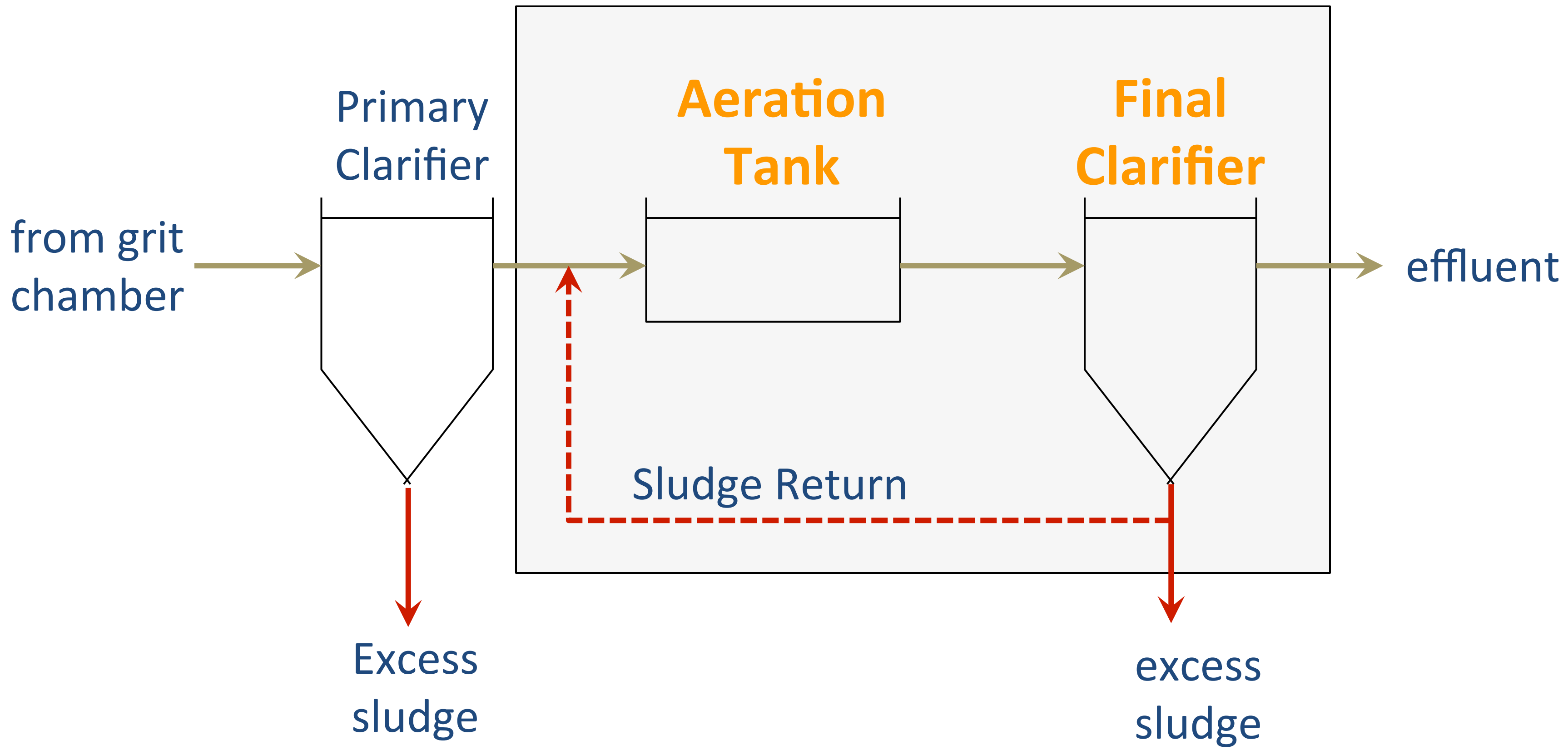
ACTIVATED SLUDGE


Primary
Clarifier
Aeration
Tank
Final
Clarifier
from grit
chamber
effluent
Sludge Return
Excess
sludge
excess
sludge

“Activated” Sludge

The name refer to the **return sludge** (biomass) that is **being activated** upon returning to the aeration tank from secondary clarifier

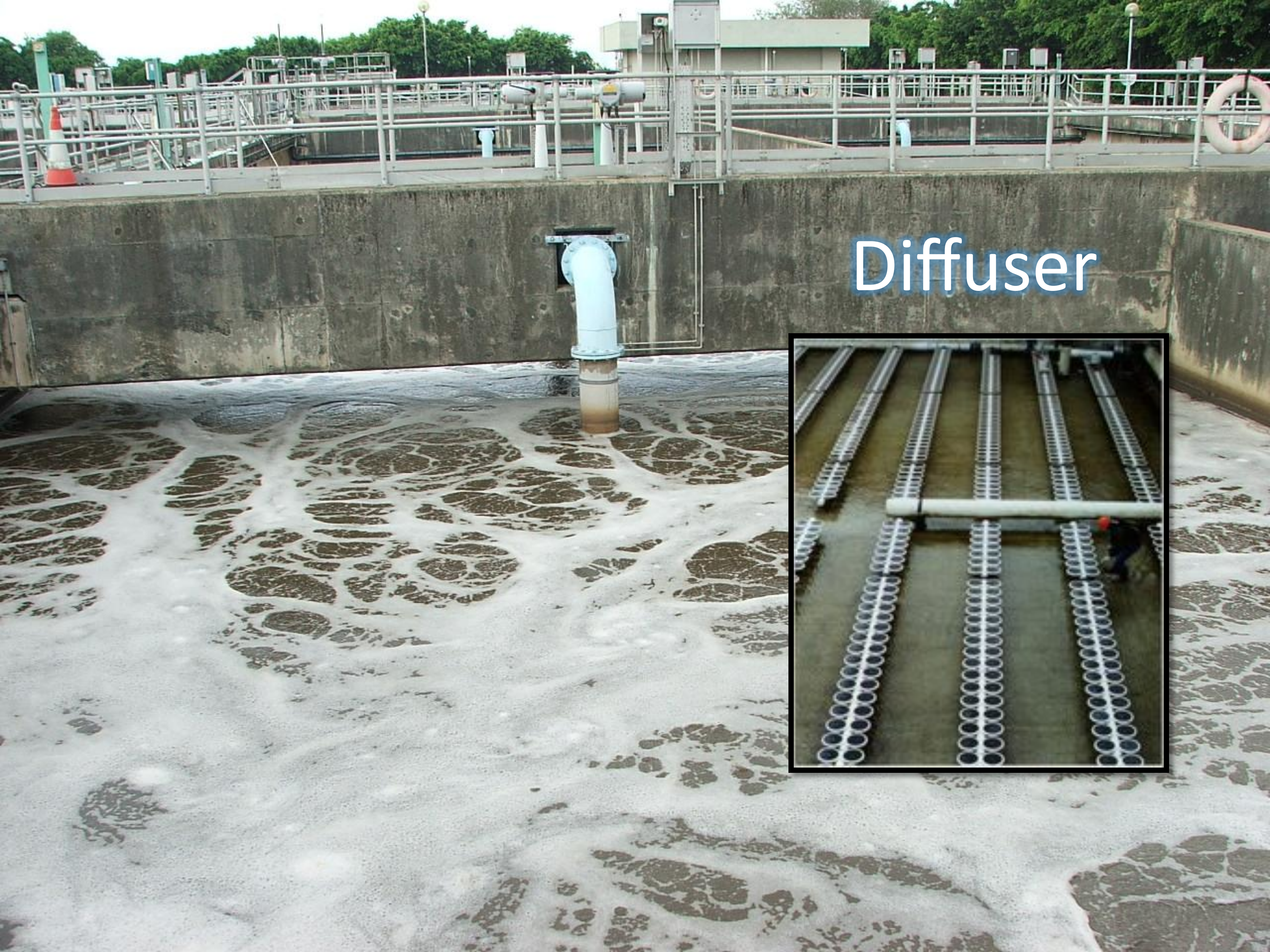

Aeration Tank

Organic decomposed in **aerobic** condition

Air through **diffuser** or **mechanical mixer**

Air supply also gives **mixing** in wastewater

Combination of suspended solids and microorganisms is called "**mixed liquor suspended solids**" (MLSS)


Diffuser

Mechanical Mixer

Sedimentation Tank

Separate biomass from liquid and return some to aeration tank

Advantages

High quality of effluent (95% BOD removal)

Effluent quality is controlled by sludge return

Disadvantages

Need **high skill** labour

Relatively high capital, operation and maintenance **costs**

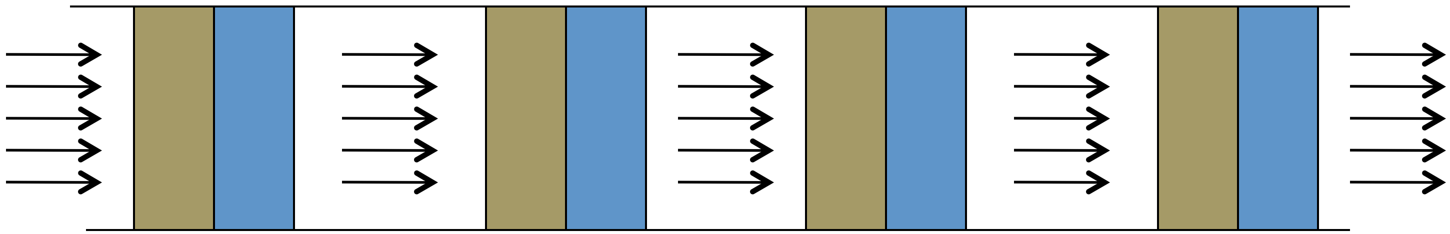
Type of Reactor

Plug-flow (continuous flow)

Completely-mixed (continuous flow)

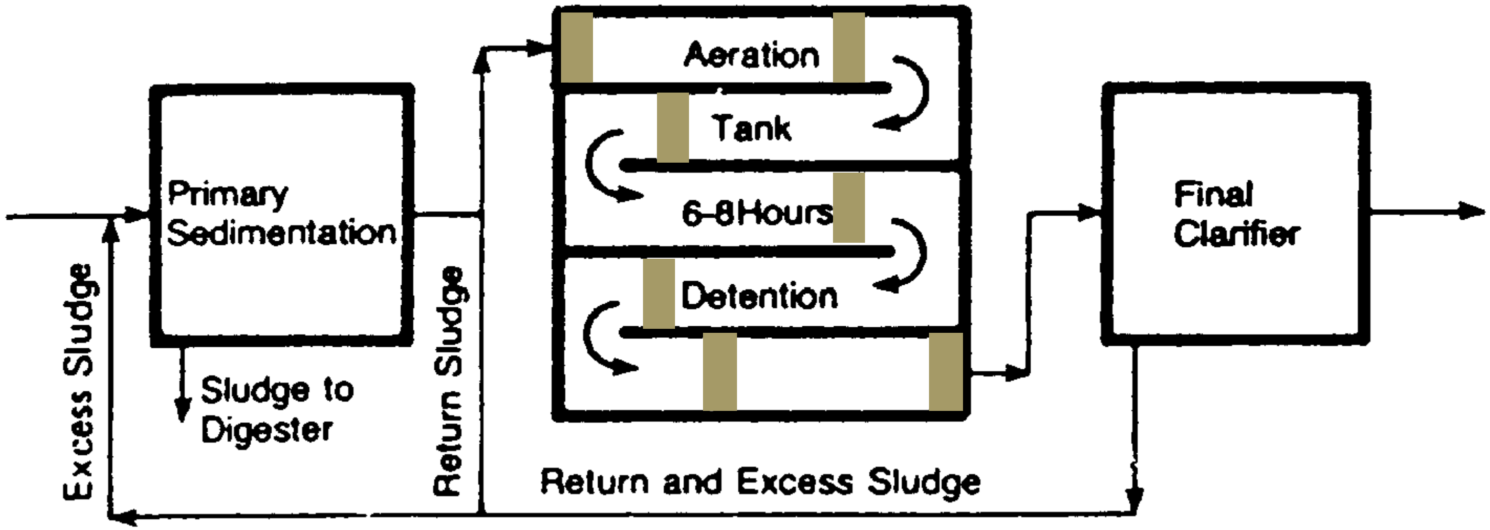
Completely-mixed (batch flow)

Plug Flow



t = i t = i+1 t = i+2 t = i+n

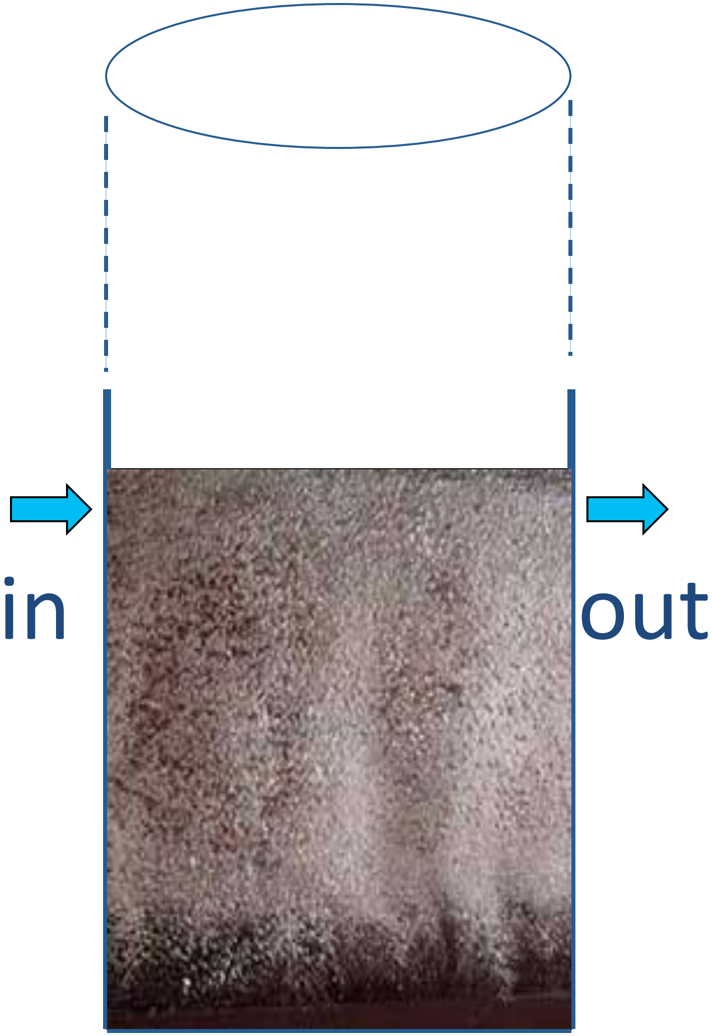
Plug Flow


Aeration
Tank
6-8Hours
Detention
Primary
Sedimentation
Sludge to
Digester
Excess Sludge
Return Sludge
Return and Excess Sludge
Final
Clarifier

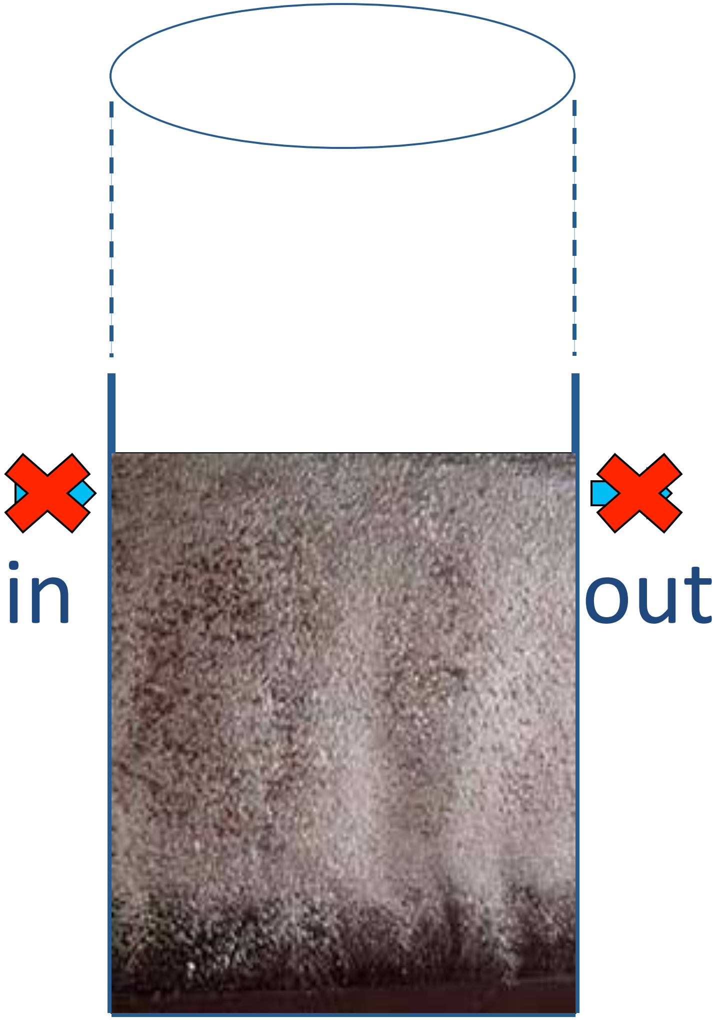
Plug flow:
Long rectangular tank

Completely Mixed

(continuous flow)



Completely Mixed
(batch flow)



Modification of Activated Sludge

Step aeration

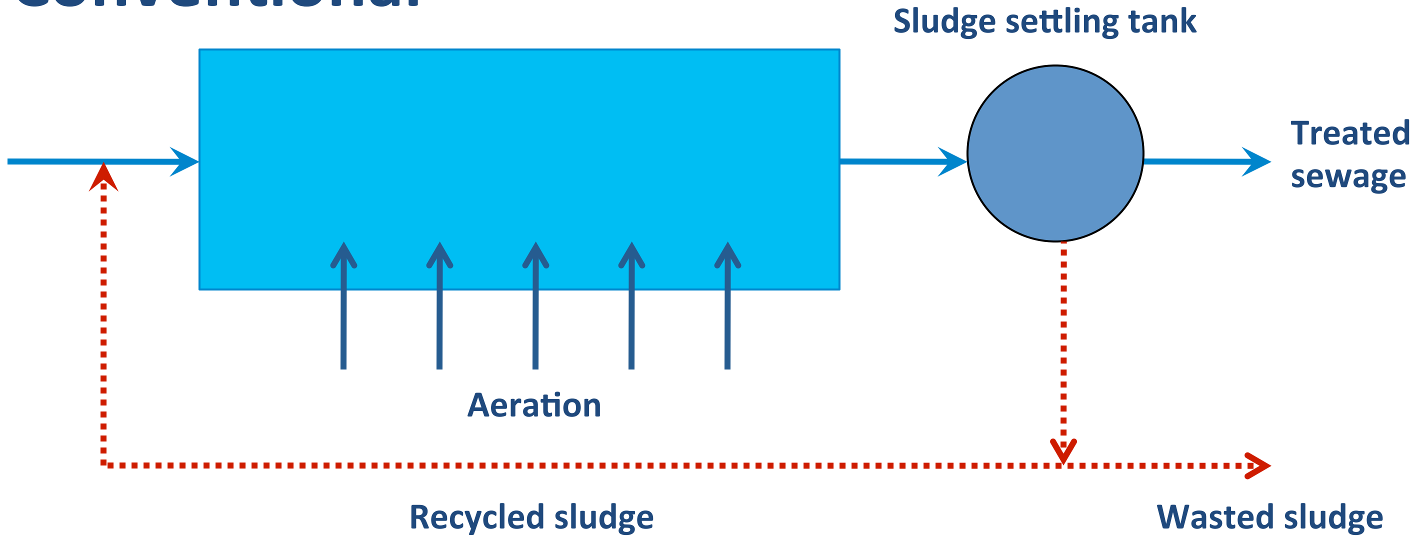
Tapered aeration

Oxidation-ditch

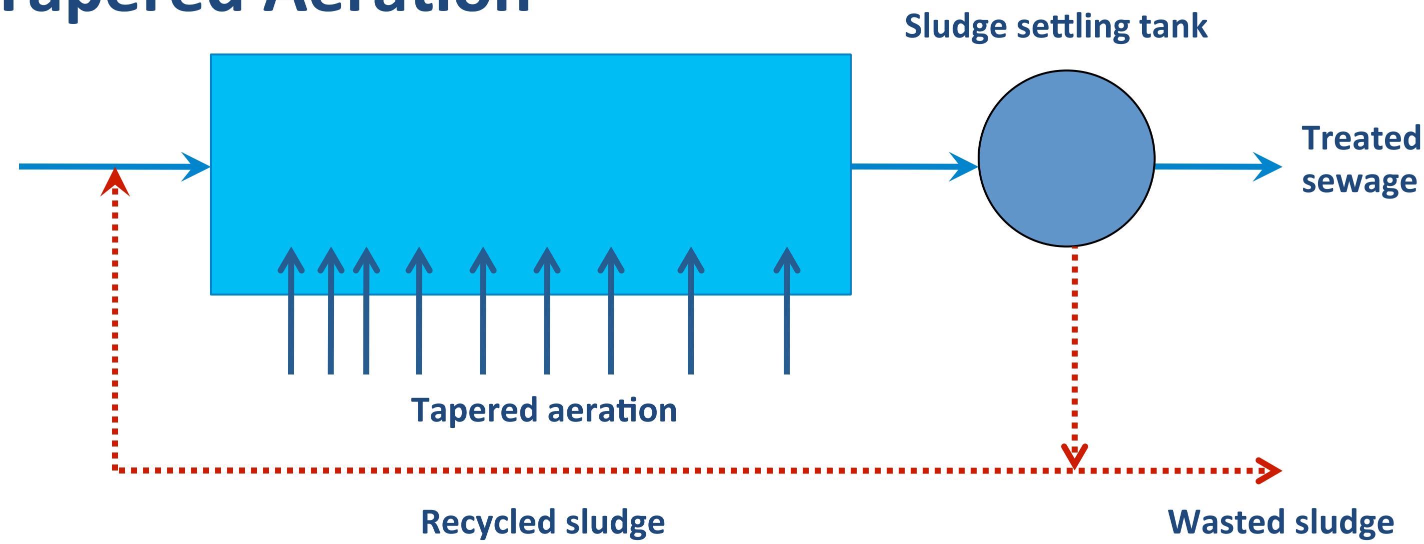
Extended Aeration (EA)

Sequencing Batch Reactors (SBR)

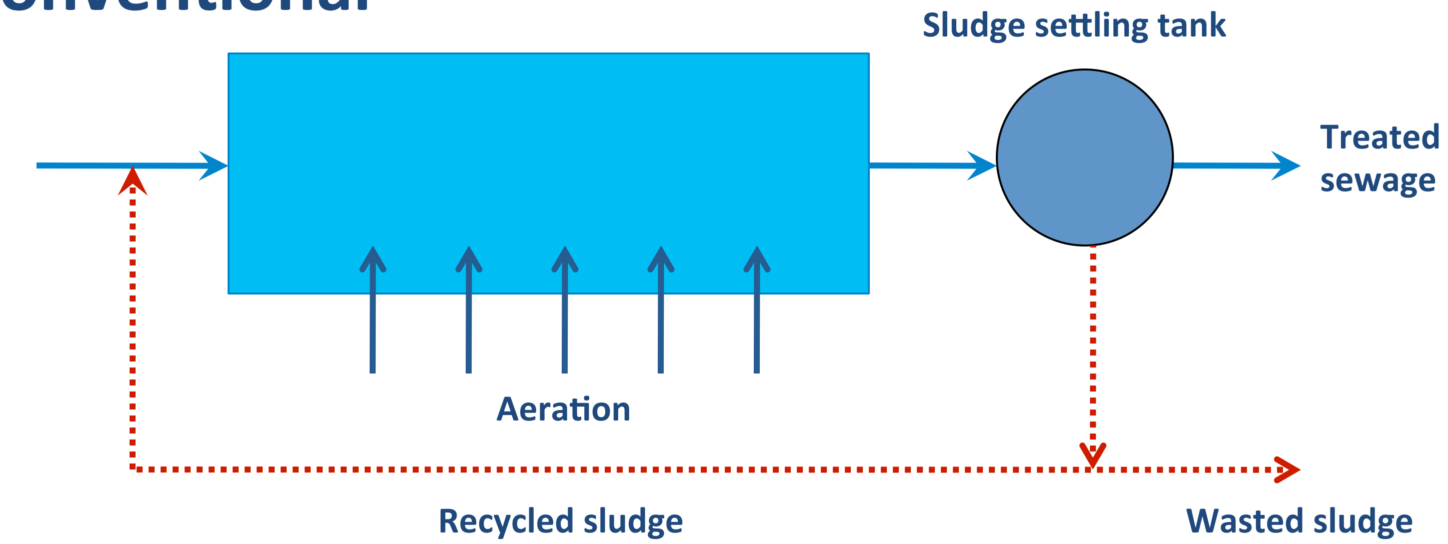
Conventional



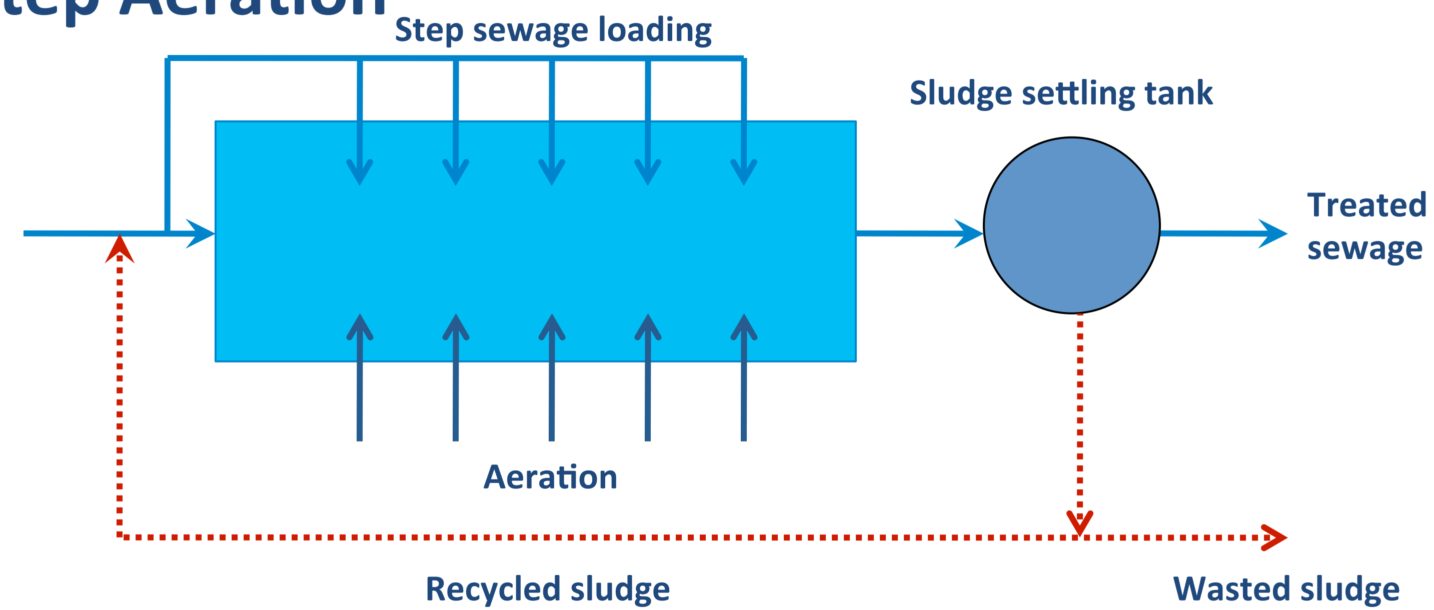
Tapered Aeration



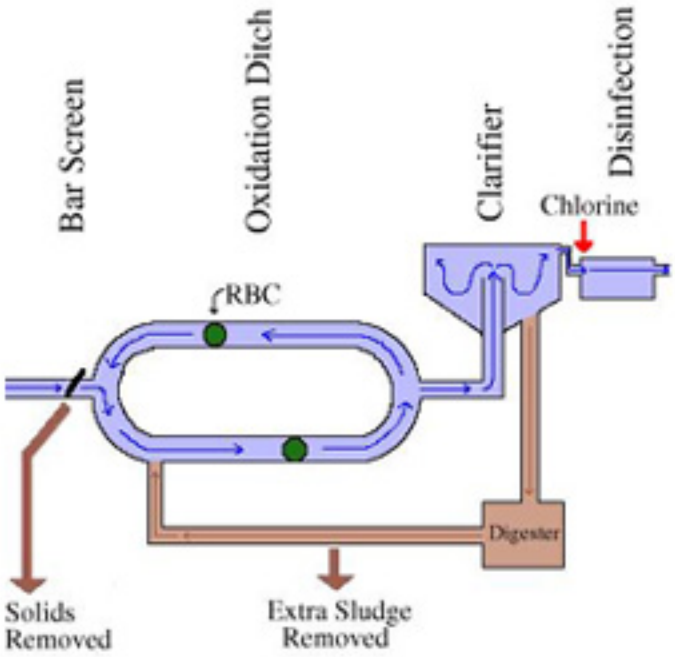
Conventional



Step Aeration



Oxidation Ditch




Oxidation Ditch
(under construction)

Brush Aerator

Extended Aeration

Similar to conventional activated sludge except **longer** hydraulic retention time

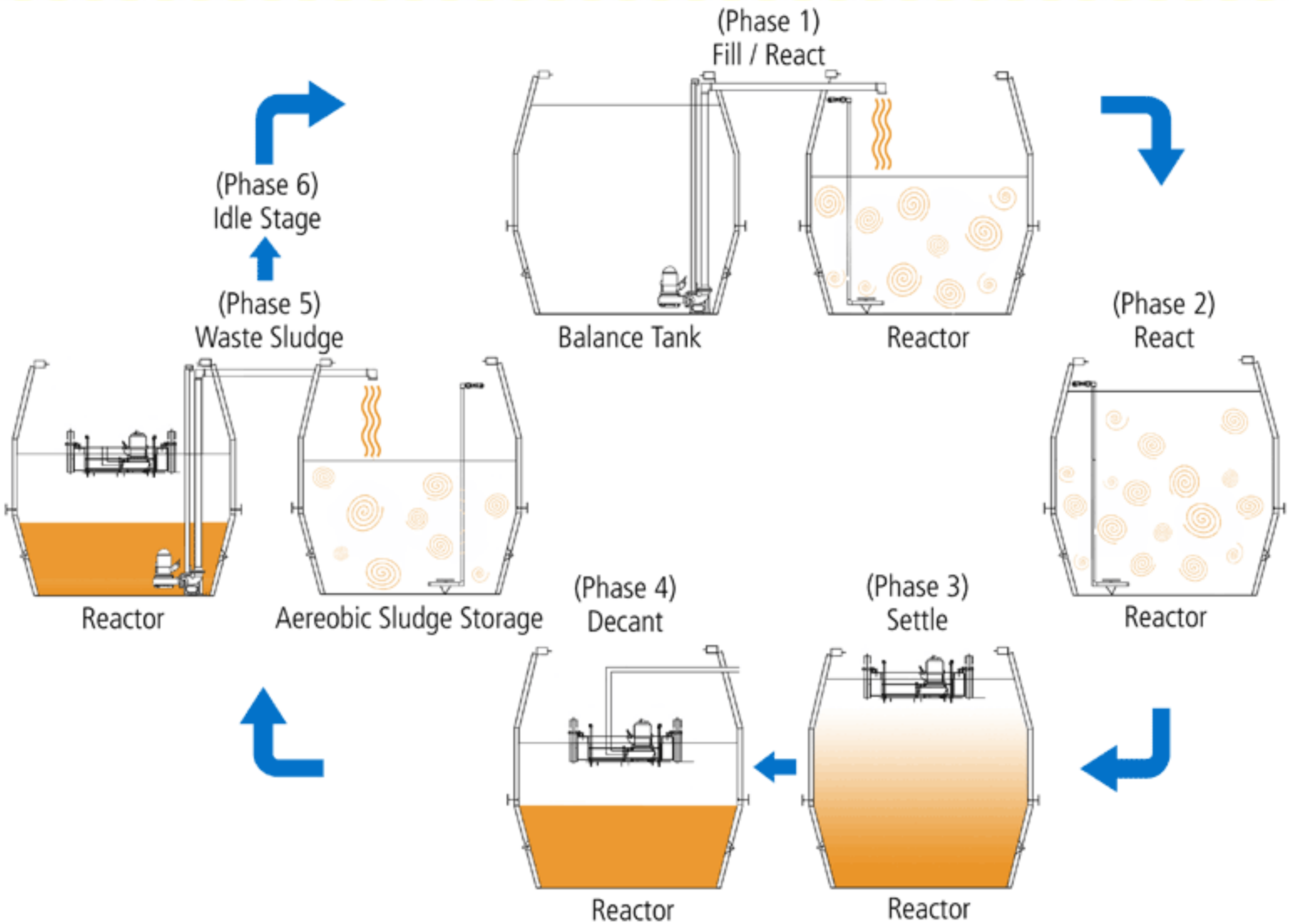
Sequencing Batch Reactor

Similar to conventional activated sludge except **in batch mode**

Use **single** reactor

Require **holding** tank

Operating Cycle



Advantages

Single reactor - require less space and lower cost

Operating flexibility

Disadvantages

Must have automation

Higher level of maintenance

Potential discharging of settled sludge during decant phase

Reactor Design

Mass Balance Generic Equation

Rate of accumulation of mass within the system boundary	=	Rate of flow of mass into the system boundary	-	Rate of flow of mass out of the system boundary	+	Rate of mass generation or loss within the system boundary

$$dm/dt = m_{in} - m_{out} + m_{reaction}$$

Mass Flux In (m_{in})

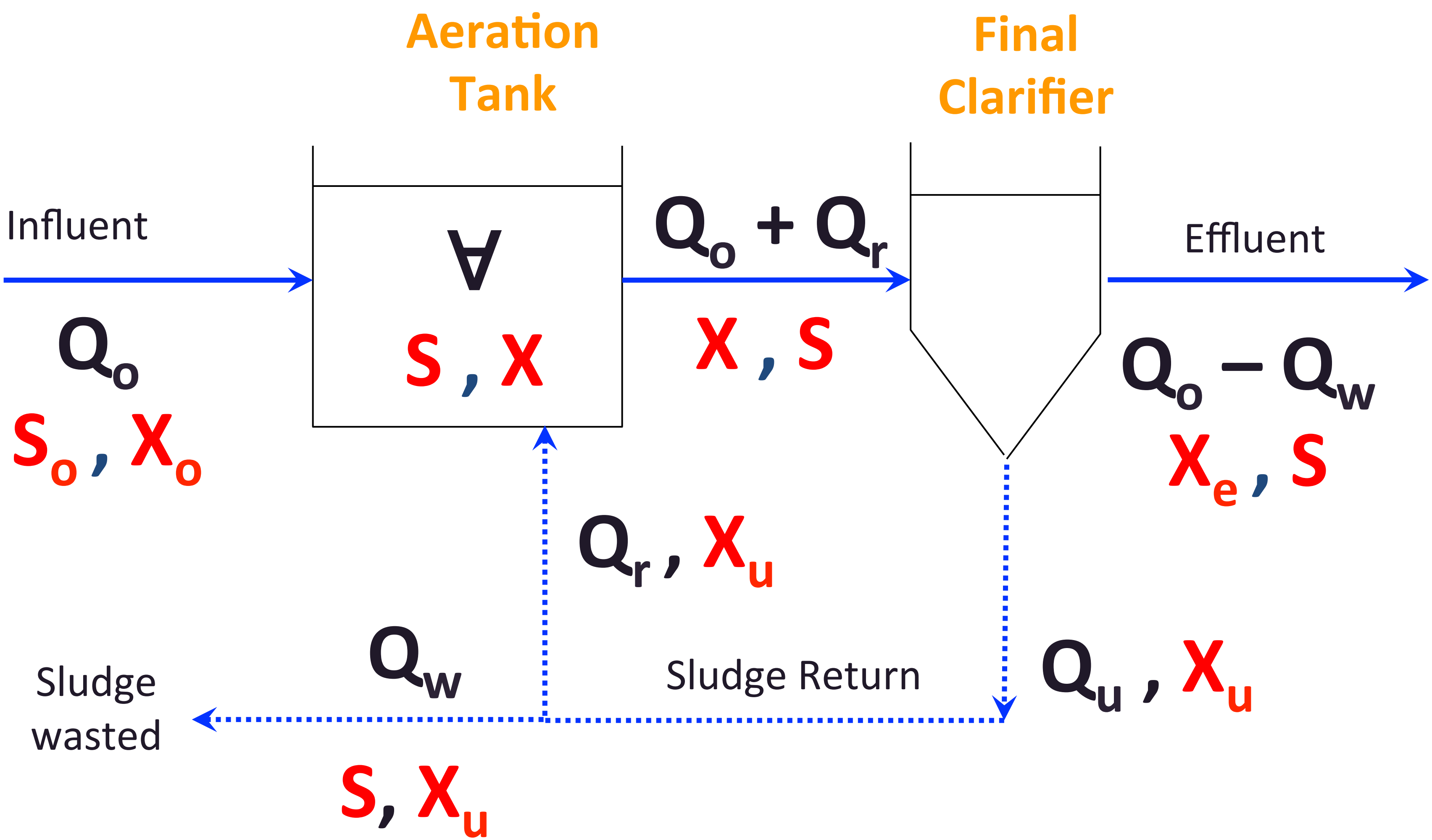
Rate of flow of mass into the system boundary

$m_{in} = Q_{in} \times C_{in}$

Mass Flux Out (m_{out})

Rate of flow of mass from the system boundary

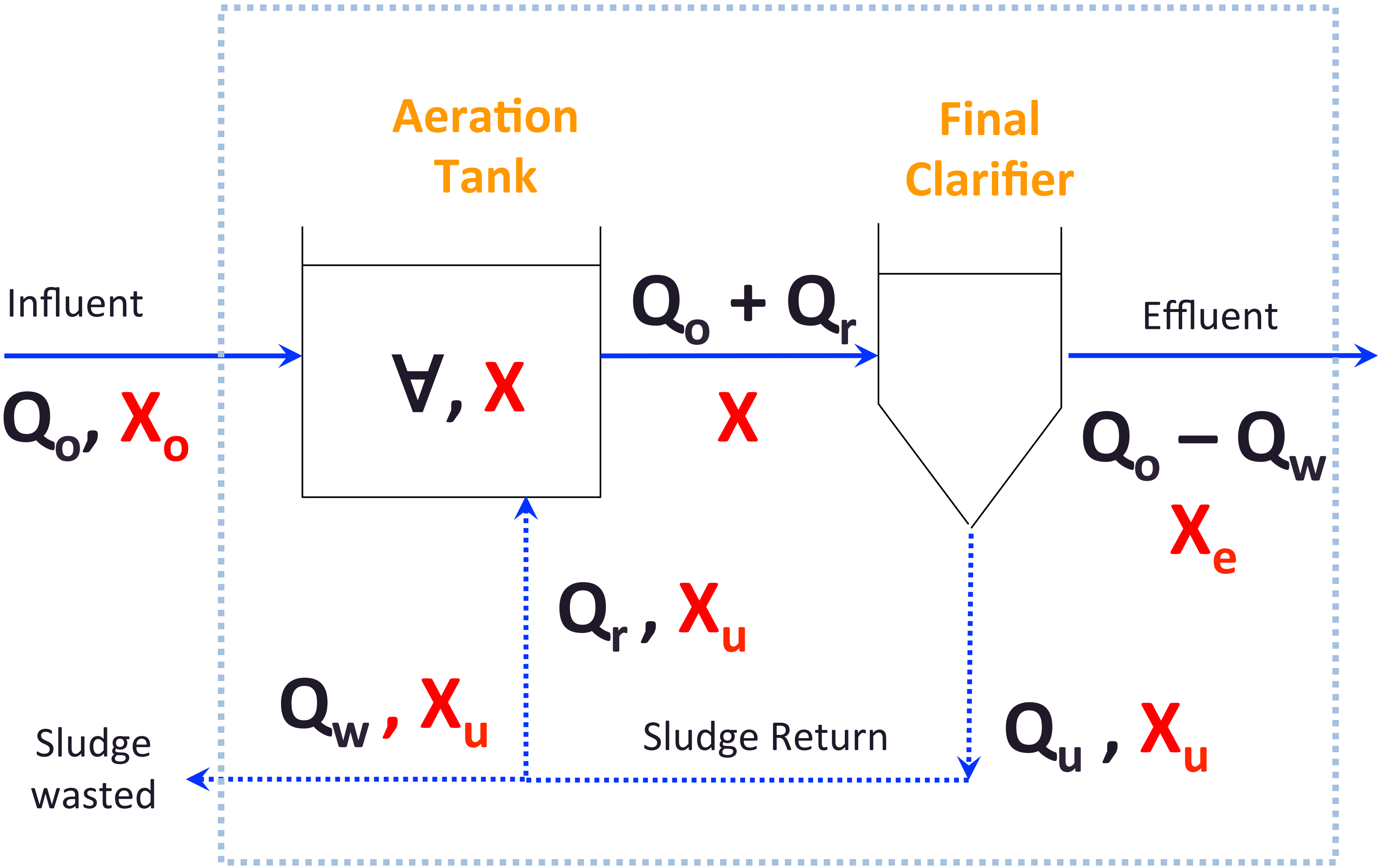
$$m_{out} = Q_{out} \times C_{out}$$



Aeration Tank
Final Clarifier
Influent
Q_o
S_o , X_o
∀
S , X
Q_o + Q_r
X , S
Effluent
Q_o – Q_w
X_e , S
Q_r , X_u
Q_w
Sludge wasted
S, X_u
Sludge Return
Q_u , X_u

Mass Balance

Suspended Solids


Aeration Tank
Final Clarifier
Influent
Q_o, X_o
$\forall, X$
$Q_o + Q_r$
X
Effluent
$Q_o - Q_w$
X_e
Q_r , X_u
Q_w , X_u
Sludge wasted
Sludge Return
Q_u , X_u

Biomass in + Biomass Growth = Biomass Out
(effluent + wasted sludge)

$$Q_o X_o + \forall\left(\frac{k_o X S}{K_s + S} - k_d X\right) = (Q_o - Q_w) X_e + Q_w X_u$$

(7.1)

where

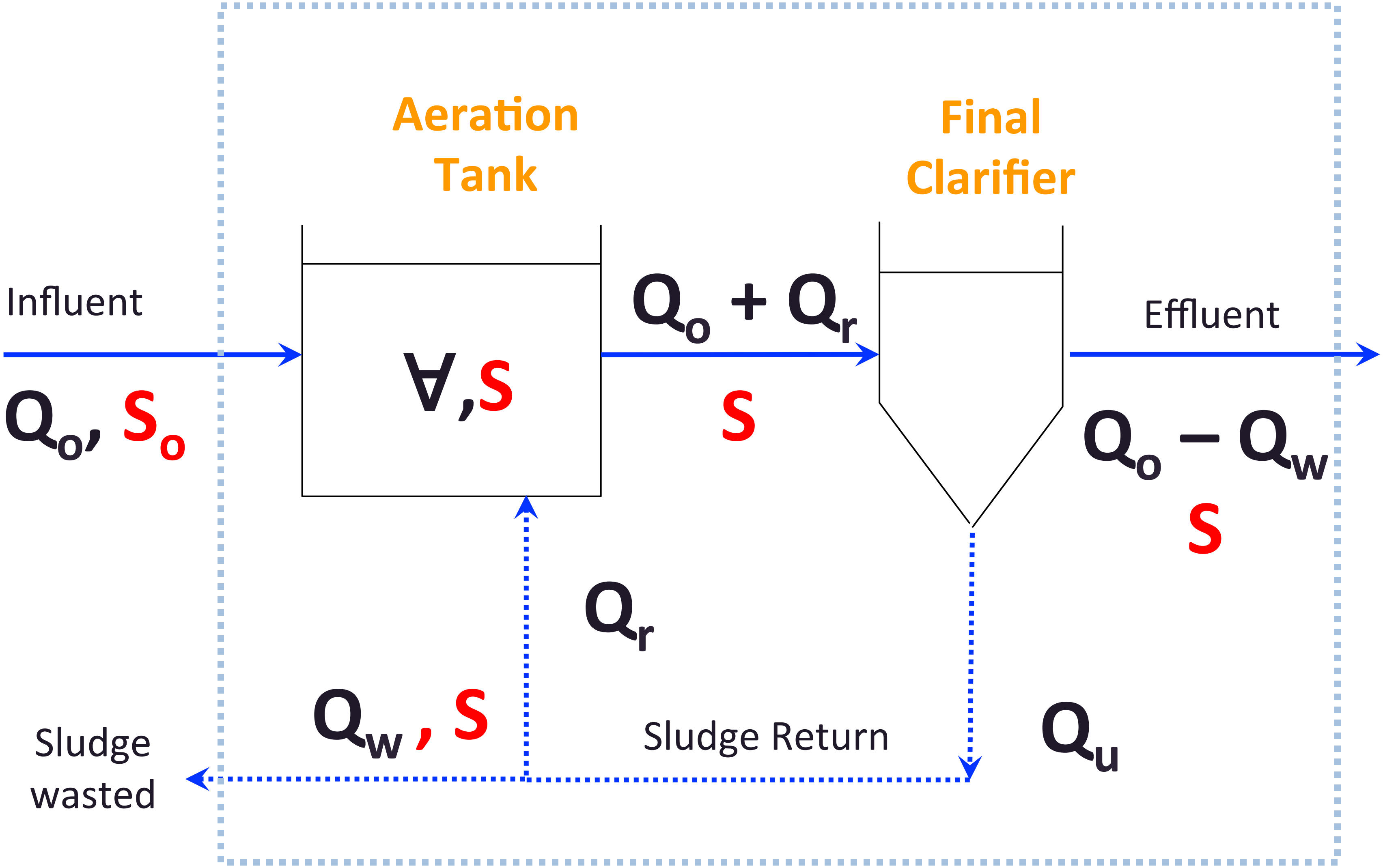
K_s = half saturation constant, kg/m^3

K_o = maximum growth rate constant, d^{-1}

K_d = endogenous decay rate constant, d^{-1}

Mass Balance

Substrate (Food/BOD)



Aeration Tank
Final Clarifier
Influent
Q_o, S_o
$\forall$, S
$Q_o + Q_r$
S
Effluent
$Q_o - Q_w$
S
Q_r
Q_w , S
Sludge Return
Q_u
Sludge wasted

Food In – Food Consumed = Food Out

$$Q_oS_o - \forall \frac{k_oXS}{Y(K_s + S)} = (Q_o - Q_w)S + Q_wS$$

(7.2)

Y = decimal fraction of food mass converted to biomass

= (mg/L biomass/mg/L food utilized)

Assumptions

The influent and effluent biomass concentrations are negligible compared to biomass at other points in the system

The influent food concentration S_o is immediately diluted to the reactor concentration S because of the complete-mix regime

All reactions occur in the reactor. Therefore, the volume, ∀ represents the volume of the reactor only

$$Q_o X_o + \forall\left(\frac{k_o X S}{K_s + S} - k_d X\right) = (Q_o - Q_w) X_e + Q_w X_u$$

$$Q_o S_o - \forall \frac{k_o X S}{Y(K_s + S)} = (Q_o - Q_w) S + Q_w S$$

$$\frac{k_o S}{K_s + S} = \frac{Q_w X_u}{\forall X} + k_d \qquad (7.3)$$

$$\frac{k_o S}{K_s + S} = \frac{Q_o}{\forall}\frac{Y}{X}(S_o - S) \qquad (7.4)$$

Combining Eq. (7.3) and (7.4) gives:

$$\frac{Q_w X_u}{\forall X} = \frac{Q_o}{\forall}\frac{Y}{X}(S_o - S) - k_d \qquad (7.5)$$

The **hydraulic detention time** in the aeration tank:

$$t = \frac{\forall}{Q_o} \qquad (7.6)$$

The **mean cell-residence time** (**sludge age** / the average time that microbes spend in the reactor)

$$t_c = \frac{\forall X}{Q_w X_u} \qquad (7.7)$$

Substituting Egs. (7.6) and (7.7) into Eq. (7.5):

$$\frac{1}{t_c} = \frac{Y(S_o - S)}{tX} - k_d \qquad (7.8)$$

The **concentration of biomass in the reactor** (**MLSS**) is found by solving Eq. (7.8):

$$X = \frac{t_c Y(S_o - S)}{t(1 + k_d t_c)} \qquad (7.9)$$

The **volumetric loading rate**, $\forall_L$ is the mass of BOD in the influent divided by the volume of the reactor,

$$\forall_L = \frac{Q_o S_o}{\forall} \qquad (7.10)$$

The **food-to-microorganisms ratio** is used to express BOD loadings with regard to the biomass in the reactor,

$$\frac{F}{M} = \frac{QS_o}{\forall X} \qquad (7.11)$$

The **recirculation ratio** is:

$$R = \frac{Q_r}{Q_o} \qquad (7.12)$$