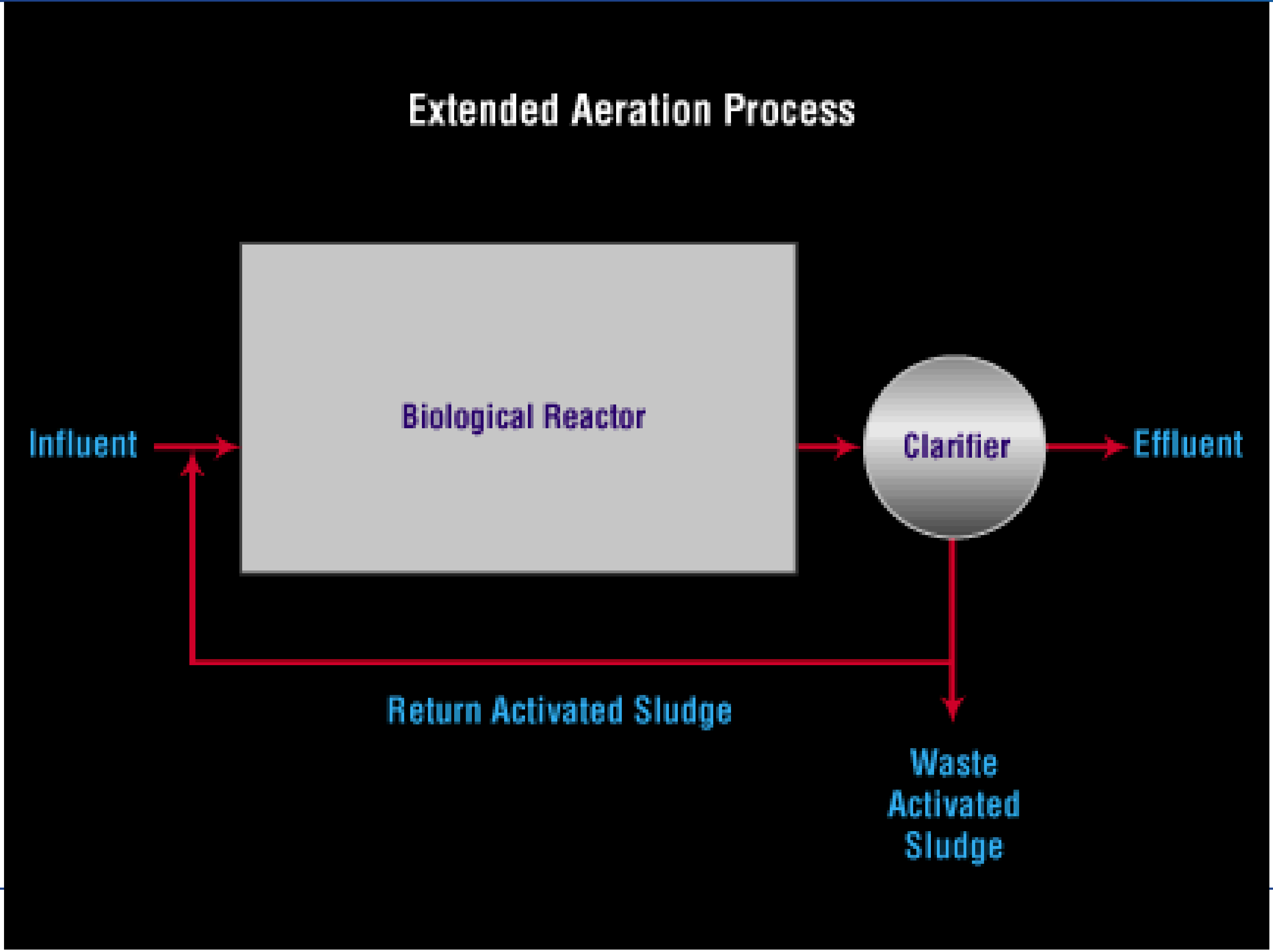
Low Rate Activated Sludge

- 85% to 95% BOD removal efficiency
- Essentially operates in endogenous growth phase
- Relatively good bio-flocculation occurs
- Can consistently meet 20 mg/L BOD_5 and TSS effluent limits
- Aeration detention time = 18 to 36 hours
- MLSS = 2000 to 5000 mg/L

Low Rate Activated Sludge

- SRT = 20 to 40 days
- F/M = 0.05 to 0.15
- Volumetric loading = 5 to 15 lb BOD_5/(day-1000 cu ft)
- Recycle ratio = 0.5 to 1.5
- Volatile fraction of MLSS = 0.6 to 0.8

Low Rate Activated Sludge



Low Rate Activated Sludge

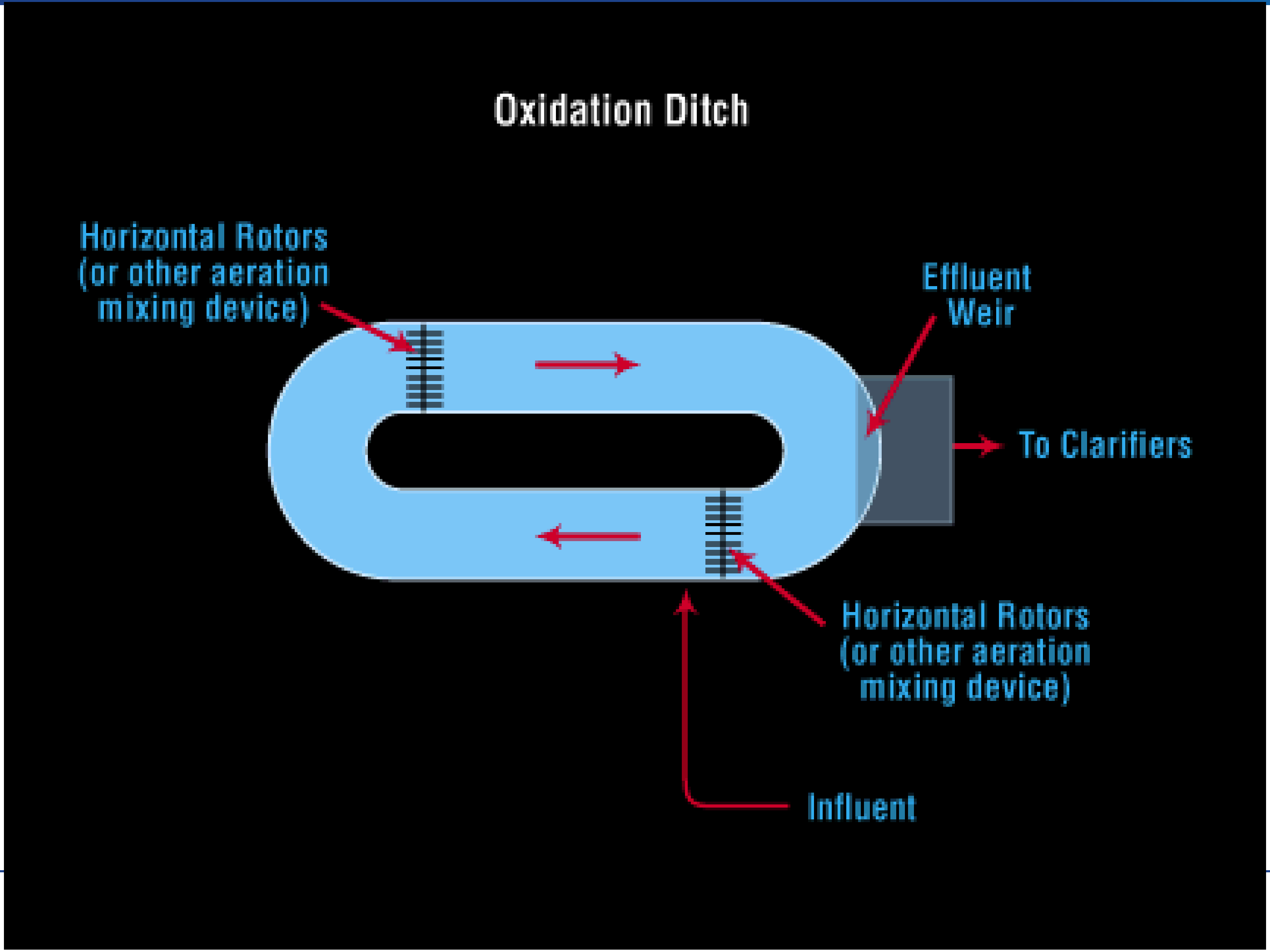
Extended Aeration Process Typical Design Parameters

Application	Smaller Communities and Package Plants
BOD Removal Efficiency	85 - 95%
Aeration Type	Diffused or Mechanical
SRT (Biological Reactor)	20 - 30 days
Aeration Time	18 - 36 hours
MLSS	3000 - 6000 mg/L
RAS Flow	50 - 150% of the Influent
F:M	0.6 - 1.7 mg BOD/kg MLVSS • s (0.05 - 0.15 lb BOD/d/lb MLVSS)
Organic Loading	0.2 - 0.4 kg BOD/m^3 • d (10 - 25 lb BOD/d/1000 cu ft)

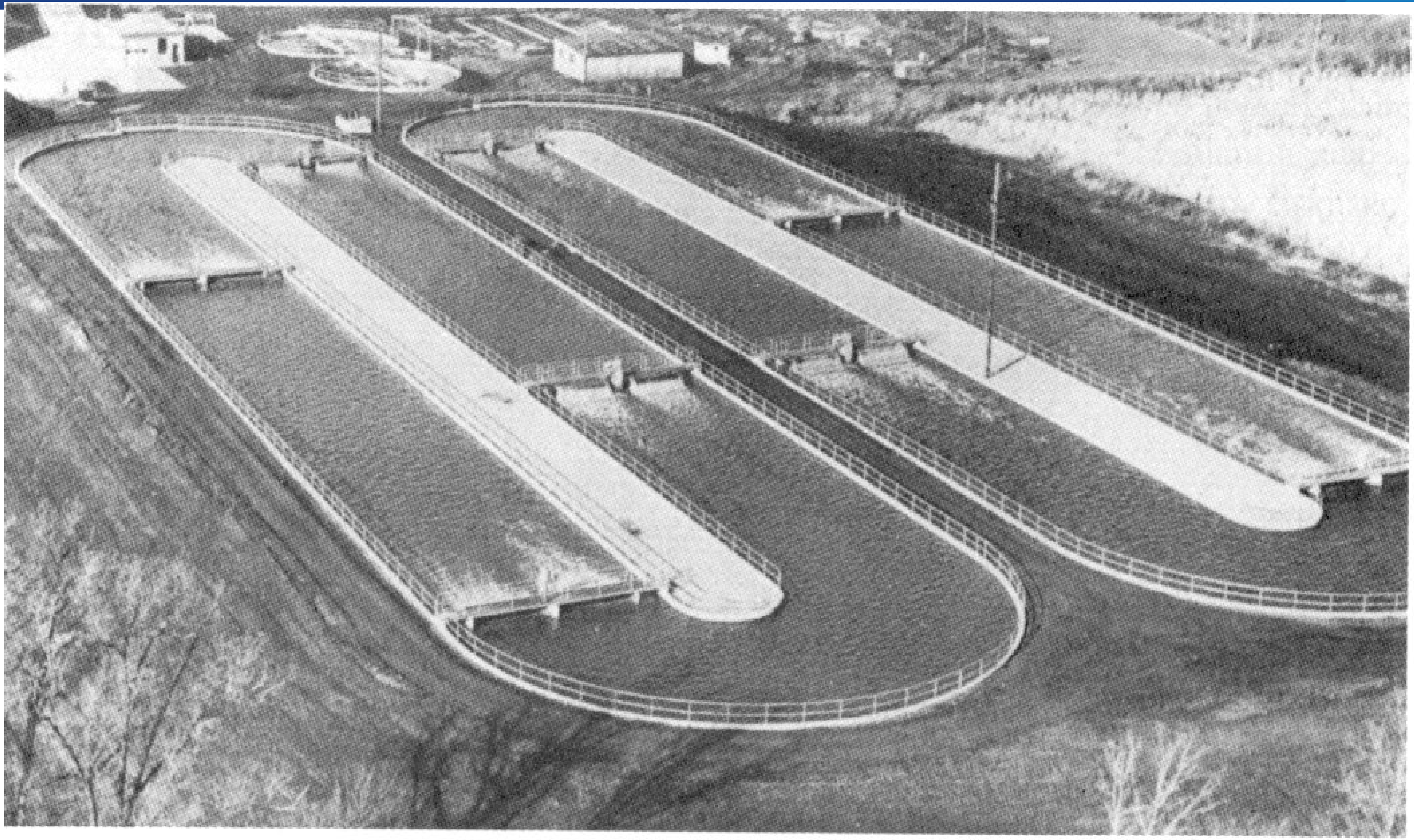
Extended Aeration Activated Sludge

- Operates in the endogenous phase of growth
- Mixing rather than oxygen needs usually controls aeration system design
- Produces high quality effluent
- Primary clarifiers generally are not used
- Can achieve effective nitrification because of long SRTs
- Although biosolids are well stabilized, additional biosolids stabilization is required to permit beneficial reuse
- Has higher oxygen demand but produces less waste sludge

Low Rate Activated Sludge



The Oxidation Ditch



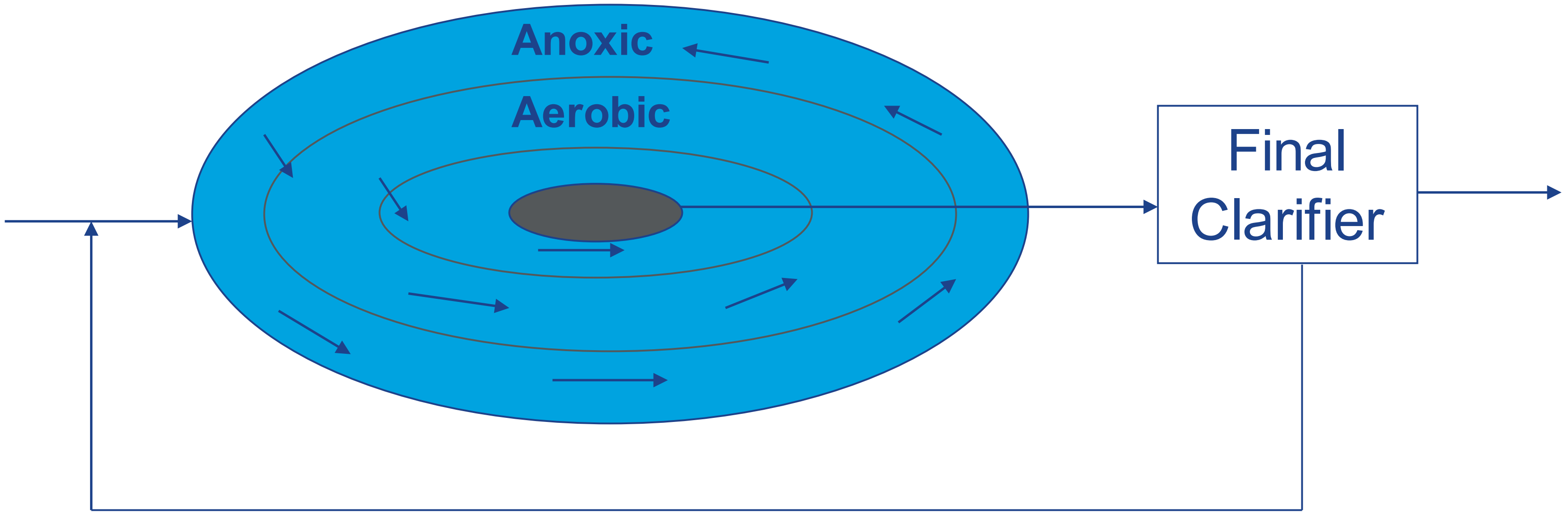
Ref: Reynolds & Richards,1996, Unit Operations and Processes in Environmental Engineering

Oxidation Ditch Activated Sludge

- Consists of oval-shaped channel with mechanical aeration
- Channel velocity should be 0.8 to 1.0 ft/s
- Mixed liquor completes a tank recirculation in 5-15 min
- Dilutes influent flow by a factor of 20-30
- Process kinetics approach a complete-mix reactor
- Can be modified easily to achieve denitrification
- Very good for design flow rates < 10 mgd

Oxidation Ditch Activated Sludge

Orbal™ Process



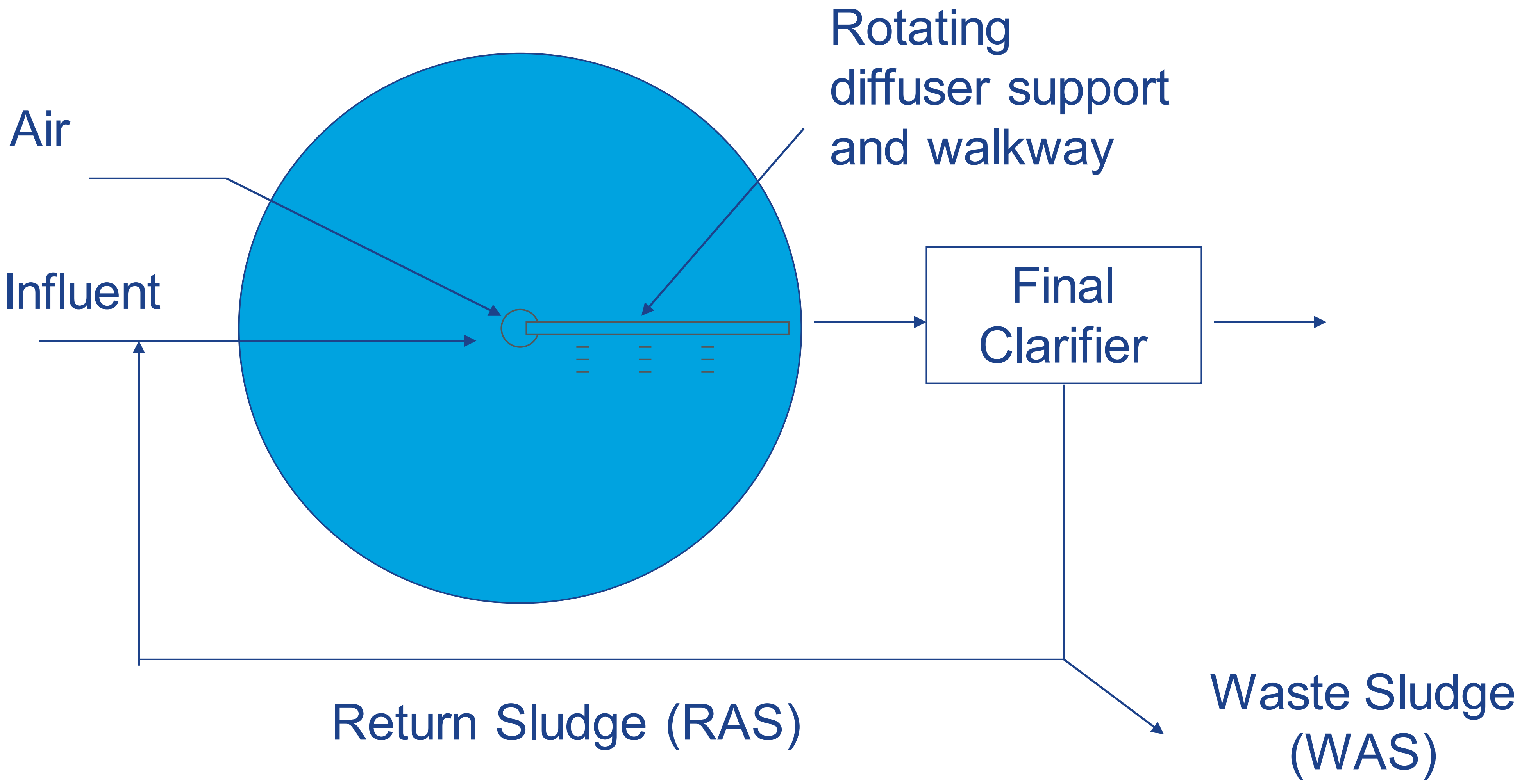
Aerial View of an Orbal Oxidation Ditch

Orbal Disk Aerator

Orbal^{TM} Process

- Uses a series of concentric channels
- Wastewater enters the outer channel
- Mixed liquor flows typically toward the center of the structure through at least two more channels before entering an internal distribution box
- Disk aerators mounted on a horizontal shaft provide aeration
- Often outer channel is maintained at 0 to 0.3 mg/L DO to achieve simultaneous nitrification and denitrification
- Volume in 1st channel ≈ 50%; volume in 2nd channel ≈ 33%; volume in 3rd channel ≈ 17%.

Countercurrent Aeration System (CCAS)



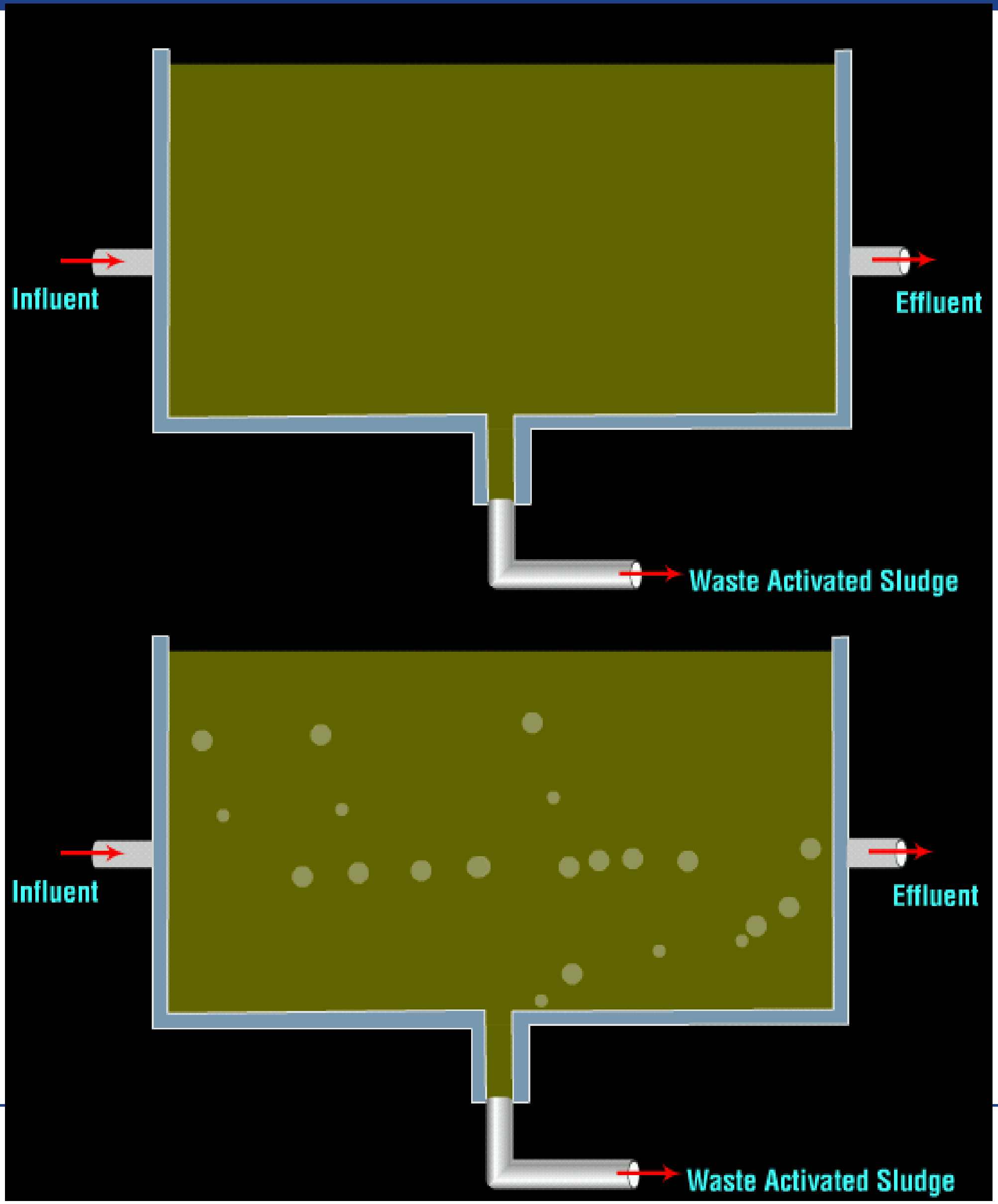
Countercurrent Aeration System (CCAS)

Countercurrent Aeration System (CCAS)

- Air diffusers are mounted at the bottom of a revolving bridge in a circular aeration basin
- Fine bubbles are dispersed in a sweeping motion behind the traveling bridge
- When the air is turned off, the movement of the diffusers creates enough mixing energy to keep the tank contents in suspension
- The process is operated at a DO ranging from 0.7 to 1.0 mg/L
- The low DO is sufficient for nitrification at the long SRT, while allowing anoxic conditions to develop to promote denitrification
- The system is usually designed with extended aeration SRTs

Sequencing Batch Reactor (SBR) Facility

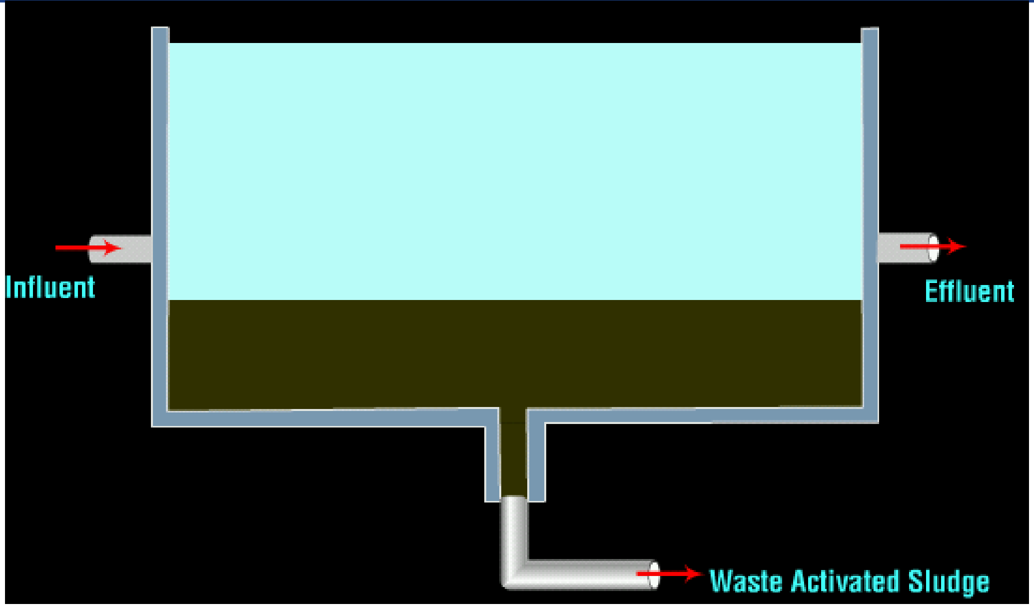
The first two steps involved in the SBR process are:

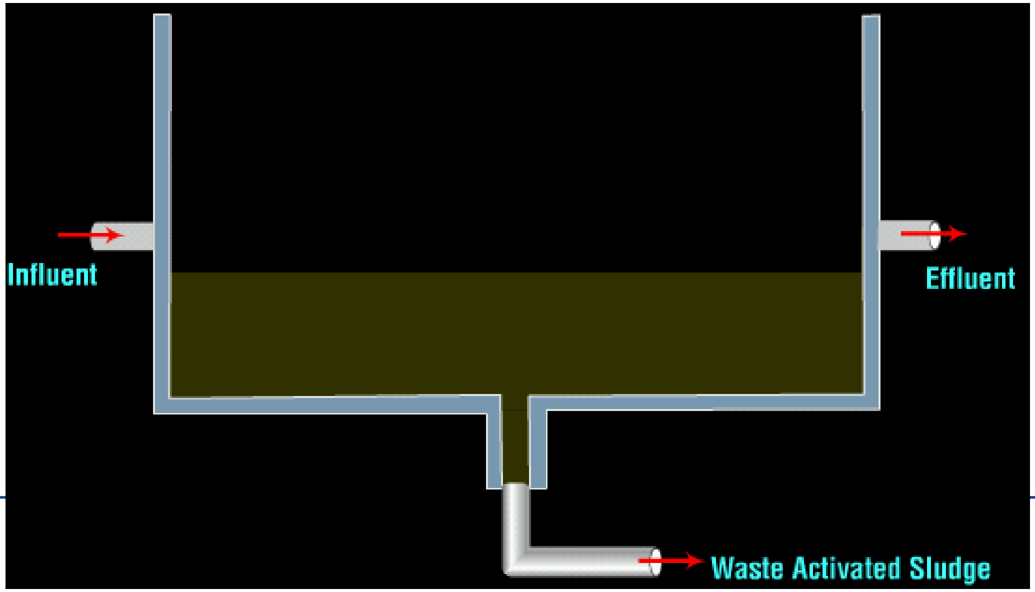


1. Fill – reactor is filled with wastewater.

2. React – the wastewater is aerated.

The next two steps of the SBR cycle are:

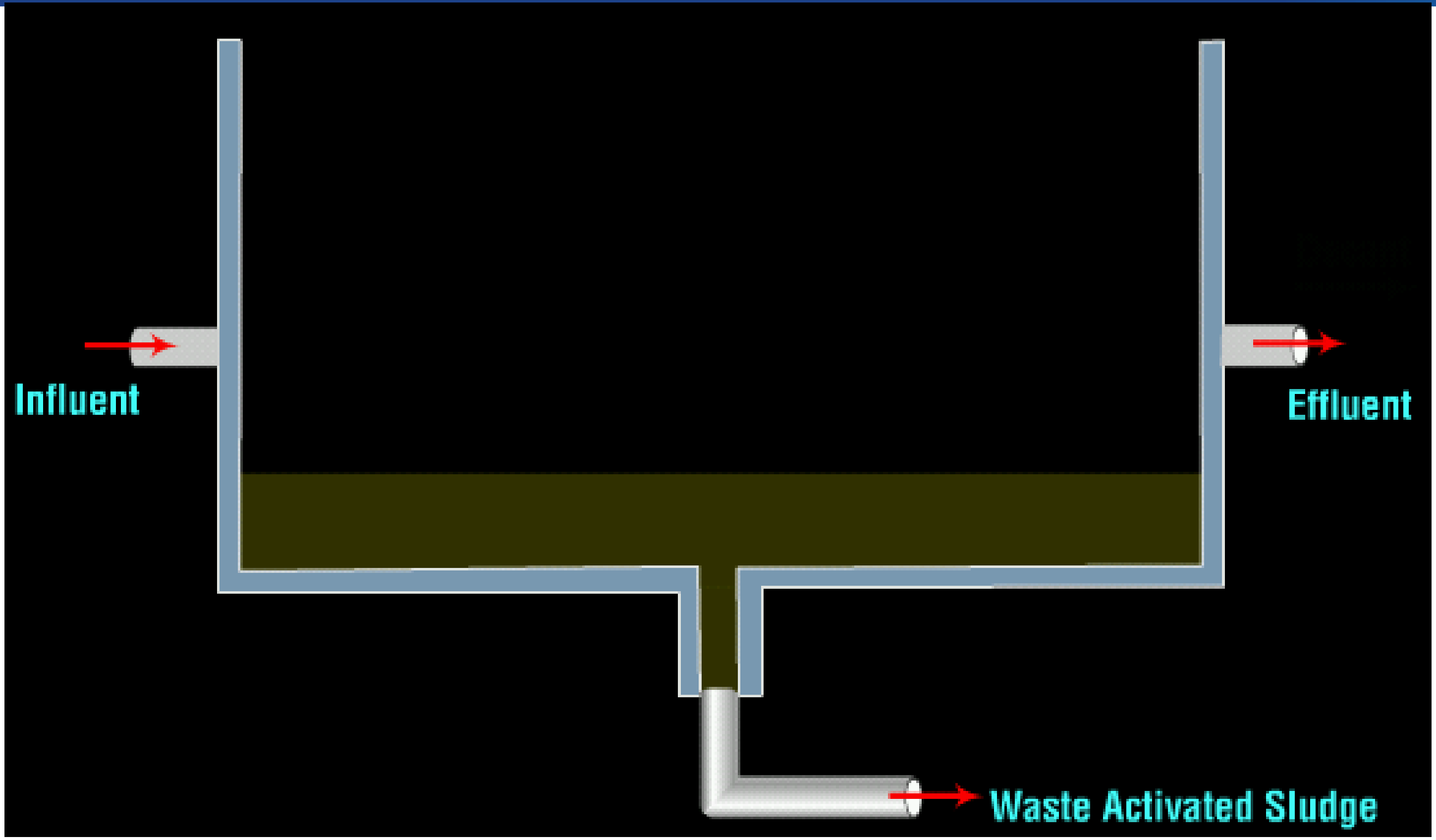




3. Settle – MLSS is separated .

4. Decant – treated wastewater is removed.

The last step of the SBR cycle is:



5. Idle – a portion of the waste sludge is removed with adequate sludge left in the tank to provide biomass for the next treatment cycle.

Design of the SBR Process

SBR Process Typical Design Parameters

Application	Smaller Communities
BOD Removal Efficiency	85 - 95%
Aeration Type	Diffused
SRT (Biological Reactor)	n/a
Aeration Time	12 - 50 hours
MLSS	1500 - 5000 mg/L
RAS Flow	Not Applicable
F:M	0.6 - 3.5 mg BOD/kg MLVSS • s (0.05 - 0.3 lb BOD/d/lb MLVSS)
Organic Loading	0.4 kg BOD/m^3 • d (25 lb BOD/d/1000 cu ft)

Comments on Sequencing Batch Reactor (SBR)

- Fill-and-draw process
- Uses a single, complete-mix reactor
- Need for separate clarifier is eliminated
- Since it is batch process, must provide multiple reactors to handle continuous flow
- Gives operators high level of control over effluent quality
- Decanting is done by either fixed or floating decanter mechanisms

Comments on Sequencing Batch Reactor (SBR)

- Hydraulic detention times typically are 18 to 30 hours
- Aeration may be achieved by jet aerators or coarse bubble diffusers with submerged mixers
- Separate mixing provides operating flexibility and is useful during the fill period for anoxic operation
- Sludge wasting may occur during the aeration period
- Some SBRs have continuous influent feed by using a pre-reactor chamber (ICEAS process)

Typical SBR Treatment Cycle

- Fill (raw or settled wastewater) (≈ 3 hour)
- React (contents are aerated/mixed) (≈ 2 hour)
- Settle (MLSS settles) (≈ 0.5 hour)
- Draw (treated wastewater is decanted from the top of the reactor) (≈ 0.5 hour)
- Idle (waste sludge may be removed from the reactor bottom)

Thank you!

For Questions or Comments please reach out to the following:

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